Arabic Science in Decline?
Evidence from Counting Manuscripts

Richard Solomon
University of Chicago
July 29, 2022

A paper submitted in partial fulfillment of the requirements for the Master of Arts degree in the Master of Arts Program in the Social Sciences.

Faculty Advisor: Robert Gulotty
Preceptor: Yan Xu

I would like to thank my two advisors, Robert Gulotty and Yan Xu for their insightful comments and feedback throughout the project. My gratitude also extends to David Cantor-Echols for his thoughtful criticism and encouragement, the staff of the University of Chicago Digital Humanities and Visual Resources Center, in particular Bridgett Madden, Jeffrey Tharsen, and Carmen Caswell, for their help digitalizing and processing *Kash Al-Zanūn*, Marlis J. Saleh for bibliographic advice, reviewers at the 2022 Midwest Political Science Association conference Gary Johnson and Joanie Willett for helpful feedback, and my friends and colleagues Indran Fernando, Derya Calis, Hongding Zhu, Paweł Rybacki, Ethan Greist, Sewei Dai, and Yinghui Zhou for their advice.

Abstract

The question of the decline in Arabic science and the rise of the West has a long and storied history. In this article, I count manuscripts by author over time in different subject areas with newly digitalized data from *Kashf al-Zanūn*, a 17th century book catalogue written by Kâtip Çelebi, as well as the Islamic manuscript collections of over 2,500 libraries. The results of my linear and generalized differences-in-differences analysis are consistent with the Sunni Revival thesis, which argues that the political empowerment of Abbasid and Seljuk religious élite in the 11th and 12th centuries facilitated the spread of madrasa institutions, professionalized the *'ulamā* class of religious scholars, and channeled talent and state patronage away from empirical sciences. I argue however that the medieval decline did not occur in the context of the 'ulema's opposition to science as part of a nakedly reactionary ideology nor was the madrassa college the unique institutional vehicle for the decline of science. The process involved, rather, the acceptance and assimilation of scientific research into the heart of religious, scholastic life. These findings cast doubt on narratives that attribute intellectual stagnation in the Islamic world to the Mongol, Spanish, and Crusader invasions, the Black Death, the Medieval Climate Anomaly, or modern European colonialism.

1 Introduction

> "Scientific activity disappeared there, save for a few remnants that may be found among scattered individuals and that are controlled by the orthodox religious scholars." - Ibn Khaldūn, *Prolegomena* Vol. 2 (1377 CE).

Why did scientific innovation in the Islamic world rise and fall in the medieval era? It has become customary to refer to the period 700 and 1300 CE as the 'Islamic Golden Age' in which trade and public works programs intensified in the Middle East, population sizes grew, and technological advancements accelerated in the fields of algebra, optics, metallurgy, engineering, physics, astronomy, and chemistry. Powerful Islamic polities – the Umayyads, Abbasids, Fatimids, Mamluks, Seljuks, Caliphate of Córdoba, and Taifa kingdoms – consolidated territory, spread Arabic as a *lingua franca*, advanced religious liberty, and sponsored science and the arts. When and why did this era end in the shadow of Western expansion? By the end of the 20th century, Muslim countries in the Organization of Islamic Cooperation (OIC) had an estimated 8.5 scientists, engineers and technicians per 1000 people, compared to the world average of 40.7, and 139.3 for OECD countries (Anwar and Bakar, 1997). Of the 1,800 or so universities in the OIC, only 312 employ scholars who have published a scientific article in a peer-reviewed journal (Hoodbhoy, 2007). Spain, according to the Arab Human Development Report (2003), translates more books per year than the entire Arab world has in the past millennium.

Why the reversal of fortunes? Far from a dull and obscure topic of medieval or Islamic studies, the question continues to inspire strident public debate. Popular histories have blamed the decline of Muslim science on particular events such as the Crusader, Spanish, and Mongol invasions, environmental stresses like the Medieval Climate Anomaly, or the stifling role of Islamic orthodoxy. The latter point has attracted particular emphasis in Orientalist literature. As Nicholas de Condorcet wrote in 1795, "the Arabs were able to revive some sparks of the Greeks' genius; but they were subjected to a despotism backed by religion" (48). Nearly a century later, the German Arabist Eduard Sachau concurred, writing in the preface to his translation of Al-Birūnī that "but for [prominent religious scholars] al-Ash'arī and Al-Ghazālī, the Arabs might have been a nation of Galileos, Keplers, and Newtons" (p. x). The notion enjoys a following. Goldziher (1916), Madkūr (1968), Sabra (1987), Huff

(1993), Kuru (2019), and Chaney (2016) are also proponents of the view that the growth of religious authority stifled scientific inquiry, precipitating a decline between the 11th and 12th centuries.

However, George Saliba (2007), Dimitri Gutas (1998), and Sonja Brentjes (2004, 2018) have recently questioned the medieval decline thesis, arguing that important advances continued to be made long after the so-called Sunni Revival. In this telling, Ibn al-Nafīs' discovery of pulmonary circulation in Mamluk Egypt, al-Fārisī's experiments with the colors of the rainbow in the Ilkhanate, and Ulugh Beg's 1429 observatory in Samarqand illustrate the persistent vitality of the Muslim scientific tradition into the 15th century. Religious life and scientific inquiry in classical Islam were not at odds, but often symbiotic. *Ex oriente lux*. In Brentjes' (2018) words, the notion of a historically instantiated religious antagonism to science in the Islamicate are "trivializations" endemic of an "older narrative" characterized by "profound falsity" (211). Rather, the transition of the Islamicate world from producer to consumer of scientific ideas is distinctly modern, the result of rapid European expansion after 1500 CE. In Joseph Needham's (1969) words, "modern science developed only in Western Europe in the late Renaissance," (p. 15) however until that point the scientific ideas of Ming China and classical Islam were "comparable to those of medieval and Renaissance Europe" (1954, p. 212). What needs to be explained then is not the internal sclerosis of Muslim science, but the meteoric rise of colonial Europe after Galileo.

Which of these stories is correct impacts not only our understanding of medieval and early modern Islamic history. For one, as Lowe and Yasuhara (2016) show, the story of Islamic education is also the story of the Western academy – its classics, rituals, and methods of disputation. By the 19th century, the engines of empirical research had invariably shifted westward, while the university corporation as an eleemosynary institutional form has taken root across the Islamic world, supplanting the cathedral school, monastery, madrassa, mosque, *bimaristan* hospital and military college as the seat of professional scholarly life. Alexander et al. (2016), Seth (2007), and Conroy-Krutz (2015) provide good treatments of this transition. Secondly, as Joel Mokyr (2005, 2011) has thoroughly documented, the Industrial Revolution and the rise of European powers and their settler states did not simply reflect a regime of private property incentives, "good" political institutions, or geographic advantages conducive

to growth. It also reflected the application of scientific principles and useful knowledge to medicine, warfare, agriculture, and the production process. Inventions such as the galleon ship, power loom, sextant, spinning jenny, steam engine, water frame, canal lock, and vaccine were the material instruments of this advance. Moreover, as Benedict Anderson (1983) has shown in his classic study *Imagined Communities*, the rise of print culture and mass vernacular literacy in Europe profoundly shaped the course of nationalism and capitalist modes of production. Consequently, a study that focuses on the creation and distribution of knowledge, particularly knowledge of the material world, will improve our understanding of economic history, the evolution of institutions, and political development across the *longue durée* both in the West and the Islamicate.

1.1 Preview of Data and Research Design

In my contribution to this debate, I present new data to an old question. The celebrated Ottoman polymath Kâtip Çelebi wrote the compendium *Kashf al-Zanūn* (Dispelling Doubts) in 1652 CE, cataloguing about 15,000 books by 9,500 authors, across hundreds of subject areas, written in Arabic, Persian, and Ottoman Turkish over 900 years. For each book, I code the subject matter, author, author's death date and honorific title, and *nisba*. In a second dataset, I investigate 17,262 unique manuscript titles by 15,823 authors over a thousand years of Islamic history in Arabic, Turkish, and Persian collected from the catalogue records of 2,663 national, university, and private libraries across the world. The particular kind of data I extract from these records are counts by author over time and place, sorted by category. Applying linear and geo-spatial models to the datasets, I document a declining proportion of scholarly work associated with science and technology in the 11^{th} and 12^{th} century closely tied with the rise of honorifics titles indicative of a madrassa education and nisba naming patterns indicative of a consolidating Sunni orthodoxy. I also show a concurrent spatial shift in scholarly production in both the Persian East, the Levant center, and the Andalusian West.

These findings suggest the decline of Muslim scientific scholarship was well under way by the 12^{th} century and reflected a long-term shift in the elite balance of power. It was characterized not so much by the opposition of religious authorities

to empirical science, but the assimilation of Arabic scientific traditions stripped of Hellenistic excess into the fabric of Islamic life. Although this process helped purify the Greek cannon of occultism and its Aristotelian baggage and stimulate new avenues of research such as trigonometry or algebra, it also came to be self-limiting. My results cast doubt on theories attributing the Islamic world's decline to the Mongol invasions, the Crusades, soil exhaustion, climatic events, or modern European colonialism. I also challenges the view that Islam is inherently or uniquely anti-science by situating scientific production within the political equilibrium of medieval Islamic society (Francisco, 2007). The structure of the article is as follows. In part 2, I present a literature review on the decline. In part 3, I present the data and my findings. Part 4 discards alternative theories for my results. Part 5 discusses causal mechanisms. Part 6 concludes.

2 Literature Review

The question of Islamic decline and the rise of the West has a long and storied history. Max Weber (1922, 1930) noted a correlation between economic backwardness, dictatorship, and Islamic societies. Islam he characterized as a "warrior religion," that glorified violence and discouraged personal thrift and initiative (626). On the intellectual revival that occurred in early Muslim empires, the French Orientalist scholar Ernest Renan argued in 1883 that scientific advancements in the Islamic world happened not because of Islamic orthodoxy, but in spite of it; the scientists of Islamicate civilization were in fact "Zoroastrians, Christians, Jews, those from Harran, Ismailis, Muslims with internal revolts against their own religion" (16). More recently, the Syrian poet Adonis has argued that Islam inherently stifles intellectual progress: "The Mu'tazila were not part of the recognized Muslim 'body' – neither the mystics, nor the philosophers, nor the poets" (2015, 25).

