Religion and the Rise and Fall of Islamic Science

Extremely Preliminary and Incomplete

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Abstract

Using information on thousands of books written in the medieval Islamic world, I document a sustained decline in innovative intellectual production starting in the 12^{th} century CE. I show that this decline coincides with an increase in the percentage of books dedicated to religious topics and in the proportion of authors employed in religious occupations. These findings are consistent with historical evidence that the political power of religious leaders increased during this period, leading to institutional changes that decreased the relative payoff of producing books on innovative and non-religious topics.

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What explains differences in human capital formation rates across societies? While there is a general consensus that human capital plays a central role in economic development (Mokyr, 2002; Glaeser et al., 2004; Goldin and Katz, 2008; Acemoglu and Autor, 2012), its determinants remain a topic of ongoing research. Recent studies suggest the importance of religious beliefs (e.g. Botticini and Eckstein, 2005; Becker and Woessmann, 2009) in determining human capital investments. However, the reasons why certain religious groups seem to encourage human capital formation to a greater extent than others remain less understood.

At least since the European Enlightenment, scholars have hypothesized a negative relationship between human capital formation and the political power of religious leaders within a society. The premise underlying this view is that certain types of human capital accumulation lead to skepticism of the teachings of religious elites, weakening the popular influence of religious leaders and reducing their political power.[1] The prospect of the loss of political power, in turn, explains their resistance to the accumulation of such human capital unless otherwise constrained (Acemoglu and Robinson, 2000). The Enlightenment thinkers that espoused this view saw the conflict between reason and religious elites as "central to the inherent logic of human history" (Israel, 2006, p. 103). Among other examples, these thinkers cited the decline of science in the medieval Islamic world in support of their hypothesis, claiming that it fell victim to "obscurantism, priestcraft, and fanaticism" (Israel, 2006, p. 620).

Did innovative intellectual production decline in the medieval Islamic world? If so, can the actions of religious leaders explain this decline? In this paper, I investigate these questions using data on over 10,000 books written in the Islamic world before the 18^{th} century. I document a significant and sustained decline in innovative intellectual production starting in the 12^{th} century. I also show that this decline coincides with an increase in the percentage of intellectual production dedicated to religious topics. To the best of my knowledge, this is the first systematic empirical evidence of a medieval decline of intellectual production in the Islamic world and is not consistent with recent revisionist work suggesting that such a decline did not occur (e.g. Saliba, 2007).

Why did intellectual production decline in the medieval Islamic world? One influential hypothesis is that a series of military shocks between the 11^{th} and 13^{th} centuries -which included both the Crusades and Mongol invasions- destroyed significant amounts of physical and human capital in the Islamic world, leading to a sustained decline of intellectual production. The data, however, are not consistent with the simplest forms of this hypothesis.

[1] For evidence that human capital accumulation reduces religious beliefs see Glaeser and Sacerdote (2008); Hungerman (2011). For evidence that religious leaders derive political influence from their popular influence see Chaney (2013)

For example, although the data confirm a relative decline in intellectual activity in the areas conquered by the Mongols, the start of this decline predates the Mongol invasions. Furthermore, the results are qualitatively similar if I omit areas directly conquered by the Crusaders and Mongols.

More sophisticated versions of this hypothesis suggest that these shocks led to an increase in the political power of religious leaders across the Muslim world and to accompanying institutional changes that decreased the relative payoff to producing non-religious intellectual work. These institutional changes have been referred to as the "Sunni Revival" and included the emergence of educational institutions such as madrasas that were supported by ruling elites and controlled by religious leaders. The emergence of institutions providing significant monetary incentives to the production of books on religious topics may have contributed to the decline of scientific production in the Islamic world.

A related but alternative view attributes these institutional changes to the introduction of slave armies in the Islamic world in the 9^{th} century CE and the conversion of local populations to Islam (Blaydes and Chaney, 2013; Chaney, 2012). As the widespread use of slave armies destroyed local elites, Muslim religious leaders took their place. Although these institutional transformation took centuries, they are believed to have been complete by the 12^{th} century CE. Thus, in this view the relevant institutional changes generating the observed decrease in intellectual production were due to the long-run increase in the political power of Muslim religious elites. This increase in political power, in turn, was ultimately a product of the undermining of pre-Islamic elites by the introduction of slave armies and their replacement by religious elites following the conversion of local populations to Islam.

Although data limitations do not allow me to distinguish between these two competing explanations for the empirical patterns, the data are consistent with historical evidence that institutional changes decreasing the relative payoff to producing non-religious intellectual work were responsible for the observed decline in intellectual output. For example, I document that the decline in intellectual production coincides with an increase in the percentage of authors employed in religious occupations. This result provides support for the hypothesis that increased state patronage of religious leaders both during and after this period was an important impetus for the increased production of religious books. This is because the production of books of religious topics made it more likely that an individual would be appointed to a lucrative state post. The production of non-religious topics, however, did not have such an effect and could even decrease the probability of a lucrative appointment by casting doubt upon the religious orthodoxy of an individual.

My interpretation of the results is closely related to studies stressing the importance of the reward structures in a society in determining how talent is allocated (Baumol, 1990;

Murphy et al., 1991; Acemoglu, 1995). The results in this paper are consistent with such studies, and provide evidence of a shift from secular to religious intellectual production as the relative rewards to producing the two types of knowledge changed.

In this sense the results are related to the ongoing debate regarding the relative importance of human capital and political institutions as the fundamental causes of economic growth (Acemoglu et al., 2001; Glaeser et al., 2004). This study suggests that differences in human capital levels within and across societies may be related the political power of groups -such as religious elites- that have incentives to limit the accumulation of such capital. Where such interests groups are more powerful, they may alter the institutional framework to discourage human capital accumulation that threatens their position (see Acemoglu and Autor, 2012, for a related discussion).

Finally, the results are related to a growing literature investigating the link between religion and economic outcomes. Although this paper provides additional evidence that "religion matters" it takes a different approach than much of the recent literature which has focused on the importance of religious beliefs (Guiso et al., 2003; McCleary and Barro, 2006). Instead of emphasizing beliefs, the paper highlights the importance of actions taken by religious leaders in the political and institutional spheres. The results suggest that future research investigating the actions of religious leaders in these arenas may help explain correlations between religious affiliations and economic outcomes.

The remainder of the paper proceeds as follows: the first section provides a historical background, the second section describes the data and documents the basic empirical trends, the third section discusses possible explanations for the results and a fourth section concludes.