Modern Islamists, meanwhile, such as Sayyid Qutb (1964), Ruhollah Khomeini (1970), and Said Nursi (1929-34) attributed the Islamic world's intellectual, military, and economic decline to an alleged deviation from orthodox Islam. Qutb, for instance, wrote that the decline was the result of "unfortunate circumstances which accompanied the Renaissance and the industrial age to divert them from God's own system" (1974, 113). Nineteenth and 20th century *ijtihadi* reformers such as Muhammed 'Ab-

duh and Rashid Reda in Egypt (1897), Jamal al-Din al-Afghani in Iran (1883), and Muhammed Iqbal in India (1909) emphasized the emancipatory role of the Protestant reformer Martin Luther and Enlightenment philosophers such as Jean Jacques Rousseau, with the implication that Islam lacked such fathers of renewal. In this formulation, only through social and legal reform – of the kind prescribed by 'Abduh, Reda, and al-Afghani – could enable Islam to claim its lost glory.

Questions about the relationship between reason and revelation have endured as a source of intense polemical exchange. Between 1901 and 1903, for instance, Ottoman journalist Aḥmed Midḥat's translations of John William Draper's book *History of the Conflict between Religion and Science* (1875) provoked a heated debate in the popular Arabic journals, *al-Jāmi'a* (The Gatherer, 1899-1910) and *al-Manār* (The Beacon, 1898- 1935). On one side, liberal secularist Faraḥ Anṭūn pointed to the tumultuous career of Andalusian philosopher Averroës (1126-1198), who faced persecution from the religious establishment. Anṭūn argued that Christianity welcomed philosophy and science more fully than Islam, as made obvious by the Enlightenment and Western leadership of modern science. Azhar clerics Rashid Reda and Muhammed 'Abduh accused Anṭūn of being prejudiced and offensive and recruited Draper's own positive view of Islamic science to refute the conflict model. According to Akkach (2019), 'Abduh's passionate critique "has endured in the Muslim collective imagination ever since" (8).

A second tradition of scholarship and popular commentary attributes the decline of Islamic civilization to unique historical events between the 11th and 14th centuries. The Crusaders, from 1095 to the fall of Acre in 1291, occupied important Levantine cities such as Antioch, Tripoli, and Jerusalem. European invaders limited Muslim access to the Eastern Mediterranean (Runciman, 2005) and plundered several libraries and schools (El-Abbadi et al., 2008). The Crusades, argued Amin Maalouf (1984), "led to long centuries of decadence" in the Middle East (264). Wilhelm Barthold (1900) advanced similar arguments about the 13th and 14th century Mongol invaders, who massacred entire Muslim cities (Smith, 1975), destroyed urban infrastructure (Lambton, 1969), plundered libraries (Starr, 2013), and vandalized complex irrigation systems (Shatzmiller, 1993), which in the arid climates of Central Asia, Persia, and Iraq were costly to rebuild. Looking westward, the Spanish *Reconquista* of Iberia

from the Moors in the 13th and 14th century – immortalized by the Andalusian poet Abu al-Baqa' al-Rundi in *Lament for the Fall of Seville* – evokes a parallel image of civilization lost in Maghribi literature (Monroe, 1974).

For centuries, a prevailing view about science in the classical age of Islam held that the consequent depopulation, spread of pastoralism, and political and economic fragmentation of Muslim lands led to a catastrophic decline in scholarly, scientific output. Persian historian Rashīd al-Dīn Ṭabīb in his *Collection of Histories* (1314) that chronicle the Mongol siege of Baghdad in 1258 colored the waters of the Tigris black with the ink of scholarly texts. In 1727, the Hungarian-born Muslim Ibrahim Muteferrika, in his request to Ottoman authorities for permission to run the first moveable type Arabic printing press, stressed this issue, arguing that "Genghis, Hulagu, and the Spanish Catholics destroyed Muslims' books, and since that time there had been a scarcity of books in the Muslim world" (288). Responding to Ernest Renan's argument about Islam's deleterious impact on scientific advancement, the Ottoman intellectual Namık Kemal (1910) retorted that the Crusader and Mongol invasions were to blame for the decline in Muslim scholarship (42). The Indian Muslim commentator Syed Ameer Ali (1891) concurred: "Rationalism, philosophy, the sciences and arts went down before that avalanche of savagery – never to rise again" (42).

A more subtle, but also event-driven narrative of the Islamic world's medieval decline focuses on soil exhaustion, climatic stresses, and epidemiology. Jared Diamond (1991) popularized the notion that Muslim societies in arid lands over-exploited soil and water stocks, which led to "ecological suicide." Europe escaped that fate because it had "the good luck to live in a more robust environment with higher rainfall, in which vegetation regrows quickly" (411). Similarly, Hodgson (1974) and Christensen (1993) argued that in Abbasid-era Mesopotamia, intensive irrigation and poor drainage increased soil salinization, leading to gradual declines in agricultural yields of cereal grains and cotton. For a tax regime based on a feudal system of land revenue assignments to the military élite (*iqtā'*), declining yields stressed state finances, reduced patronage to educational institutions, and led to periodic famine and public disorder (Bulliet, 1994 and 2009). Ellenblum (2012) argues that volatile climatic cooling between 950 and 1072 in Iraq, Iran, and Central Asia disrupted nomadic herding and weakened state authority, while Latin Christendom experienced the Medieval

Climate Anomaly. Dols (1977) documented the destruction of the Black Death in 1348-49, which killed almost a third of the population in Mamluk Egypt and Syria. Campbell (2016) argued for the centrality of these data for explaining why Europe's long-term development path diverged from China and the Islamic World.

A third thread of literature considers the various mechanisms of endogenous, institutional path-dependence and elite competition. These theories tend to understand institutions as systems of rules that define transaction costs and uncertainty (North, 1993) and argue that institutions determine living standards, intellectual production, economic dynamism, and political life across the globe in the *longue durée* (North and Thomas, 1973 and Acemoglu et al. 2005). Timur Kuran (2011), for instance, highlighted the conspicuous absence of Islamic institutions that could facilitate impersonal exchange, capital accumulation, and long-distance trade. Avner Greif (2006) elaborated in game theoretic terms the transactional institutions developed by Maghribi Jewish traders in the medieval Mediterranean, contrasting them to institutions developed by Genoese and Venetian competitors.

For many scholars in this tradition, the choice of institutions ultimately reflects either the balance of power among different elites in society. Ahmet Kuru (2019) argued that the Islamic world's intellectual stagnation is the inevitable consequence of the 'ulema-state alliance', an enduring coalition between the political class and clerical authority, which worked to stifle innovation and undermine the growth of secular institutions vital for democracy, economic dynamism, and scientific life. Rubin (2017) similarly identified Ottoman rulers' over-reliance on the religious establishment to propagate and legitimize their rule as the primary reason for the Middle East's delay in adopting capitalist enterprise and the movable-type printing press. Blaydes and Chaney (2013) argued that European feudal institutions cultivated executive restraint, while the Muslim sultan's reliance on Mamluk slave armies limited the bargaining strength of local nobles and merchants. Makdisi (1961, 1981) posited a 'Sunni Revival' period in the 11th century strengthened the bargaining position of religious leaders, who opposed the study of science as part of their campaign to confront religious skepticism.

What institution translated these political currents into a durable, self-enforcing equilibrium? For those looking for what Greif and Laitin (2004) call a "theory of endogenous institutional change", the answer is often the madrassa. Makdisi (1981) and Berkey (2002) argue that the madrassa as an institutional complex began in Baghdad under the Seljuk dynasty, combining the charitable endowment (*waqf*) with the college of law (*masjid*) and student residence (*khan*) under a unified roof. It primarily served as a center of training for young clerics. Unlike the medieval university corporation which conferred a diploma, madrassas relied on personal relationships; each professor granted personal licenses, or *ijaza* (similar to the medevial *licentia docendi*) to certify his students' expertise to teach particular books, subjects and/or issue legal opinions. Moreover, the founder defined the nature, endowment, and status of the madrasa in perpetuity, securing the waqf to serve the wishes of the mortmain (or "dead hand"). Azzam (2016) and Safi (2006) demonstrate that this innovation occurred under intense sectarian conflict, in which traditionalist forces (*ahl al-hadith*) forged an alliance with caliph al-Mutawakkil and later the Seljuks to crush the rationalist Mu'tazili movement. Islamic law and the madrassa thus became a vehicle of Seljuk ideology and conservatism. It was under these circumstances, they argue, that the traditionalists chose to close ranks under the legitimizing authority of the Shafi'i, Hanbali, and Zahiri schools. Scientific inquiry suffered as a result.

3 Data and Empirical Analysis

Kâtip Çelebi's seven volume book catalogue *Kashf al-Zanūn* (1652) is uniquely positioned to break the intellectual stalemate between those who argue for a medieval decline and their detractors. By systematically documenting the names, authors, and subject fields of about 15,000 books written in the Islamic world throughout its history, *Kashf al-Zanūn* (Dispelling Doubts) provides a rare and comprehensive measure for the evolution of Muslim intellectual output. Çelebi's personal background and privileged position in the milieu of the multi-ethnic, multi-religious Ottoman Empire of the 17th century afforded him a unique perch from which to document the emerging polarity of rational and religious sciences and the advance of early modern European science. A scribe in the fiscal administration (*Anadolu muḥāsebesi*) and member of a well-established Istanbul family, Çelebi's father provided the financial means to hire private tutors for his son's education. As Morkoç (2019) writes,

> "The fact that he came from outside the traditional madrasa system might explain his broad perspective and tendency to synthesise knowledge from the many sources and disciplinary fields available to him. He explained the wide horizon of thinking which his works reveal by describing '[t]he supreme zeal he owned', which 'did not allow him to suffice with one single scientific field'" (115).

In his critical edition of Çelebi's celebrated *Mīzān*, Turkish scholar Süleyman Uludağ argues that what differentiates Çelebi from the Ottoman scholars of his time was his devotion to reconciling Islamic law (*sharī'a*) with Sufism (*ḥikma*), rationality (*'aql*) with tradition (*naql*), and religion (*dīn*) with philosophy (*falsafa*). In Çelebi's own words, "Because two wings are necessary to fly, one cannot take a distance with one wing. Rational and religious sciences are comparable to two wings" (*Mîzānü l-hakk*, 229-230). This keenness to represent works of both rational and religious value informs the listings of *Kashf al-Zanūn*, promises a degree of balance in the sample, and militates against possible Western-specific biases in the book collection.

Unfortunately, Çelebi's catalogue information does not include subject categories for each text, so to supplement the Çelebi data with an independent source, I gathered data on 17,262 unique manuscript titles by 15,823 authors over more than a thousand years of Islamic history in Arabic, Turkish and Persian. These data were compiled by the Al-Req Al-Manshour project (الرق المنشور), a proprietary, global and comprehensive catalogue of Islamic manuscripts, compiled from the records of more than 2,500 libraries across the Middle East, Europe, East Asia, and North America. Not only does the Al-Req data document the location and number of manuscripts held in libraries for each unique text, it also assigns each text a subject field sub-class by Dewey Decimal system. These data sources represent an improvement on previous attempts to quantitatively document the evolution of Muslim intellectual life, such as Sorokin and Merton's (1935) textual analysis of George Sarton's multi-volume tome *History of Science*, or Eric Chaney's (2016) working paper on Islamic science. Chaney's data for instance only reflects metadata gathered from books in the Harvard library "written by authors with an Islamic-sounding name" (8), raising questions about the sample's representiveness, both of the manuscript medium ubiquitous in pre-modern scholarship, as well as the authorship and subject matter. My approach is hopefully more

comprehensive.

3.1 Data Collection and Cleaning

The data collection and cleaning process proceeded as follows. For the Çelebi set, I obtained the full information for every manuscript entry from a digitalized copy of *Kashf al-Zanūn* hosted on the Arabic website shamela.ws. To ensure the text was represented faithfully, I cross-referenced entries with a 2008 typeset edition of Çelebi's original Arabic text from the Beirut-based publishing house Dār al-Kutub al-'Ilmīyah. Then using the R programming language, I extracted the titles, author names, author death dates (converting Hijra to Gregorian calendars), and author honorifics (judge, sheikh, imam, etc). Author names containing honorifics indicative of formal legal training (*Qadi, Faqiḥ*) were labeled as such. To pinpoint the author's location, I exploited a naming convention among pre-modern Islamic encyclopedists to give the author's *nisba* (Al-Baghdadi, Al-Qurtubi, Al-Tusi, etc) at the end of their name, indicating place of birth or origin (Baghdad, Cordoba, Tus). I hand-coded more than a thousand of these *nisbas*, only keeping those that refer to a specific place, and not ethnic group, tribe, religion, Sufi order, or occupation. To validate whether the *nisba* indeed indicates a place of birth, I randomly sampled 100 entry and counted by hand whether their *nisba* matched place of birth. For those who I could geo-reference using their Encyclopedia of Islam and Arabic Wikipedia entry, my geo-locating strategy was 96% accurate.

Then, using the Google Maps API, I obtained the latitude-longitude coordinates for each book's author based on the last *nisba* of their name. For the Al-Req dataset, I followed a very similar process to obtain author location, death date, and honorific. I then counted the books by location. Figures 1 and 2 map the centers intellectual life from 650 to 1650 for the Çelebi and Al-Req datasets respectively:

Figure 1: Centers of Intellectual Production 650-1650 (Çelebi)

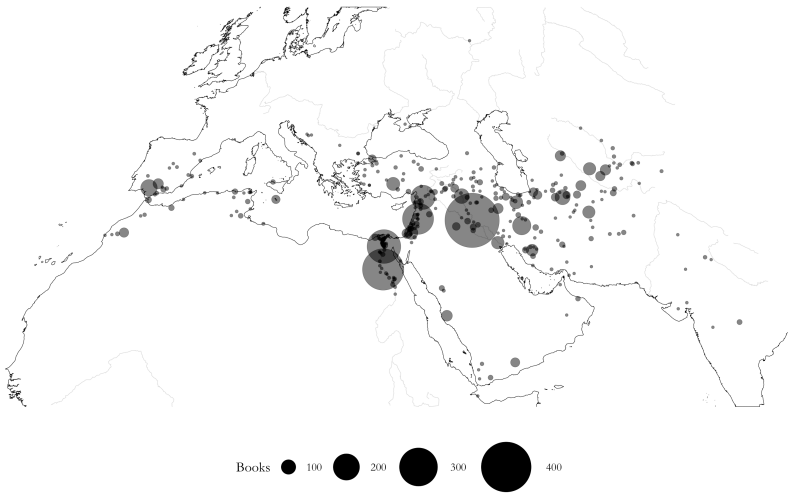
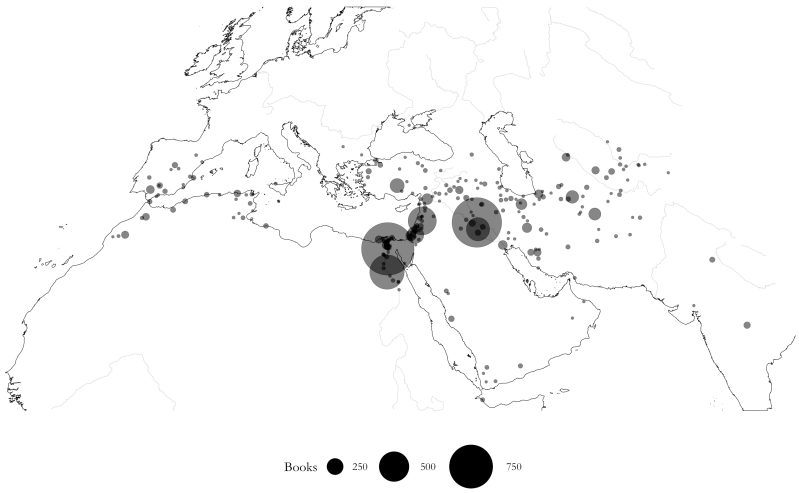


Figure 2: Centers of Intellectual Production 650-1650 (Al-Req)



In general, the maps confirm the conventional view about the centers of intellectual life in the pre-modern Islamicate. Cairo, Baghdad, and the Levant corridor are major hubs, with a constellation of regional centers in Northern Iran, central Asia, Anatolia, Andalusian Spain and the Mediterranean shores of North Africa. However it's very possible that Muslim scholars, like contemporary ones today, were remarkably itinerant; one might be born in Khorasan, study under a master's tutelage in Baghdad, and then teach at a mosque in Damascus or Basra, with an extended trip to

Mecca in between. Very few men were like the old Kant who lived and died in Königsberg. This fact requires a subtle change in the interpretation of the *nisba* data. Rather than locating the "centers" of intellectual life, the *nisbas* indicate "feeder" schools and towns, that is, where scholarly talent is being sourced. Another strategy to deal with itinerancy is to bin the *nisbas* into regions, since under the travel constraints of the medieval era, it would be very uncommon for example for a Bukhari from modern-day Uzbekistan to wash up in Tunis, or a Tunisi in Mecca. To this end, for the time trend analysis below, I assign anyone born east of Baghdad is assigned "East", any west of Alexandria "West", and everyone in between "Center."

Finally, I categorize manuscript entries by subject field. For the Al-Req data, Dewey Decimal fields were already assigned by professional librarians to each entry, and so to analyze changes in the volume and proportion of scholarly output, I binned the subfields into "Science" and "Religious" categories according to Table 1 below:

Table 1: Subject Fields for Ar-Req Project

Religious		Science	
Qur'anic sciences	علوم القرآن	Astronomy	الفلك
Sufism	التصوف الإسلامي	Natural Sciences	لعلوم الطبية
Principles of Fiqh	أصول الفقه	Math, engineering	الرياضيات والهندسة
Theology, Creed	العقيدة	Logic	المنطق
Mosque Sermons	الخطب والمساجد	Earth Sciences	علوم الأرض
Prophetic Biography	السيرة النبوية	Chemistry	الكيمياء
Hadīth	الحديث	Veterinary Sciences	البيطرة
Maliki, Shafi'i Fiqh	الفقه المالكي والشافعي	Pathology	الأمراض
Hanafi, Hanbali Fiqh	الفقه الحنفي والحنبلي	Physics	الفيزياء
Islamic Ethics	الأخلاق والآداب	Political science	العلوم السياسية
Religious Fatwas	الفتاوى	Animal sciences	العلوم الحيوانية
Religious sects, debates	الفرق والأديان والردود	Agriculture	الزراعة
Qur'anic exegesis	التفسير	Economics	الاقتصاد
Inheritance	الفرائض	Psychology	علم النفس
Dhikr, Ritual	الأذكار والشعائر الإسلامية	Military Arts	العلوم العسكرية
Qur'anic Recitation	التجويد والقراءات	Sociology	علم الاجتماع
Proselytism	الدعوة والدفاع عن الإسلام	Empirical Sciences	العلوم البحتة

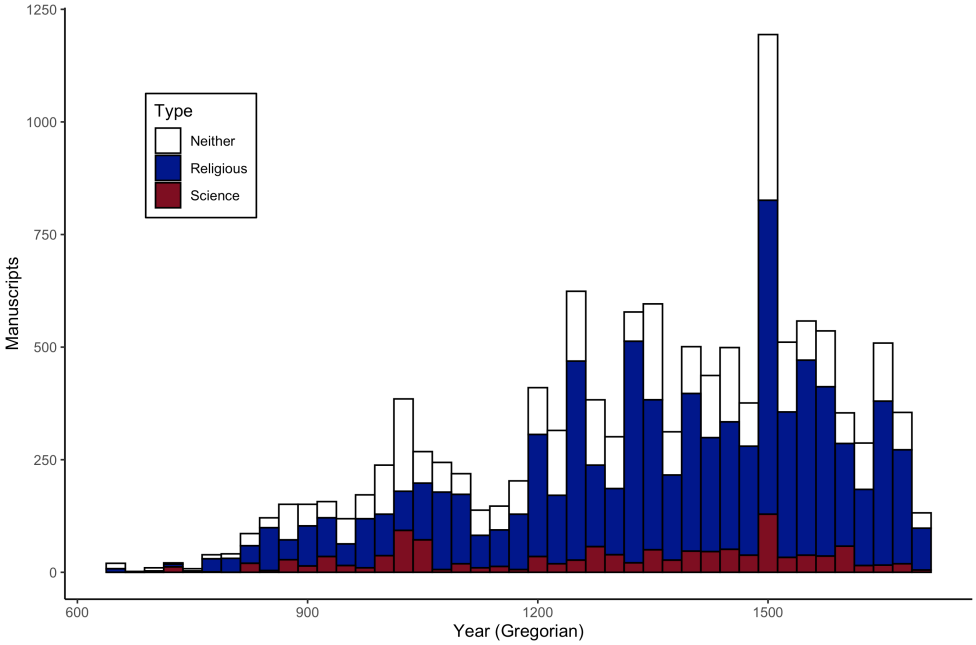
[a] Notes: See replication files for full list of subject field sub-classes by Dewey Decimal system. Philosophy, music, history, linguistics, genealogy, geography, arts, family law, grammar, and literature fields not included in main analysis. See الرق المنشور for more information.