1 Historical Background

During much of the Middle Ages, the scientific output of the Islamic world was the world's most advanced (Kennedy, 1970, p. 344). This output included important advances in fields as varied as astronomy, mathematics, medicine and optics and the achievements of scientists in the Islamic world included the creation of new branches of inquiry such as the creation of trigonometry (Kennedy, 1970, p. 337). Many of these advances passed to Europe through the translation of scientific works from Arabic to Latin in 12th century Spain and these translations are widely believed to have played a critical role in the scientific development of medieval Europe (e.g. Lindberg, 1978). Signs of this medieval scientific heritage remain in many Western European languages today. For example, among other scientific loan words from Arabic that continue to be used today, Muslim scientists gave English the terms alcohol, algebra, algorithm, amalgam, almanac, azimuth, chemistry, and zero.

Rulers provided much of the financial support for scientists in the medieval Islamic world. One scholar has noted that this arrangement resembled "the situation during the sixteenth century, the Age of Enlightenment, when the state, personified by reigning monarchs, founded academies of science and competed for scholars to staff them"(Kennedy, 1970, p.329). These rulers patronized scientists for both prestige and for the "practical benefits promised by the practitioners of medicine and astronomy and astrology and applied mathematics" (Sabra, 1996, p. 662).

While in many fields medieval Islamic science appears to have been on the verge of a "scientific revolution" similar to the revolution that began in Enlightenment Europe such developments did not occur. Until recently, there was a broad scholarly that this was due -at least in part- to a decline in scientific activity during the Middle Ages. Possible explanations for this decline included the Crusades, the Mongol invasions of the 13th century or increased resistance by religious authorities to scientific production. While many continue to claim that scientific output declined in the latter middle ages (e.g. Sabra, 1987) others note that the recent discoveries of important scientific advances as late as the 15th century raise the possibility that such a decline did not occur (Saliba, 2007).

1.1 The Rise of Islamic Science

Accounts of the historical evolution of scientific production in the Islamic world often begin with the start of the translation movement into Arabic. This movement, in which almost all non-literary and non-historical secular Greek books available were translated into Arabic between the middle of the eighth century to the end of the tenth (Gutas, 1998, p. 1) has captivated generations of historians. While there is still little consensus regarding the reasons behind the emergence of this movement, recent research suggests that it may have been motivated -at least in part- by attempts to convert local populations to Islam.[2]

Regardless of the exact reasons behind this movement, during the following centuries scientific production flourished. Although the educational history of the region during this period remains poorly understood, the available evidence suggests that individuals interested in studying scientific topics studied in libraries and study circles that appear to have been sponsored by both government officials and wealthy individuals such as merchants.

Although it appears that such scientific activity enjoyed significant popular and governmental support throughout much of this period, from a very early date some Muslim religious leaders objected to the study of these "rational sciences" which were claimed to often stand in opposition to the "traditional or religious sciences". This opposition was noted by al-Kindi

[2]For a detailed overview of the translation movement, see Gutas (1998).

-who was known as the "philosopher of the Arabs"- and who claimed that some individuals as early as the 9th century CE sought to "repudiate the study of philosophy in the name of religion, of which they are devoid, and which they merely exploit for their personal aims and ambitions"(Fakhry, 1970, p. 87).

The available evidence is consistent with claims that some religious leaders resisted the study of the rational sciences -and in particular philosophy- because it caused individuals who studied it to question the authority of religious leaders. One informative passage illustrating this point is provided in the work of al-Ghazzali -an influential thinker in the Islamic world. He notes: "[t]he heretics in our times have heard the awe-inspiring names of people like Socrates, Hippocrates, Plato, Aristotle etc. They have been deceived by the exaggerations made by the followers of these philosophers [...] that the mathematical, logical, physical and metaphysical sciences developed by them are the most profound [...] and that with all the subtlety of their intelligence and the originality of their accomplishments they repudiated the authority of religious laws: denied the validity of the positive contents of historical religions, and believed that all such things are only sanctimonious lies and trivialities" (Al-Ghazālī, 1111 [1963], pp. 1,2).

Although there were many religious leaders that resisted the study of the rational sciences, others appear to have embraced the use of rational methods. Indeed, one group of Muslim religious scholars -known as the Mu'tazilites-, developed a rational interpretation of Islamic religious doctrines and enjoyed government support for a period in the 9th century. While this group eventually became less influential, during the period prior to the eleventh century, those opposed to the widespread study of the rational sciences appear to have been unable to meaningfully restrict the study of the rational sciences.

1.2 Did Scientific Production Decline in the Medieval Islamic World?

Traditionally, scholars believed that scientific production declined in the medieval Islamic world. Although the exact date of the start of this decline is debated, it is thought to be located somewhere between 1100 and 1300 CE.[3]

At the very start of this period, the introduction of the madrasa began to change the institutional landscape of education in the Islamic world. Scholars believe that the introduction of madrasas -which were run by religious leaders- transformed higher education (Chamberlain, 1994, p. 69). Interestingly, the introduction of madrasas -the largest of which were funded by political rulers- has been generally interpreted as an attempt by political leaders to coopt religious leaders.

[3]Some have seen the roots of this decline as early as the ninth century.

Why did madrasas emerge in the 11th century? The evidence is consistent with claims that it was only after this date that Muslim religious leaders commanded enough popular support -and thus wielded sufficient political power- to significantly influence the institutional equilibrium and limit the study of topics that they believed detracted from their authority. This hypothesis is consistent with evidence that Islam emerged as the majority faith in Iraq and Iran during this period (Lapidus, 2002, p. 143). Scholars have suggested that the purpose of providing such patronage to religious leaders was "to gain control of the popular masses by having their religious leaders in one's pay" (Makdisi, 1981, p. 39).

As religious elites commanded increasing political power, rulers and political elites created posts to channel patronage to religious leaders. This process has been dubbed the "Sunni Revival" and is believed by some scholars to have been accompanied by a significant upsurge in traditionalism and a decline in original and secular intellectual output. One view is that this process had roots in the introduction of slave armies across the Islamic world starting in the 9th century and the response of disenfranchised social elites to this situation (e.g. Berkey, 2003, p. 150). An alternative view suggests that these changes are better understood as a response to a series of military shocks that affected the regions starting in the 11th century.