To give a concrete example, Ibn al-Haytham's *Book of Optics* (كتاب المناظر) and *Doubts Concerning Ptolemy* (شكوك على بطليموس) would be categorized as scientific because they fall under "Physics" and "Astronomy" labels respectively, while the al-Tabari's *Exegesis* (تفسير الطبري) and Al-Ghazali' s *Revival of the Religious Sciences* (إحياء علوم الدين) would be religious because they fall under "Qur'anic Exegsis" and "Sufism" categories, respectively.

3.2 Linear Model Estimation

Predictions of the Sunni revival hypothesis are that 1) the proportion of intellectual activity (proxied by manuscript production) dedicated to scientific topics compared to religious topics declines over the period of the sample, 2) this decline began in the 11th century with the Seljuk innovation of madrassa-waqf educational institution. And 3) the decline shows a clear geographic pattern, starting in population centers in the East such as Baghdad and Mosul, continuing through the Levantine belt of Beirut, Istanbul, Cairo, and Alexandria, and ending in the Western region of Moorish Spain and Morocco. To illustrate prediction (1) in a preliminary and exploratory fashion, I count the number of scientific and religious works in the Al-Req data in each 25 year bin and present the histogram below in Figure 3:

Figure 3: Volume of Manuscripts by Topic, 650-1650 (Al-Req)



It appears that the number of scientific works per quarter-century tends to remain fairly stable over time, while the number of religious works grows. How reliable is this eyeball result? A specification for the linear regression model that defines the rate of scholarly decline β is the following:

$$\%\text{Science}_{th} = \beta_0 + \sum_{h \geq 1100} \beta_h D_h + \epsilon_{th} \tag{1}$$

where $\%\text{Science}_{th}$ is the fifty-year moving average for the proportion of books on science written by authors who died in year t in hundred year bin h. Century year dummies D_h are for 700 to 1600 CE. I estimate the intercept β_0 and coefficient β_h using Newey-West standard errors allowing for the error structure to be heteroskedastic and autocorrelated by one lage. I weight regression (1) by the total number of books written by authors who died in year t. If the Sunni revival hypothesis is correct, then we should expect $\hat{\beta}_h < 0$ and statistically significant in the centuries after 1100CE. Similar regression equations for $\%\text{Religiou}_{th}$ can also be estimated, where $\%\text{Religious}_{th}$ is the share of works on religious texts. I estimate equation (1) with the raw counts of science and religion as well. Point estimates for this specification are given in Table 2, Columns 1 - 4.

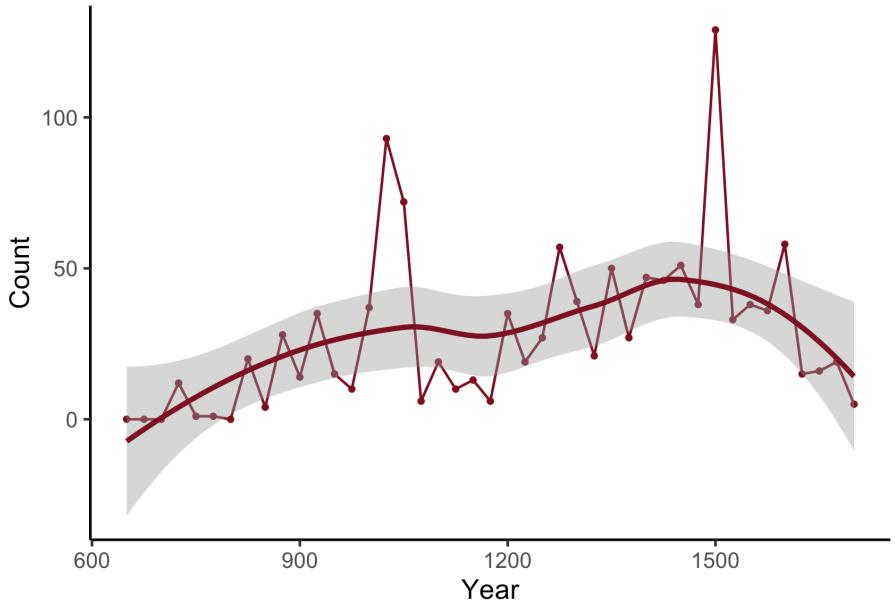
Table 2: Decline of Science in Islamicate: 696 - 1700 CE

	%Science	%Religious	Religious	Science
	(1)	(2)	(3)	(4)
(1000, 1100]	4.76	−16.17	1.62	1.69
	(1.34)	(1.79)	(0.17)	(0.20)
(1100, 1200]	−6.73	8.82	2.27	−0.10
	(0.83)	(1.28)	(0.28)	(0.04)
(1200, 1300]	−6.01	7.73	7.58	0.60
	(0.85)	(0.92)	(0.46)	(0.07)
(1300, 1400]	−6.00	12.63	10.29	0.76
	(0.83)	(1.11)	(0.41)	(0.05)
(1400, 1500]	−3.45	7.93	8.66	1.22
	(0.87)	(0.70)	(0.17)	(0.09)
(1500, 1600]	−5.10	10.56	14.89	1.70
	(0.84)	(1.08)	(0.45)	(0.12)
(1600, 1700]	−5.87	12.27	8.15	0.55
	(0.91)	(1.09)	(0.57)	(0.07)
Baseline [696, 1000)	13.33	54.16	2.61	0.60
	(0.80)	(0.58)	(0.09)	(0.04)
Year-observations	1,005	1,005	1,005	1,005
Manuscripts	12,678	12,678	7,757	1,202

Notes: Results in (1-3) are calculated on the Al-Req sample. The dependent variable in column 1 is the 50-year moving average for the proportion of books on scientific topics as defined in section 3.1. The dependent variable in column 2 is the proportion of books written on religious topics. Column 3 and 4 report the 50-year moving average for the raw count of religious and scientific texts, respectively. I multiply the coefficients by 100 for exposition. Newey-West standard errors are presented in parentheses. All point estimates break the 99% confidence level.

The results are generally consistent with the medieval decline thesis. From 696 to 1000, the share of books written on scientific topics is about 13%. This share reaches a zenith during the 11th century at 18%, but falls to 7% by 1300 and never recovers. The share of books on religious topics steadily rises after the 11th century, and column 3 confirms that this trend reflects a rise in the raw number of religious texts, not a decline in the number of scientific texts. These results hold true at the 99% confidence level and are robust to autocorrelation, heteroskedasticity, and alternative moving-averages and weights. How do we reconcile this result with Saliba (2007) and Brentjes's (2018) observation that the works of later scientists such as Ali Qushji (d. 1474) and Shams al-Din al-Khafri (d. 1550) are as progressive, impressive and worthy of historical study as the early Thābit ibn Qurra and Avicenna three centuries before? One insight is that the raw counts of scientific texts convey a different impression than the proportions. Below I present the raw Al-Req count of scientific texts in 25-year bins overlaid with a local polynomial regression:

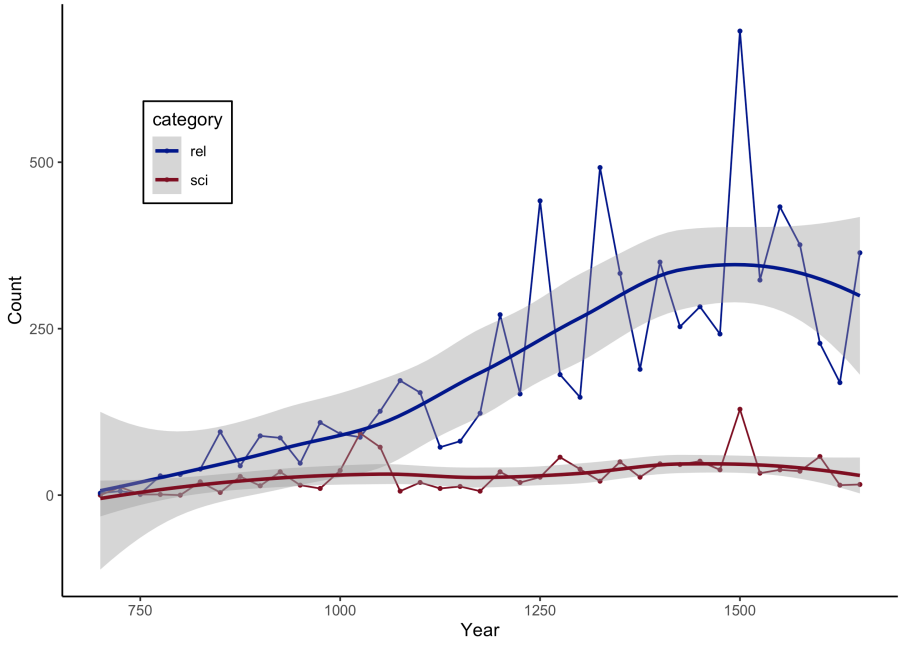
Figure 4: Volume of Scientific Manuscripts every 25 years, 650-1650 (Al-Req)



For the narrowly focused historian of science, the 16th century would appear as much a treasure-trove of textual material as the twelfth. Looking at the raw count, it might appear that the Sunni Revival played little role in a purported medieval decline of Arabic science. However, when we examine those same data juxtaposed against

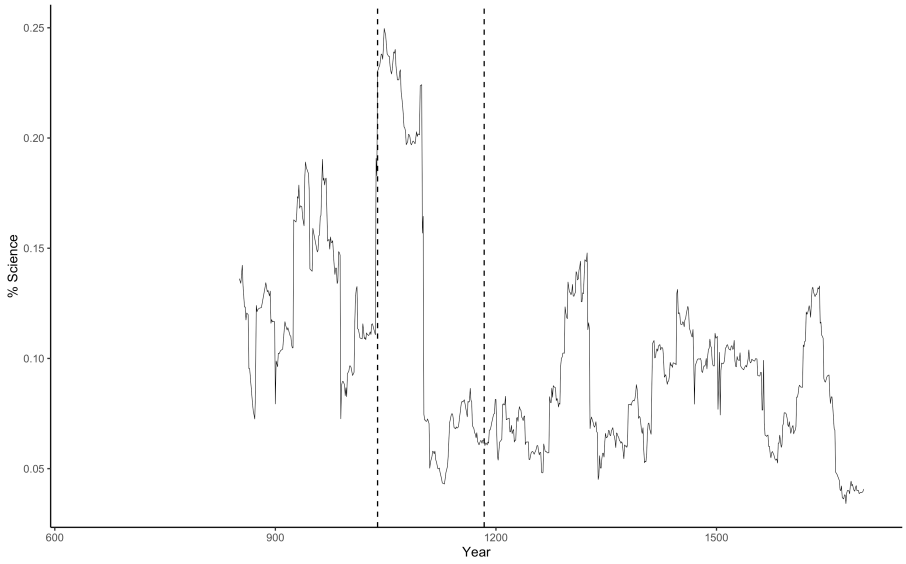
the count of religious texts, we can observe a clear shift in the emphasis of scholarship that becomes statistically significant around the latter half of the 11th century:

Figure 5: Volume of Manuscripts every 25 years, 650-1650 (Al-Req)



Can we get even more precise about the point of decline? Chow tests (1960) on %Science$_{th}$ across most years between 1000 and 1200 allow us to reject at very high confidence levels the null hypothesis of no structural break points. Bai and Perron (1998, 2003) provide a framework for identifying structural breakpoints in a multivariate time-series. Suppose the share of texts devoted to science is a function of some underlying time series process and an error term: $\%Science_t = \gamma_t + \mu_t$. Treat m possible breaks as unknown, where $t = T_{j-1} + 1..., T$ and $j = 1, ..., m + 1$. Using this specification on the 50-year moving average of $\%Science_t$, the algorithm selects one break point at 1039CE with a 95% confidence interval of (1039, 1047). Another break point at 1184CE defines a 95% confidence interval of (1168, 1185). In alternative specifications defining a $\%Science_t$ as a 75-year and 100-year moving average, the range defined by these two breakpoints 1039 and 1184 is always significant. Figure 6 overlays these two breakpoints across the 50-year moving average used for Table 2.

Figure 6: Fifty-Year Moving Average of % Science (Al-Req)



This century interval defined a period of rapid growth for madrassa institutions across the heartlands of the old Islamicate. Although exact numbers are difficult to find, Gilbert (1980) for instance, documents a rise in the number of established madrassas in Damascus from two in 1100 to twenty-six in 1200. But how do we know that these trends – the rise of madrassas and the declining scientific emphasis of scholarship – are associated and not mere coincidence? Or that the Ar-Req manuscript data is trustworthy and not subject to the bias of modern scholars and bibliographers? A few more variables can be brought to the analysis. Although naming conventions differ, both Çelebi's bibliography and the Ar-Req repository tend to record if a scholar is affiliated with a school of Islamic law (or *mathhab*) such as the Maliki, Shafi'i, Hanbali, Hanafi, and Zahiri schools. In addition, Çelebi's bibliography records honorific titles, three of which – *qadi*, *faqih*, *mudaris* – indicate the author has some form of legal training, works as a judge or juris-consult, or teaches at a madrassa. Ar-Req unfortunately does not record honorifics in a consistent fashion. Table 3 presents the estimates for the proportion of scholars in each year who identify with a school of law and adopt a legalistic title.

Table 3: Rise of Mathhabs and Juris-Consults

	Relative to Average on Baseline		
	%Law	%Law	%LawTitle
	(1)	(2)	(3)
(1000, 1100]	2.04	2.66	2.38
	(0.59)	(0.89)	(0.22)
(1100, 1200]	2.92	8.71	4.13
	(1.31)	(0.89)	(0.32)
(1200, 1300]	8.92	3.97	1.96
	(1.37)	(0.40)	(0.29)
(1300, 1400]	29.48	11.36	3.61
	(3.06)	(0.41)	(0.23)
(1400, 1500]	17.40	11.81	2.91
	(0.85)	(0.56)	(0.25)
Baseline: [851, 1000]	2.83		
	(0.47)		
Baseline: [622, 1000]		11.27	2.07
		(0.34)	(0.20)
Observation-years	545	607	607
Manuscript titles	8,295	5,271	5,271

Notes: Column 1 estimates the proportion of authors in the Ar-Req dataset affiliated with one of the five schools of Sunni law. Columns 2 estimates that same proportion but on the Çelebi dataset. And Column 3 estimates the proportion of authors in the Çelebi dataset using honorifics indicative of a legal profession. Newey-West standard errors are presented in parentheses. All point estimates break the 99% confidence level. Note that the baselines are different because Çelebi's set was compiled in the 1650s and contains works that no longer survive.

If the results of the preceding analysis which indicate a medieval decline in scientific work are driven by modern biases, then we should expect that time-trends in these specific *nisbas* to be unrelated across the modern and pre-modern sets. However columns 1 and 2 both separately record a persistent increase in the use of legal *nisbas*. Although the magnitudes and starting baselines differ, both Ar-Req and Çelebi record a general increase in the proportion of scholars who identify with a Sunni school of law. By 1500, the proportion in both sets has converged to 20%. Column 3 of Table 3 also records a modest, but palpable increase in the proportion of authors who adopt a legalistic honorific such as *qadi* or *faqih*; the use of such titles doubles from the pre-millennium average of 2.07% to about 5%. However other titles such as *imam* and *sheikh* appear to have enduring appeal, so the author titles may not adequately reflect the spread of madrassa institutions. It is now worth investigating the linear association between the rise of Sunni legalism and scientific output over time. In what centuries was it significant? In Table 4, I estimate the following specification on the Ar-Req dataset:

$$\%\text{Science}_{th} = \alpha + \beta \cdot \%\text{LawNisba}_{th} + \epsilon_{th} \tag{2}$$

where $\%\text{Science}_{th}$ is the 50-year moving average for the proportion of texts by authors who died in year t in 200-year bin h which are about scientific topics. $\%\text{LawNisba}_{th}$ likewise represents the 50-year moving average for the proportion of texts by authors who died in year t in 200-year bin h which indicate an affiliation with one of the five Sunni schools of law, as reported in their *nisba*. α is the intercept, β is the coefficient, and ϵ is the error term. I estimate this equation in 200-year bins and from years 800 to 1600 due to data constraints. And once again, I weight regression (2) by the total number of books written by authors who died in year t. If the Sunni Revival hypothesis is true, then we should expect that $\beta < 0$, particularly in the most decisive window of the 11^{th} to 14^{th} centuries, when the share of science declined most severely and the Sunni schools registered their fastest growth. In blunter words, more Islamic lawyers should mean less science. To validate the historic specificity of that prediction, earlier as well as later centuries should produce little or no association between %Science and %LawNisba, since each or both of the variables had presumably plateaued, and the little variation in one shouldn't explain the little variation in the other.

Table 4: Mathhab Authors and Science: 800 - 1600

	%LawNisba			
	(1)	(2)	(3)	(4)
(800, 1000]	0.01			
	(0.08)			
(1000, 1200]		−0.52***		
		(0.19)		
(1200, 1400]			−0.05***	
			(0.02)	
(1400, 1600]				0.04
				(0.04)
Intercept	12.43***	16.26***	8.37***	8.15***
	(0.60)	(1.51)	(0.54)	(0.76)
Observation-Years	200	200	200	200
Manuscripts	1,067	1,813	3,643	4,550

Notes: Point estimates are calculated on the Al-Req set, years [800, 1600). Columns 1-4 report point estimates for equation (3) in each 200-year bin. The independent variable %LawNisba is the 50-year moving average for the proportion of authors who have *nisbas* that indicate an affiliation with one of the five Sunni schools of law. The dependent variable %Science is the 50-year moving average for the proportion of texts catalogued as scientific. I present Newey-West standard errors in parentheses and weight the regression by the total number of books written by authors who died in that year. *p<0.1; **p<0.05; ***p<0.01.

Interpreting these results, we observe that in the 200-year bin (1000, 1200], a 1 percent increase in the proportion of authors connected to a Sunni school of law predicts a 0.5 percent decrease in the proportion of texts dedicated to science. From 1200 to 1400, the negative correlation is still statistically significant, but predicts less variation. By the last bicentennial, the correlation has vanished. The row of intercepts α affirm the general pattern of the medieval decline in %Science that Table 2 demonstrated earlier. These results are robust to serial autocorrelation, heteroskedasticity and the use of wider moving averages and alternative weighting schemes. On the whole, this evidence suggests that the 11th and 12th centuries marked a critical juncture in the long-term decline of Arabic science. Moreover, its stagnation was closely tied to rising currents of orthodoxy and legalism.

3.3 Spatial Predictions

The linear regression results from section 3.2 have so far vindicated the notion of medieval decline in Arabic science and provide some evidence of a Sunni Revival underway. Was the madrassa its institutional vehicle? To answer this question about causal mechanisms, we might exploit the geographic legacy of the institution. Shatzmiller (1994) along with Lapidus (2014) detail how the madrassa began in late-Abbasid Baghdad. After the Order of Assassins murdered the Seljuk vizier Niẓām al-Mulk in 1092, state madrassas called Niẓāmiyyahs percolated into Abbasid and Seljuk cities of Mesopotamia, the Iranian platau, and Greater Khorasan. By the early 12th century, the madrassa had rapidly expanded to Egypt and the Levant. However, it did not reach Tunis until 1249, Fez until 1271, and Andalusian Spain until 1349. Makdisi (1981) tentatively attributes this delay in the West to the role of the Maliki *madhab* predominant in the Maghrib:

> "Unlike the other Sunni schools of law, it did not allow waqf institutions to be controlled by their founders. The founder of a madrasa could not appoint himself as its trustee-administrator. It thus discouraged the founding of madrasas by private individuals, who frequently resorted to waqf in order to put their wealth out of the reach of confiscating sovereigns and immobilize the corpus for the benefit of their heir-descendants in perpetuity. As this was not possible under Maliki law, Maliki madrasas did not thrive in countries where Maliki law was

> predominant... It therefore fell to the sovereigns and some other highly placed men of power and influence to found colleges in Spain and North Africa, founders whose motives in so doing lay primarily elsewhere than in providing for their descendants" (238).