Regardless of the exact mechanism driving these institutional changes, the "professionalisation" of Muslim religious leaders (Gilbert, 1980, p. 106) stands in contrast to the situation in previous centuries in which Muslim religious leaders did not generally receive financial support from rulers and made a living primarily by engaging in secular occupations (Gilbert, 1980, p. 124).

As religious leaders gained greater control over institutions of learning across they Muslim world, they appear to have tailored the relevant institutions to discourage the widespread study of certain rational sciences. In general the study of such sciences was "banished from the regular courses of institutionalized education" and after this point "these sciences lived a silent, discrete life" (Makdisi, 1981, p. 283). After the introduction of the madrasa, the institutions where these sciences were studied began to disappear, becoming extinct by the twelfth century (Makdisi, 1981, p. 10). Although individuals could continue to study science in private, the open study of these sciences could ruin one's career. Moreover, the study of these science were not "subsidized in the same manner as the Islamic sciences and its ancillaries" (Makdisi, 1981, p. 78).

The emergence of institutions subsidizing the production of religious knowledge is thought to have changed the specialization of scholars across the Muslim world. First of all, individuals who desired to obtain a teaching post in a madrasa or other educational institution "had to specialize in an acceptable field" (Makdisi, 1981, p. 285). Unsurprisingly, as the relative payoffs to the production of religious works increased individuals increasingly spe-

cialized in such endeavors. This change was noted by one market inspector in 14^{th} century Egypt who complained that "no [Muslim] occupies himself with [medicine]; everyone repairs to the study of the law and more particularly that portion of it given over to disputes and litigiousness and the town is full of legists occupied with granting fatwas and giving replies to legal queries on points which arise. Can there be any reason for the faith's permitting a state of things in which large numbers occupy themselves with one particular duty while another is neglected, except that by medicine there is no access to judgeships and governorships where by it possible to claim superiority over rivals and to acquire authority over enemies?" (Ibn al Ukhuwwa, 1329 [1938], pp. 56-57).

As religious leaders enjoyed both increased political influence and increasing control over the education system scholars believe that "freedom of thought and discussion" declined in the Islamic world (Makdisi, 1981, p. 290). Although some madrasas continued to teach and other individuals continued to produce scientific works, these works were often not widely circulated. One prominent scholar of science in the Islamic world has noted that the final result of these changes was "an instrumentalist and religiously oriented view of all secular and permitted knowledge [... confining] scientific research to very narrow, and essentially unprogressive areas"(Sabra, 1987, p. 241).

In sum, the historical evidence suggests that institutional changes beginning in the 11th century significantly increased the control of Muslim religious leaders over the educational system. This evidence suggests that these changes led to a relative decrease in non-religious intellectual production and an increase in the percentage of scholars employed in religious occupations. In the following sections I investigate this hypothesis empirically.

2 The Evolution of Intellectual Output in the Medieval Islamic World

2.1 Data

The data on intellectual production used in this paper are drawn from Hajji Khalifa's biographical dictionary Kashf al-Ẓunun an Asāmi 'l-kutub wa'-funūn. Hajji Khalifa (his given name was Mustafā ibn 'Abd Allah) was born in Istanbul in February of 1609 CE to a family with a military background.[4] From a young age, two large inheritances enabled him to pursue learning. He spent much of his life and these financial resources compiling the Kashf al-Ẓunun which is one of the most important sources of information on the intellectual history of the Islamic world. This work is a "vast bibliographical dictionary" containing

[4]See Abdulhak (1939) for an overview of Hajji Khalifa's life.

information on approximately 14500 books written over a period spanning over one thousand years (Chelebi, 1656 [1957], p. 11). Hajji Khalifa lists the entries by the title of the book alphabetically.

Hajji Khalifa described the writing of this source in his autobiography and states that he used previously-written biographical dictionaries which he supplemented with "thousands of volumes in the libraries I had personally examined, and the books which for twenty years the book-sellers had been bringing to me in a steady stream" (Chelebi, 1656 [1957], pp. 143). In compiling this vast catalog, Hajji Khalifa was continuing a long tradition in the Islamic world of gathering both the names of prominent scholars and their works. Such catalogs were ubiquitous and have been called "the greatest untapped source of information on the medieval Middle East"(Bulliet, 1970, p. 195).

Why did authors in the Islamic world compile such dictionaries? Chamberlain (1994) suggests that such dictionaries acted as a "who's who", enabling scholars to know the most important and trustworthy sources of knowledge in a given time period. Such a source was particularly important given the highly decentralized nature of education in the Islamic world historically. While there is no way to exactly verify the extent to which Hajji Khalifa's dictionary provides a reliable sample of intellectual output in each period, this source has been trusted by generations of scholars of the Islamic world and is perhaps the most complete of all the surviving dictionaries that cover the period examined in this paper.

To understand how I use Hajji Khalifa's dictionary to construct the data set, consider the book number 10083 (Hajji Khalifa, 1657 [1835], p. 79, vol. 5). This entry reads "10083: The Pure Book (Kitab al-Khālis) on Chemistry written by Jabr bin Hayyan [...] al-Tusī, the eminent chemist who died in 160. He mentions in this book the secrets of alchemy." I code the topic of this book as chemistry. In Arabic, many authors names have *nisbas* or additional terms that give information on their place of birth or occupation. In this entry, al-Tusī is one such nisba indicating that the author was from Tus. Throughout, I use Kennedy and Kennedy (2011) to identify the latitude and longitudes of an author's birth place. In this source, we learn that Tus is located in Eastern Iran and its modern day latitude and longitude.

Interestingly, Hajji Khalifa organizes his dictionary by original works. In other words, he usually provides commentaries, glosses or other works derived from a work in the entry of the original book. For example the entry 7261 (Hajji Khalifa, 1657 [1835], p. 512, vol. 2) reads: "Sunan ibn Majah on Hadīth (sayings of the prophet Muhammad) written by Abu Abd Allah Muhammad bin Yazid bin Majah al-Qazwini who died in the year 273 [...] and a portion of this work was explained in 5 volumes by 'Ala al-Din Mughlati ibn Qalij who died in 762 [... other commentaries are also mentioned]". Here we learn that the writer of

this work was from Qazwin in modern day Iran and that 'Ala al-Din Mughlati ibn Qalij who died in 762 wrote a commentary on this work.

Throughout the paper, I use this information to classify a book as original or as derivative from an earlier work. This metric is perhaps the best available measure of the quality of intellectual production, since presumably original works were on average more innovative than those that were commentaries on previous works. Measuring the proportion of books that are original in each period is straightforward, available for all books listed by Hajji Khalifa and requires no interpretation on the part of the researcher. In addition, the value of this metric is suggested by claims that scientific production in the Islamic world was accompanied by a "fervent opposition to innovations" (Berkey, 2003, p. 202) and an increase in the proportion of intellectual works that were derivative and were safe from accusations of innovation. For these reasons I use the proportion of original books in each year as my main measure of the quality of intellectual production throughout the paper.

In Figure 1 I plot the 100-year moving average of the number of books written in each year. The vertical lines mark the start of the first crusades (1095 CE), the Mongol sacking of Baghdad (1258 CE) and the Ottoman conquest of Constantinople (1453 CE). Figure 2 provides the geographic location of the authors in the sample, along with the areas conquered by Crusaders and Mongols. Finally, table 3 provides the evolution of these locations over time dividing the authors by geographic region (here the vertical lines mark the start of the first crusades (1095 CE) and the Mongol sacking of Baghdad (1258 CE)). The sharp decline in authors from Iraq and East is consistent with that found in previous studies (Bulliet, 1979) as is the decline in the Maghrib following the increase in the pace of the *reconquista* of Spain by Christian forces at the start of the 13th century.

2.2 The Medieval Decline of Muslim Science

Since I am interested in evaluating the evolution of intellectual production over time, I only include in the sample books whose author can be assigned a date. This date is the death date for the vast majority of authors. Throughout the analysis, I measure time using the birth date of the author that composed a work. Do do this, I subtract 78 lunar years from this date since on average scholars lived 78 lunar years (Bulliet, 1970, p. 200). In addition, I drop all authors who were born on or after 1500 CE.

I investigate the evolution of intellectual production in Table 1, where I present the output from a regression of the form:

$$original_{itf} = \gamma + \sum_{f \geq 1050}^{1500} \beta_f + \epsilon_{itf} \tag{1}$$

Where $original_{itf}$ is an indicator variable equal to one if book i, written by an author born at time t in the fifty year bin f is an original work and the β_f are fifty-year dummies giving the proportion of original books in each fifty-year period relative to the average prior to 1050. The results of equation (1) are provided in column (1) of Table 1 and show that the proportion of original books experienced a sustained decline of roughly 10 percentage points after the year 1200. Throughout I report 100 times the relevant coefficient for expositional ease. In column (2) of this Table, I show that this pattern also characterizes the proportion of books dedicated to secular topics.[5]

In sum, the data provide systematic evidence of a decline in the proportion of intellectual works dedicated to original/secular topics around the year 1200 CE. It is important to note, however, that the production of both secular knowledge (which include works on the rational sciences) never ceased. Rather, the results suggest that these works were a smaller share of intellectual production over time. In this sense, the results provide quantitative confirmation of qualitative work by scholars (e.g. Saliba, 2007; El-Rouayheb, 2008) suggesting that such sciences continued to be cultivated long after the end of the "golden age" of Islamic science.

2.3 Dating the Decline

These results provide -to the best of my knowledge- the first systematic empirical evidence of a decline in intellectual production in the medieval Islamic world. When did original scientific production begin to decline? Was this decline related to the introduction of madrasas and/or other institutional changes? In the ideal world, I would view the institutional equilibrium in each locality and examine intellectual production in these locations both before and after its introduction. Unfortunately, the necessary data to construct such a metric does not exist.

Despite such limitations, the data do allow for an investigation of the timing of changes in the aggregate trend. I provide the 100-year moving average of the percentage of books written on original topics in Figure 4. Variation in this average suggests that the proportion of books written on original topic began to decline somewhere in the 12th century.

To investigate the timing of this decline more formally, I check for breaks using the framework developed by Bai and Perron (1998b,a). Specifically, I limit the sample to authors born before 1500 CE and allow for m breaks in a specification of the form

$$original_t = \alpha_j + \epsilon_t, t = T_{j-1} + 1, ..., T_j \tag{2}$$

for j=1,..., 6. Here, I use 15% trimming and allow for 5 breaks (m+1) regimes. In other words, I estimate a step function and allow the proportion of original books to have

[5]Secular topics are defined as those that are not on religion or grammar.

a different intercept on each interval. When this is done, the data identify one break in the year 1165 CE and a 95% confidence interval spanning the interval [1145,1185].

3 Interpretations

3.1 Institutional Interpretation

The data provide evidence for a relative decline in non-religious intellectual production starting in the 12th century CE. In this section I investigate the extent to which the historical evidence presented in section above is consistent with the data.

Recall that there is historical evidence suggesting that institutional changes starting in the 11th century and spreading throughout the Islamic world in the 12th century led to the professionalisation of religious leaders and increased control of these religious leaders over the educational system. This evidence suggests that the observed decline in the proportion of books written on science is a product of a change in the relative rewards to producing non-religious production.

Perhaps the cleanest test of this prediction comes from the names of the authors contained in Hajji Khalifa's dictionary. As noted above, the geographic origins of many of these authors is contained in their names. Similarly, one can infer the occupation of many authors based on their names (e.g. Cohen, 1970). Equipped with this information, in column (1) of Table 2 I present results from a regression similar to (1) replacing the indicator variable for an original book with one equal to one if the author had a religious occupation. These results mirror those presented in the previous section and show that employment in religious occupations increased as original/secular intellectual production declined (here I also present 100 times the estimated coefficient for expositional ease).

3.2 Alternative Interpretations

3.2.1 Time-Varying Selection

The data provide evidence consistent with a decline in scientific production in the medieval Islamic world. It is unlikely, however, that Hajji Khalifa's dictionary provides a random sample of intellectual production in each period. Instead, it is better characterized as providing the population of intellectual production produced in the Islamic world that was known in Istanbul in the year 1650. As I show in the appendix, the observed data will provide the correct sign of the true evolution of original books unless the relative probability of observing an original book is decreasing over time. To explain the observed patterns, this probability

would have to witness a sharp and persistent decrease starting in the 12^{th} century.