Whatever the reason is, we can investigate the extent to which Ar-Req and Celebi's data are consistent with this alleged spatial pattern. If madrassas displaced scientific life and redirected state patronage, then we should expect the proportion of scientific texts in the Western Islamicate to register a decline substantially after, and not before the lands east of the Levant do. To estimate these spatial shifts, I estimate the following regression:

$$\%\text{Science}_{th} = \alpha + \gamma \text{West} + \sum_{h \geq 1100} \beta_h D_h + \sum_{h \geq 1100} \delta_h D_h \text{West} + \epsilon_{th} \qquad (3)$$

where $\%\text{Science}_{th}$ denotes the 50-year moving average for the proportion of texts on scientific topics written by authors who died in year t and in hundred year bin h. The D_h are century dummies, and *West* is an indicator equal to one if the author was born in the Western Islamic world, defined as all cities west of Alexandria.[1] In this "generalized differences-in-differences" specification, α is the proportion of works on science in the Gold Age in the non-Western Islamic regions, γ is the difference between this quantity in the West and that in the East, the β_h are the change in the proportion of works on science relative to the Golden Age in the non-Western regions, and δ_h provide the differences-in-differences coefficients. To capture regional shifts in religiously-oriented work tied to the madrassa institutions, I estimate equation (2) with the dependent variable $\%\text{Fiqh}_{th}$ defined as the 50-year moving average for texts concerned with the jurisprudence of the five Sunni schools of law. Point estimates are reported in Table 4 below.

[1] As the late Moroccan philosopher Mohammed Abed Al-Jabiri (1990) noted, the Maghreb ends where couscous ends, and couscous ends in Alexandria.

Table 5: Spatial Shift in the Decline with Spread of Fiqh: [800-1500)

	%Science		%Fiqh	
	East	Diff	East	Diff
	(1)	(2)	(3)	(4)
[1100, 1200)	−7.43***	−4.49***	3.10***	1.13*
	(0.56)	(1.49)	(0.40)	(0.63)
[1200, 1300)	−7.29***	−0.02	1.42***	−2.99***
	(0.53)	(1.49)	(0.35)	(0.59)
[1300, 1400)	−7.28***	−3.72**	7.67***	−1.94**
	(0.55)	(1.46)	(0.43)	(0.78)
[1400, 1500)	−6.98***	7.82***	7.82***	−1.84**
	(0.52)	(1.48)	(0.56)	(0.84)
Baseline [800, 1100)	13.93***	1.11	6.25***	−2.89***
	(0.49)	(1.43)	(0.33)	(0.56)
Manuscripts	6,023		5,931	

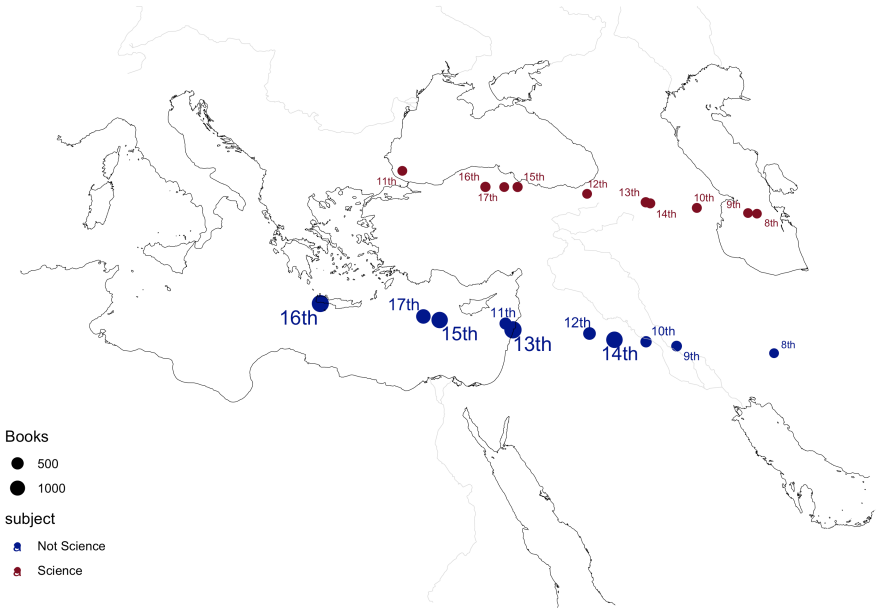
Notes: Results contained are calculated on the Al-Req sample, years [800, 1500). Columns 1 reports point estimates for model 3 where row [800, 1100) represents $\hat{\alpha}$ and the other rows report all the $\hat{\beta}_h$. Column 2 reports estimates for all δ_h where row [800, 1100) represents $\hat{\gamma}$. Columns 3 and 4 present results in similar fashion, where the dependent variable is proportion of works written on matters of jurisprudence, or fiqh. Newey-West standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01.

In column (1), we observe the familiar pattern of demise from section 3.2, in which the proportion of scholarship dedicated to scientific pursuits in the Golden Age is about 14%, but drops to 6.6% in the 12th century and never recovers. Column (2) shows that the baseline proportion in the West is statistically indistinguishable from the East. However in the 12th century the West registers a more sever decline than the East. This pattern occurs well before 1249, when the Hafsid dynasty founded the Madrasa Ech Chamaiya in Tunis, or 1350, when the Marinids built the Bou Inania Madrasa in Fes. Later centuries document that scientific production as a proportion of intellectual output in the West fluctuates – in the 13th century, the moving average %Science is statistically indistinguishable from the East. In the 14th century, it's less. And in the 15th century, it's actually 14% – twice the Eastern rate of 7%. Columns (3) and (4) show a rising proportion of scholarly material dedicated to Islamic jurisprudence in both the East and West, however the West tends to lag behind by 2-3% and starts at a lower baseline. Table 6 in Appendix I analyzes equation (2) but where the dependent variable is %Legal Nisba$_{th}$, the 50-year moving average for the proportion of authors at time t in hundred bin h who affiliate with one of the 5 Sunni schools of Islamic law as referenced in their *nisba*. Those results also indicate a secular rise in the use of orthodox, Sunni legal affiliations, with a slight delay in the West.

These results from the Ar-Req dataset cast doubt on the theory that madrassa institutions displaced scientific life West-ward. It also contradicts Chaney's (2016) finding that scientific production varied from East to West initially but then converged in the 13th and 14th century following the introduction of madrassas. Rather the Ar-Req data indicate that the demise of science happened in roughly simultaneous fashion across the Islamicate. This result is all the more surprising given the popular narrative, as documented in columns (3) and (4), that Andalusian Spain and the Maghreb tended to lag behind intellectual developments in Baghdad, Damascus, and Cairo. What could be happening? There are a few plausible explanations. First, the author *nisbas* could be an unreliable proxy for intellectual hubs across the *longue durée*, particularly in a medieval Mediterranean world characterized by fluid exchange and an itinerant scholarly class. Yet it is hard to ignore the clear shifts in author *nisbas* over the centuries, represented in the map below. For illustration, *nisbas* of authors binned in the West are assigned to Tunis as a regional hub. Those in the Center I assign to

Damascus, and those in the East to Isfahan. Then for each century, I averaged the latitude and longitude points of the bins, weighted by the number of authors in each bin. Figure 7 plots those averages. For science texts, I have shifted the centroids upwards by 7 degrees of latitude for the sake of exposition.

Figure 7: Spatial Shift in Scientific Production, 700-1700 (Al-Req)



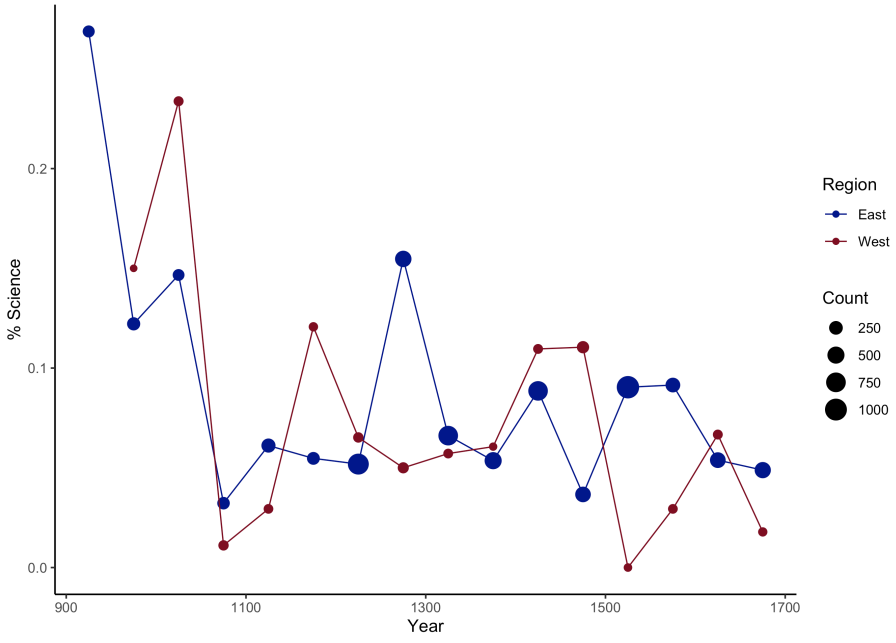
For science texts, the center of gravity shifts westward over time, slowly at first between the 8th, 9th and 10th centuries and then dramatically from the 10th to the 11th century. This jump reflects a flury of activity connected to *nisbas* from Cordoba, Granada, and Seville. The next three centuries witness a return eastward but by the 15th century, the center of gravity has again shifted west-ward for good. Parallel dynamics occur for non-scientific texts. Çelebi's bibliography shows a very similar geo-spatial shift in author nisbas in general, a graph of which is available in Appendix I. The *nisba* data are clearly capturing a long-term, parallel geographic trend, visible in both modern manuscript catalogues and a pre-modern Ottoman bibliography.