Although I do not observe how this selection probability varies over time, it is possible to examine a few variables that might change if selection was time-varying. One of these is the distance of an author's birth place to Istanbul. The basic idea behind this empirical exercise is that if Hajji Khalifa was using different sources to compile his dictionary after the mid of the twelfth-century it is likely that these sources would have had a different geographical emphasis than previous authors. However, as I show in column 2 of Table 2, the distance of an average author to Istanbul falls significantly in the century before the observed decrease in original intellectual production. In addition, the average distance of an author's home from Istanbul remains roughly constant between 1150 and 1350 which are the years in which intellectual production declines (the p-value related to the test of equality of all these coefficients is given in the row labeled p-value). This result casts some doubt on the importance of time-varying selection in generating the results.

3.2.2 Geography: Mongols and Crusaders

The observed decrease in innovative intellectual production begins in the 12^{th} century. This date lies between the start of two events that many scholars believe led to the decline of scientific production in the Islamic world. These two events are the Crusades (which began at the very end of the 11^{th} century CE) and the Mongol invasions. In their simplest formulation, these hypothesis stress the importance of the direct destruction of both Crusaders and the Mongols. Thus, these hypotheses in their simplest form predict that the effects of the Crusades and the Mongol invasions should be limited to the areas directly affected by these events. However, as I show in columns (4) and (5) of Table 2, the results are qualitatively similar to those in the broader sample when areas directly affected by the Crusader and Mongol invasions are omitted respectively (in column (3) of Table 2 I provide coefficients estimated using the entire sample of authors with non-missing places of birth).

4 Conclusion

In this paper I have provided evidence that intellectual production declined in the medieval Islamic world. In addition, the available data suggests that this decline began at some point in the second-half of the 12^{th} century. To the best of my knowledge, this is the first systematic empirical evidence that scientific production declined in the medieval Islamic world.

What explains this decline in intellectual production? Based on historical evidence, I have hypothesized that during this period there were a series of institutional changes that enabled religious leaders across the Islamic world to implement their preferred policies to a greater

extent. Among these institutional changes, the spread of madrasas across the Islamic world offered lucrative posts to individuals who excelled in producing religious knowledge. As the relative payoff to such production increased, thinkers across the Muslim world increasingly produced such knowledge. Presumably, religious leaders tailored institutions to reward the production of such knowledge because they preferred intellectual production to be more heavily weighted towards such topics and less towards non-religious and scientific topics.

While the results in this paper suggest that both original and non-religious intellectual production declined in the medieval Islamic world, they suggest that this decline was in response to institutional changes during this period. How was European science able to avoid the fate of intellectual production in the Islamic world? While this remains a topic for future research, some evidence suggests that the fragmentation of political power in Europe may have played a central role in constraining European religious elites to a greater extent than those in the Islamic world (Ben-David, 1965; Landes, 1998, p. 52). Recent research (Chaney, 2013; Blaydes and Chaney, 2013) suggests that a deeper understanding of these political developments may shed light on the abnormal rates of human capital accumulation in Europe prior to the industrial revolution.

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5 Appendix

To understand how time-varying selection affects the analysis more formally, assume that Hajji Khalifa provides the population of book available in Istanbul in the year 1650. Denote the number of book he finds on subject s written in region j at time t by $Books_{sjt} = \alpha_{sjt} Books^*_{sjt}$ where $Books^*_{sjt}$ is the total number of books written on subject s and α_{sjt} is the probability that a book written on subject s in region j at time t is available in Istanbul in the year 1650.

Since we are interested in calculating the proportion of intellectual output that is dedicated to a certain type of intellectual production denote the set of all subject in this type of intellectual production by S. Hajji Khalifa's dictionary gives us

$$P^S_{jt} = \frac{\sum_{s \in S} Books_{sjt}}{\sum_s Books_{sjt}} = \frac{\sum_{s \in S} \alpha_{sjt} Books^*_{sjt}}{\sum_s \alpha_{sjt} Books^*_{sjt}} \tag{3}$$

Suppose that α_{sjt} is constant within groups (i.e. within and without the set S), then equation (1) can be rewritten as

$$P^S_{jt} = \frac{P^{S^*}_{jt}}{P^{S^*}_{jt} + \frac{\alpha^{\notin S}_{jt}}{\alpha^S_{jt}}(1 - P^{S^*}_{jt})} \tag{4}$$

Clearly, if the survival probability of books in subjects belonging to type S is the same as that of books in $\notin S$, then we can recover the underlying or true proportion of all intellectual production dedicated to type S in each period. If the probability of books of type S surviving is smaller (larger) than that in other books than the estimated proportions with be biased downwards (upwards).

Although the underlying proportion of intellectual production of type S is of some interest, in this paper I am primarily interested in exploring the evolution of this quantity over time. In other words, I am interested in examining the extent to which changes in the observed proportions indicate changes in the true underlying proportions. To do this, I drop the subscript j and let $\frac{\alpha^{\notin S}_{jt}}{\alpha^S_{jt}} = c_t$ for notational simplicity. It is then straightforward to show that

$$sgn(\frac{dP^I_t}{dt}) = sgn(\frac{dP^{I^*}_t}{dt} c_t - \frac{dc_t}{dt} P^{I^*}_t (1 - P^{I^*}_t)) \tag{5}$$

If there is no time variation in c_t then equation (5) shows that the sign of the estimated trend is the same as that of the true trend. This also holds true if the time derivative of the odds ratio $\frac{dc_t}{dt}$ is the opposite sign as $\frac{dP^{I^*}_t}{dt}$. If these two are of the same sign, than it is possible that observed trend is of the opposite sign of the true trend. To see the issues involved in

the context of this paper, suppose that I denotes secular intellectual production and that I observe that $\frac{dP_t^I}{dt}$ or that this quantity decreases over time. Equation (5) implies that the true fraction also decreases over time unless $\frac{dc_t}{dt}$ is positive. If this quantity is positive (i.e. the relative probability of observing a secular book is decreasing over time), then it could be the case that $\frac{dP_t^{I^*}}{dt} \geq 0$. This might happen if people were able to increasingly censor or destroy such books (i.e. prohibit them from ever becoming known) if they were written in a latter period. Many such time paths of c_t, however, seem to have similar qualitative implications as $\frac{dP_t^{I^*}}{dt} < 0$ in that they suggest increased societal resistance to the circulation (as opposed to production) of secular books.

Thus, the observed data will provide the correct sign of the underlying proportion unless there is time-varying selection that affects the probability that a book of type S appears in Hajji Khalifa's dictionary. To explain the results, such time-varying selection would have to begin in the late 12th century and continue until the end of the sample.

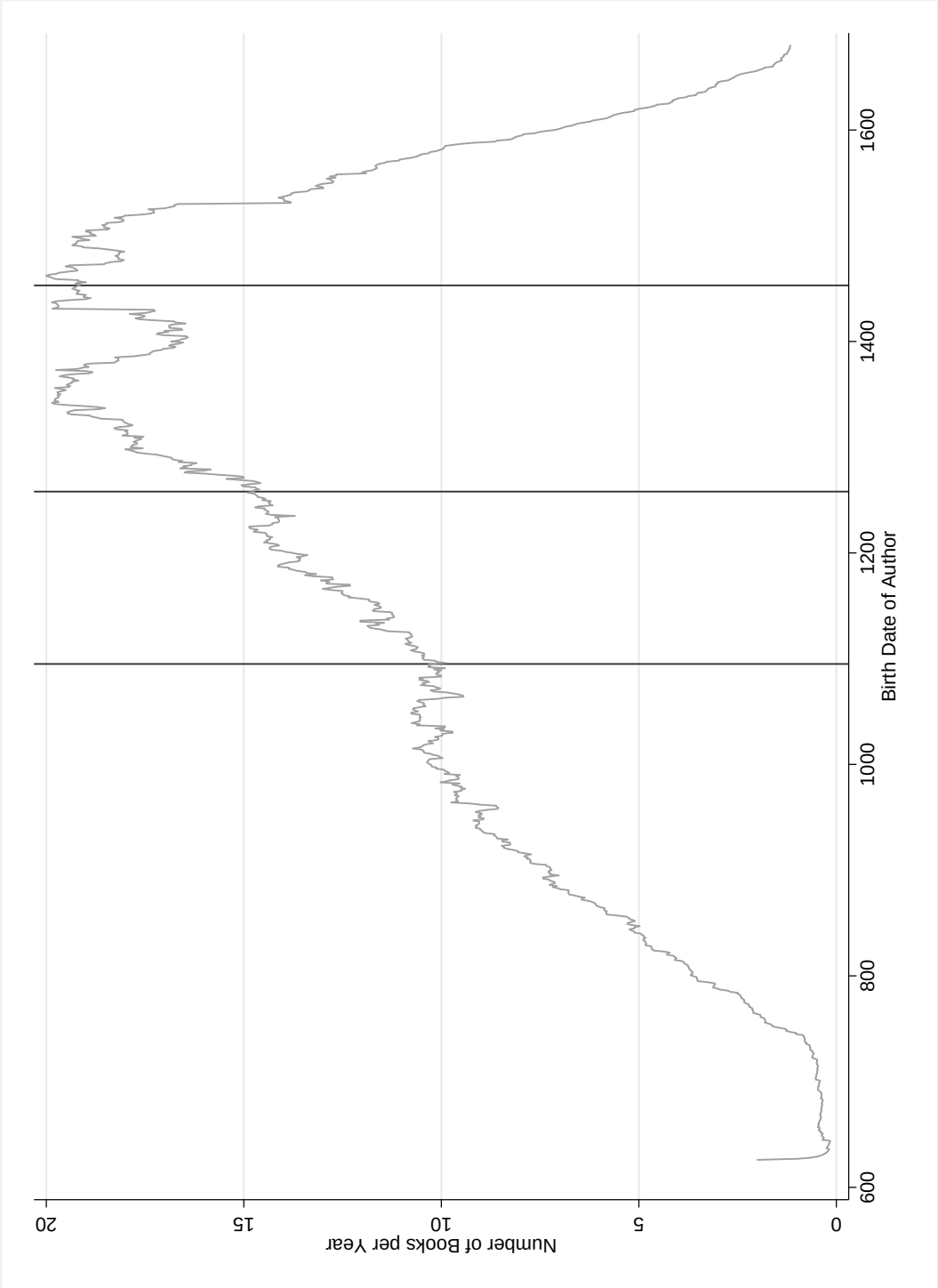

Figure 1: **Number of Books by Year**

100 year moving average

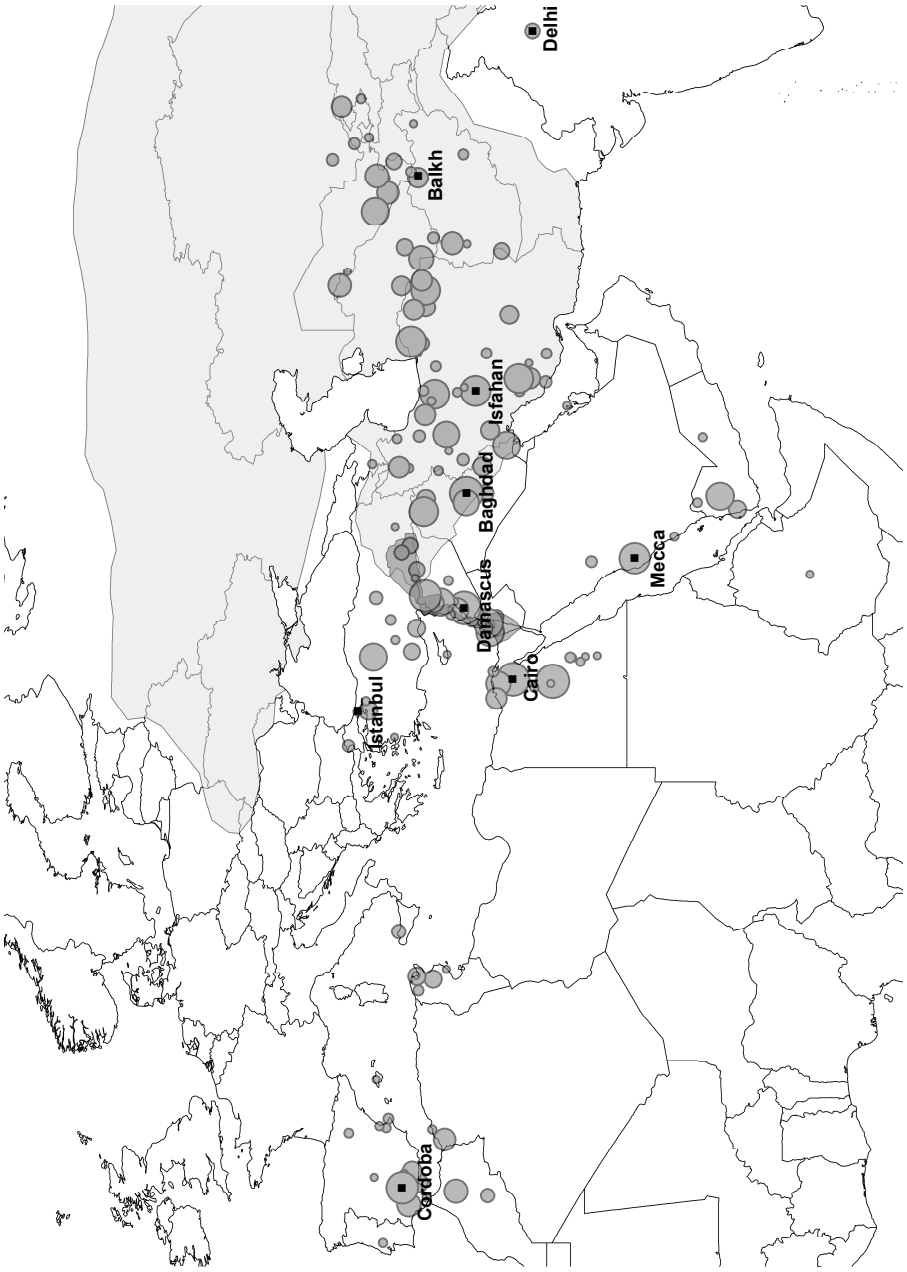

Figure 2: **Centers of Intellectual Production**
Larger circles denote more books by authors from that city. Areas conquered by the Mongols and Crusaders are shaded light and darker gray respectively.