Why then does the decline in scientific dynamism occur in roughly simultaneous fashion across the Islamic world? A second possibility could be that scholarly output arranged by author death dates creates volatility and spikes in the time-series data that even a smoothened moving average cannot remedy, particularly for the Western

region, where the absolute number of texts per century may already be low. This can problematize the parallel trends assumption necessary for equation (2). As the work of Nasr and Oliver (2013) and Sarton (1927, 1931) exemplify, historiographers tend to focus on the intellectual giants – the Galens, Euclids, Avicennas, Farabis, and Ibn Haythams – and their presence imbues a discontinuous and uneven texture to the historical record. In other words, the bins are not big enough. However using a 100 or even 150 year moving average does not vindicate the notion that madrassas served as the institutional, path-dependent vehicle for the Sunni Revival and the medieval decline of Arabic science.

An alternative view may suggest that the century bins are too small and elide a crucial lag in the regional decline of science. To investigate this possibility, I bin authors into 50-year intervals and calculate the proportion of scientific texts by region. See Figure 8, below. Points are weighted by the total number of texts in each 50-year bin. Were we to fit a local polynomial regression on each regional series, the slopes would be statistically indistinguishable, both defining a general decline. Smaller bins do not help us tease apart the trends.

Figure 8: %Science in Fifty Year Bins (Al-Req)



A final possibility is that parallel political and institutional forces were at work in

both the Maghreb and the East. It is on this explanation I wish to focus attention. The Sunni Revival is often characterized as an event centered in Abbasid-era Baghdad and lead by figures such as the Seljuk vizier Nizam ul-Mulk and the theologian Al-Ghazali (1058-1111). Azzam (2016) for instance argues the Sunni Revival began as a political campaign to tame sectarianism and erase the legacy of the Shia Buyid and Fatimid dynasties. Meanwhile, Bulliet (1994) argues that the collapse of urban life in Central Asia and Iran during the eleventh and twelfth centuries, particularly in Nishapur, propelled a highly developed religious elite to migrate westward in search of secure employment. The long-term impact of this migration – and the institutions and doctrines carried with them, such as the office of *Sheikh al-Islam*, the madrasa, Sufi orders, and Ash'ari theology – was the formation of Sunni Islam's new dogmatic and institutional base.

However, there are signs a concurrent process was at work in the West and resulted from enduring political alliances as much as path-dependent institutions. Fakhry (2001) and Arnaldez (2000) for instance argue that the rationalist philosopher Averroës fell from royal grace because the caliph Al-Mansur needed the support of the Maliki jurists in his war against the Christian kingdoms. After his 1195 condemnation at the tribunal of Cordoba, the burning of his books, and banishment to Lucena, Averroës was largely forgotten in the lands of his birth and had virtually no impact on Islamic thought until modern times (Najjar, 2002). Only half of his 38 commentaries have survived in Arabic – the rest in Hebrew or Latin translation. The contrast to Averroës' fame in Latin Europe is stark. A conduit for the recovery of Aristotelian philosophy, his appearances in Dante's *Divine Comedy* and Raphael's *School of Athens* attest to his popularity among the European literati, the Catholic Church being the noteworthy exception.

To see the sunset of Peripatetic philosophy in the Western Islamicate as emblematic of a long-term historic shift and not as an isolated event, may help us put the general medieval decline of Arabic science in context. After all, Averroës' fall from grace occurred more than a hundred years after the Taifa kingdoms (1009-1031) were united under the Almoravid dynasty (1050s - 1121). Almoravid origins as a puritan Islamic reform movement from the Berber periphery – a feature shared by their Almohads successors (1121-1269) – are frequently contrasted with a lively and competitive

culture of courtly patronage under the Taifas and Ummayad caliphate of Cordoba. Moreover, a few generations after Averroës' death, the Moroccan Ibn al-Banna (d. 1321) suffused his astronomical tables with Sufi-inspired interpretation, in contrast to the Aristotelian cosmologies in vogue centuries before. These anecdotes cannot substitute for a theory of historical change, however they might shed light on both the symptoms and the causes of decline. I shall return to these thoughts in the Causal Mechanisms section, below.

4 Discarding Alternative Theories

It is worth recapitulating the statistical portrait painted so far by Çelebi and Al-Req's data: (1) there was a sustained decline in the scientific emphasis of scholarly work beginning at or before the 12th century; (2) there was a simultaneous rise in the religious focus of scholarship, but the raw number of scientific texts plateaued; (3) there was a rise in work affiliated with madrasa institutions of Muslim learning, and (4) patterns (1) - (3) were associated and unfolded concurrently in both the East and West roughly around the time predicted by a (pan-Islamicate) Sunni Revival thesis. To take the title of Al-Ghazzali's classical book literally, the 11th and 12th century heralded a verifiable *Revival of the Religious Sciences*. Moreover, this process was already underway by the time of the Mongol invasions, the Spanish conquest of Iberia, Bubonic Plague, the restoration of powerful Muslim states in the Ottoman, Safavid, and Mughal empires, and the advent of modern European colonialism in the 16th and 17th century. Of course, as *Kashf al-Zanun* and the Al-Req repository attests, important contributions to the scientific fields continued to be made after the 13th century, but scientifically oriented work dwindled as a share of intellectual output.

For this reason, explanations that impugn the Mongol invasions, Spanish *Reconquista*, and modern European colonialism cannot explain the steady decline of scientific inquiry that began in the 12th century and predate those events. Gutas (1998) and Maalouf (1984) argued that the Crusades encouraged a more militant version of Islam to take root in Levantine lands. Although the timing of the decline in science observed by Çelebi and the Al-Req data is consistent with this view, the geographic characteristics are not. In fact, both the Persian lands east of Baghdad, Crusader-occupied Levant, and the Maghreb and Andalusia record concurrent declines. John Saunders (1963)

and Archibald Lewis (1988) meanwhile argue that the later Mongol and Timurid invasions marked a watershed moment, obstructing the Muslim world and preserving Western Europe for undisturbed development. However, Bloch (1949) and Anderson (1996) have detailed the significant incursions that routinely threatened Western European polities from Magyars in Hungary, Muslim forces in Spain, Sardinia and the Balkans, and Vikings in Scandinavia. From the Hundred Years War to the Napoleonic invasions, the history of Western Europe gives ample testimony to chronic geopolitical instability. Janet Abu-Lughod (1989) argues that the Mongols and Crusaders pushed the Mamluks to "a defensive militarization of the region that eventually undermined civil society and its vital economic institutions" (243-4). If militarization and war harms civil society, why didn't a similar process occur in Europe? Nor were invaders necessarily a blight for science itself, even if they devastated their human targets. Frederick Starr's fascinating work *Lost Enlightenment* (2013) for instance unsettles the assumption that Mongol dynasties were primitive and uninterested in scientific inquiry.

Furthermore, the Islamic world also enjoyed a recovery and expansion in military and demographic terms after the invasions. Mamluk armies recaptured all Levantine cities from the Crusaders by the end of the 13th century. Ruling elites in the three major Mongol polities – the Golden Horde, Chagatai, and Ilkhanate – converted to Islam soon after. Schools, libraries, and agricultural infrastructure were rebuilt, political order was restored, and trade resumed (Hodgson, 1974). Using novel gunpowder and cannon artillery, Sultan Memed II breached the walls of Byzantine Constantinople in 1453. Ottoman Turks laid siege to Vienna twice, in 1529 and 1623, and with the Safavid and Mughal empires of the 16th century, projected Muslim power across a vast territory "from the Balkans to Bengal." (Ahmed, 2015). Eaton (1993) for instance, documents the religious conversions and advance of Muslim political frontiers in South Asia from 1204 - 1760. If Arabic science declined due to a weakening of Islamic political strength, why didn't it return to prominence after military recovery? Nor is it clear how and why the Crusader, Spanish, Mongol, and Timurid invasions would cause scientific texts to stagnate on the whole while allowing religious texts on the whole to rise. Obviously, the intellectual climate of any place reflects military conditions; Baghdad before and after 1258 was not the same place. But the evidence for framing military shocks as the central causal device for the general medieval decline

in Arabic science, instead of a contributing factor is therefore slim.

Similar postscripts could be written about climatic events and environmental stresses. The Medieval Warming Period, however favorable to Western feudal agriculture and Andalusian Iberia, ended in the Little Ice Age from 1300 to 1850, marking centuries of crop failure, higher mortality, and economic hardship in Western Europe, including Iberia (White, 2014). If medieval warming was decisive in Europe's rise and the Islamic world's stagnation, why didn't the Little Ice Age reverse fortunes again in the 16th century? Bulliet (2009) says that nomadic incursions and the Big Chill in 11th and early 12th century Persia disrupted the cotton industry and caravan trade, leading "members of patrician families that had the necessary financial means and scholarly connections outside Iran [to] migrate to Iraq, Syria, Anatolia, or India" (136). Ellenblum (2012) concurs. However Çelebi and Al-Req's data do not indicate a statistically distinguishable shift of scientific scholarship westward; the decline happens concurrently in both East and West. Nor does scientific activity as a proportion of intellectual output in the Persian East recover to its previous levels after the Big Chill. A similar issue of timing casts doubt on Ibn Khaldūn's view (1377) that the horrific plague (الطاعون الجارف) of the 14th century explain the shift in long-term scholarly trends. In his words,

> "Plague decimated a whole generation and folded and erased many of the signs of civilization...the sharp reduction in the masses led to the destruction of cities and livelihoods, as if the voice of the universe called on the world to stagnate and contract and it responded" (*Prolegomena*, 52-53).

However the decline trend observed in the Al-Req data predates medieval Black Death. As Figure 7 demonstrated, the 14th century coincided with a shift *towards* the Mamluk Levant and Mongol states of Central Asia (where the plague originated), not away. Ibn al-Fasi (Leo Africannus, d. 1554) may have observed that the palaces of Marrakech were reduced to chicken and pigeon farms, but the long-term decline in scientific life began two centuries before. Additionally, Ibn Khaldūn himself attests to the highly original works that continued to be composed in spite of disease shocks. As the data visualized in Figure 3 attests, scholarly life resumed to its pre-plague levels, albeit not with the same scientific dynamism of the Golden Age.