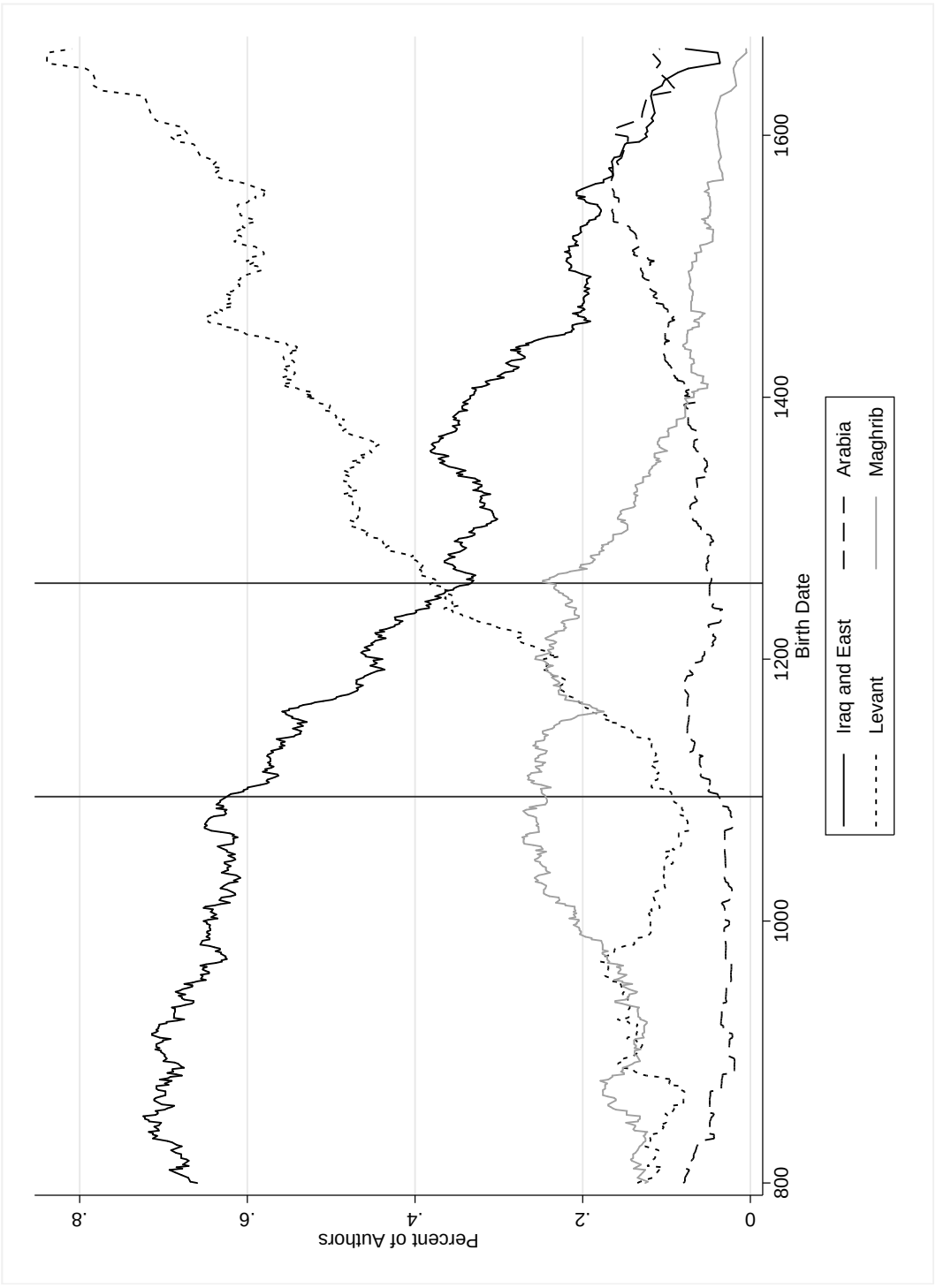

Figure 3: **Evolution of Geographic Locations of Book Authors over Time**

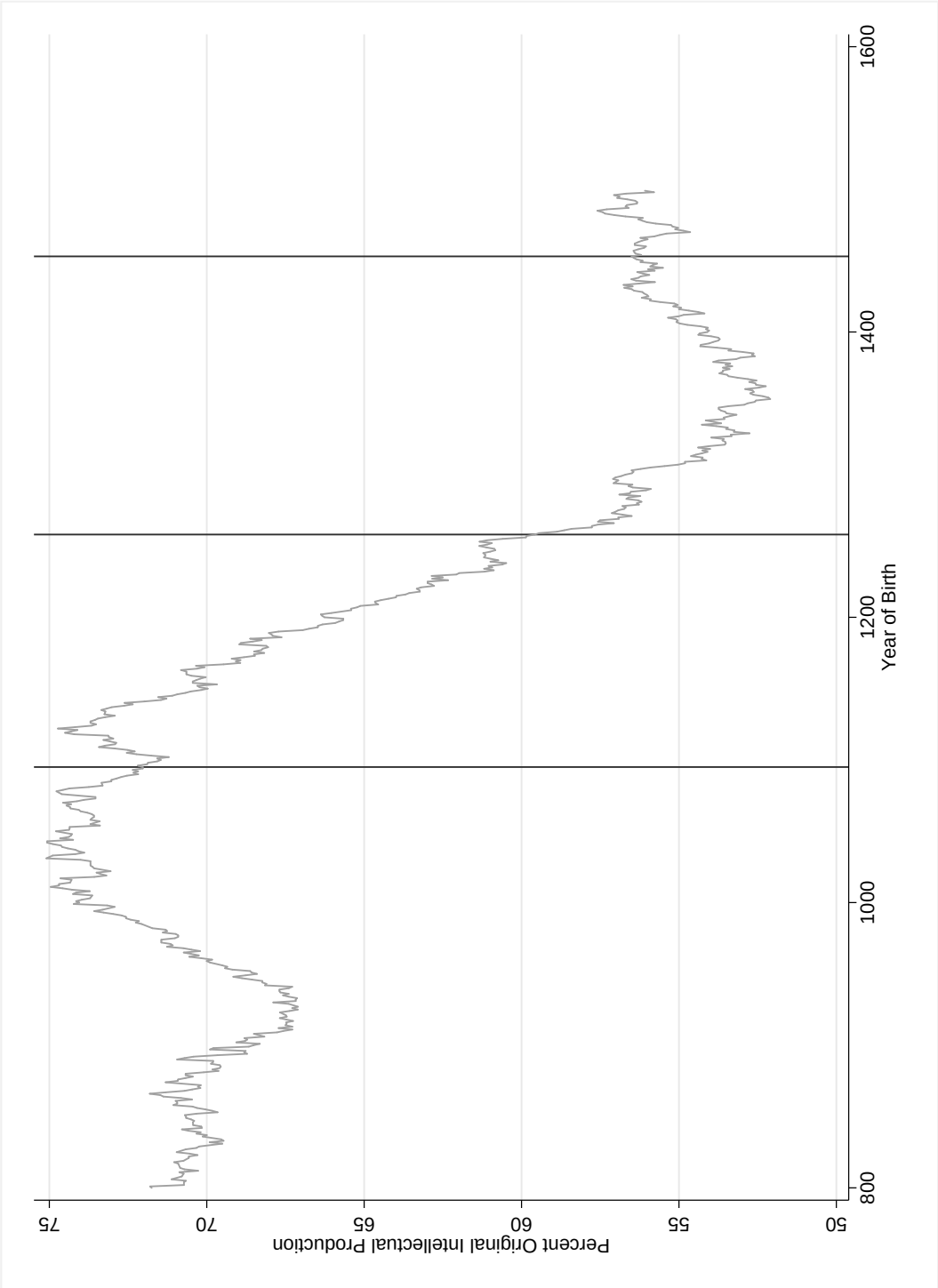

Figure 4: **The Decline of Innovative Intellectual Production in the Islamic World** Vertical lines denote the start of the Crusades (1095 CE), the Mongol Sacking of Baghdad (1258 CE) and the Ottoman Conquest of Constantinople (1453 CE) 100-year rear forward moving average at author's birth date.

Table 1: **Did Intellectual Activity decline in the Medieval Islamic World?**

	Relative to average before 1050 CE	
	Original	Secular
	(1)	(2)
[1050,1100)	1.74	-4.95
	(2.88)	(3.90)
[1100,1150)	-0.46	-1.44
	(3.41)	(3.11)
[1150,1200)	-0.91	-0.83
	(3.12)	(3.15)
[1200,1250)	-11.83***	-6.75*
	(2.67)	(3.68)
[1250,1300)	-12.59***	-14.50***
	(3.40)	(2.55)
[1300,1350)	-15.99***	-16.38***
	(3.78)	(2.98)
[1350,1400)	-15.43***	-11.47***
	(2.70)	(3.30)
[1400,1450)	-9.57	-10.23***
	(6.63)	(3.89)
[1450,1500)	-12.27***	-1.02
	(2.96)	(3.17)
p-value	[0.00]	[0.00]
N	9915	5726

Notes: Standard errors allowing for arbitrary within-year clustering are presented in parentheses. ***, **and *indicate significance at the 1%, 5% and 10% levels.

Table 2: **Interpretations**

	Relative to average before 1050 CE				
	Rel. Occ.	Istanbul	Original	Original	Original
	(1)	(2)	(3)	(4)	(5)
[1050,1100)	14.46	0.29**	4.89	-5.22	5.09
	(9.14)	(0.13)	(3.27)	(5.70)	(3.29)
[1100,1150)	4.35	-0.26***	2.63	-6.68	3.24
	(4.18)	(0.09)	(3.56)	(4.19)	(3.64)
[1150,1200)	1.64	-0.37***	-4.25	-10.11*	-4.63
	(3.16)	(3.29)	(3.41)	(5.35)	(3.56)
[1200,1250)	19.80**	-0.41***	-6.22*	-7.85**	-6.92*
	(7.75)	(0.10)	(3.63)	(3.39)	(3.75)
[1250,1300)	18.63***	-0.43***	-10.74**	-8.98*	-9.56**
	(5.61)	(0.14)	(4.41)	(5.10)	(4.65)
[1300,1350)	28.75***	-0.38***	-14.95***	-17.06***	-15.11***
	(5.88)	(0.14)	(5.03)	(5.01)	(5.42)
[1350,1400)	34.97***	-0.74***	-12.45***	-17.18***	-12.61***
	(7.82)	(0.11)	(3.79)	(4.60)	(3.68)
[1400,1450)	48.24***	-0.75***	-0.35	-0.80	0.23
	(10.51)	(0.09)	(6.44)	(5.32)	(6.48)
[1450,1500)	26.88***	-0.80***	-9.69*	-7.32	-9.10*
	(6.06)	(0.14)	(5.09)	(5.57)	(5.30)
p-value	[0.00]	[0.98]	[0.00]	[0.00]	[0.00]
N	1872	4683	4683	2551	4355
Sample	Rel.	Dist.	Dist.	Dist./NM	Dist., NC

Notes: Standard errors allowing for arbitrary within-year clustering are presented in parentheses. ***, **and *indicate significance at the 1%, 5% and 10% levels.