On a theoretical level, we might also worry that an excessive focus on particular events and external shocks may obscure the underlying causal process behind those events as they unfold in history. Immanuel Wallerstein (1992) for example argued that the Black Death weakened the four orders: "the seigniors, the states, the Church, and the Mongols" leading to the rise of the bourgeoisie and capitalism (607). Campbell (2016) argued that the Medieval Climate Anomaly interacted with Europe's institutional framework to generate urbanization and growing population densities, until a Malthusian "burden of poverty" (257) buckled under the weight of Black Death. In response to acute labor scarcity, wages rose, nutrition improved, and crops diversified for those peasants who survived – effecting a "shift in socio-ecological regime" (332). However a wealth of archaeological and textual evidence shows that the Mamluk empire suffered similar levels of mortality from Bubonic plague as England did, but Egyptian peasant wages did not rise nor did the land regime fundamentally change (Borsch, 2005). Why did the Black Death cripple Egypt, but not England?

What is needed, then, is an explanation of the mechanisms through which the climatic, military and demographic shocks of the late medieval period led Latin Europe and the Islamic world on different development paths. A shock alone cannot explain why certain social forms disarticulate, others emerge unscathed, while new ones are born. Padgett (2012) calls this the problem of organizational emergence. To explain the exact causal mechanisms behind the rise and fall of Arabic science, it is ultimately necessary to go beyond Çelebi and Ar-Req's quantitative data and consider how scientific life was embedded in the political and economics forces that created and sustained it. As the eminent historian of Arabic mathematics Rāshid Rushdī writes,

> "For a satisfactory knowledge of Arabic science, it is necessary to restore it to its context, to the society which witnessed its birth, with its hospitals, its observatories, its mosques, its schools. How indeed can one understand certain of its developments if one forgets the Islamic city and its institutions, the function that science fulfilled there and the importance of the role that it could play?" (xi)

One specific function that Arabic science had in Islamic societies was the cultivation of epistemic norms to enable a shared discourse and worldview. This insight may invite us to consider Dallal's tentative view (2010) that the relative decline of sci-

entific activity "is often coupled with a return of interest in cosmology; only this time the traditional philosophical cosmology was replaced with a religious/Sufi one" (154). In other words, the rising popularity of mystical, Sufi interpretations of Islam supplanted a previous paradigm of knowledge, dis-empowering rationalist discourse and strengthening the hand of clerical authorities. This led to institutional changes inimical to the flourishing of skeptical empiricism. North African astronomer Ibn al-Bannā' (d. 1321) for instance wrote mathematical works with Sufi-inflected cosmological interpretations instead of the Aristotelian ones in vogue centuries before. As Patricia Crone (2006) puts it, religious elites popularized mystical interpretations of Islam to prevent "reason from running wild in skepticism" (237). This theory inverts conventional assumptions that frame fundamentalists such as Ibn Taymiyya (d. 1328) at odds with mystics such as Ibn 'Arabi (d. 1240). As Makdisi (1973) and Kuru (2019) highlight, the links between clerical authority and mystic practice are clear – embodied most conspicuously in the life and works of Al-Ghazzali.

Did Sufism thus play an instrumental role in keeping the use of reason firmly in support of 'orthodox' Islam after the Revival? Preliminary investigations of Ar-Req's data on Sufi knowledge (*'Ilm a-Tasawuf)* suggests that scholarly attention to the subject did increase in the centuries after the 11th and 12th. However it remains to be investigated whether the popularity of Sufi practice is a downstream outcome of the political empowerment of traditionalist religious leaders or an independent event. Çelebi and Al-Req's data are limited in answering this question, although Chaney (2016) and Kuru (2019) tend to look upon it as a consequence, not a cause. It remains to be convincingly articulated how in fact religious forces following the Revival led to a decline in scientific inquiry – not only in Sunni lands, but in Shia Iran and Maliki North Africa. Until then however, we may safely dismiss elements of Sonja Brentjes (2018) and George Saliba's (2007) argument that the medieval decline of the Islamic scientific tradition is unsupported by historical record.

5 Causal Mechanisms

Let us presume that we accept the evidence presented thus far that a shift in the proportion of textual material dedicated to scientific topics occurred during the 11th and 12th centuries, and this shift was tied to new currents of legalism and orthodoxy and

happened concurrently across the Islamic world without significant delay or regional variation. By what causal mechanism can these historic trends be explained and made legible? Below I briefly consider three theories, recognizing that without a tight causal identification strategy, these remarks are exploratory and can only serve to stimulate further research.

The first idea, traceable to Ernast Renan (1883), the Marquis de Condorcet (1795), Voltaire (1759) and even Roger Bacon (1267) is that Islam in its essence is hostage to an intrinsic, culturally predetermined proclivity against scientific and rationalist philosophical activity. As a result, the Muslim scientists of the Golden Age were more properly characterized as custodians of an older Greek canon or personal brilliance, ever-marginal to real circles of power and the developments of mainstream Islamic intellectual life, whose legacy left little imprint on the Islam's social, economic, or educational institutions and faded later through a combination of antagonism and indifference. In John Saunders' (1963) terms:

> "Islam, from the first an essentially religious culture, turned back to its origins; the Hellenic element was gradually extruded, and profane science, which had always operated on the fringe and had never really cleared itself of the charge of impiety, was quietly abandoned as 'un-Muslim'" (719).

In this framing, the contributions of Avicenna or Ibn al-Haytham were presumably the personal, anomalous creations of great men, and Arabic science along with the Scientific Revolution of scholastic Europe are ultimately inexplicable since they could not have been predicted. At random strikes the light of genius. Alexander Koyré's *Études Galiléennes* (1939) along with Arthur Koestler's *The Sleepwalkers* (1963) and Herbert Butterfield's *Origins of Modern Science* (1951) are contemporary examples of this historical approach.

On the matter of Islam's anti-science bias, it is tempting to dismiss the notion as an aging artefact of Orientalist discourse, with the same ease that great man theory can be tossed into the rubbish bin of 19th century hero worship. Yet subtler versions of this story creep into contemporary arguments of Islamic decline under the historical institutionalist vocabulary of path-dependence. According to Jared Rubin (2017) for instance, Islam from its origins in eastern Arabia always provided "a unifying ideol-

ogy" to its acolytes and political benefactors. As a result, "the economic elite never had a place at the bargaining table because Middle Eastern rulers were strong enough, due to the legitimizing capacity of Islam, to exclude them" (p. 17).

This legitimating advantage of the religious elite did not reflect particularly medieval conditions but emanated from Islam's early doctrinal endowment. It contrasted "Christian doctrine" which could not command the same mobilizing power or symbolic capital. Rubin argues "these doctrinal differences are clear in the Bible and the Qur'an" (54), citing the Gospel of Mark's (12:17) commandment to "render unto Caesar what is Caesar's" and the Sassanian maxim – often attributed to the Prophet Muhammad in error – that "Islam and government are twin brothers." Consequently, merchant elites thus had a larger influence on Latin Europe's long-term institutional development than in the Middle East. Church-state separation was reaffirmed by the Gregorian Reforms (1050-1080), Concordat of Worms (1166), and Protestant Reformation (1521-).[2] One empirical implication of this argument is that clerical actors with pious interests shaped policy in Muslim states before the 1000 AD /390 A.H. as much as after.

As a causal mechanism to explain the medieval decline of Arabic science, essentialism and the marginality hypothesis face several immediate objections. As I have shown in the previous sections, Arabic science was characterized by significant variations over time – not only in the manuscript records but in attitudes toward it. It is not clear how an allegedly immovable, or "fundamental" feature of Islamic culture can explain such variation. Nor can it easily explain the rise of the scientific tradition in the first place. As Sabra (1987) notes, the Greaco-Arabic translation movement was "positively and generously supported (not just tolerated) by the Muslim ruling establishment - the caliphal court itself and individuals closely associated with it" (226). Nor is the image of a marginal group of scientists compatible with the record of the tradition's longevity and vigor over several centuries. As George Sarton endeavored to make clear in his multi-volume *History of Science* (1927, 1931), Arabic science lasted longer than its Greek, Latin, and even modern counterparts. A smarter view would interpret Islamic science within the cleavages of medieval social structure, as

[2]The political science literature on this topic is enormous. See Bloch (1939), Tierney (1964), Berman (2003), Van Zanden (2009), Bueno de Mesquita (2018).

well as within the historically-specific epistemic norms and balances of power that animated those societies.

A second theory situates science in the ideological arena of the early medieval Islamicate in which several factions contended for the hearts and minds of the palace and public. The *Ahl al-Ḥadīth* espoused a worldview based on the authority of the sayings and life of the prophet Muhammad. Their foils, the *Mutakalimūn* or "dialectical theologians" (sometimes called the *Muʿtazila*) were also locked in antagonistic tension with the *Sūfis* or mystics, and the Sufis in turn with the *Fuqahā* or Juris-Consults mentioned from before. Except for the dialectical theologians, Sabra (1986) and Goldziher (1917) group them for the sake of simplicity into the term "orthodox" or *ahl as-Sunna*. Yet all parties, including the dialectical theologians, opposed atheistic rationalists like al-Ma'ari and bacchic poets such as Abu Nuwas. Moreover, they held an abiding suspicion for the *Falasifa* or philosophers, whose inordinate curiosity about the workings of the natural world could lead a searching intellect astray from the faith. In al-Ghazzali's (1095) words, "Every student of mathematics admires its precision...This leads him to believe in the philosophers, and he becomes an unbeliever merely by accepting them as authorities." Opposition thus stemmed from the religious scholars' ideological position, as well as a class interest in removing threats to their symbolic capital and monopoly on knowledge.

Under the enduring political and social influence of these traditionalists, a new orthodoxy was defined (Safi, 2006) and scholarly class professionalized (Gilbert, 1980). Rationalism was stamped out and censored, while patronage and young scholarly talent were redirected toward clerical authorities, reducing the returns to a scientific vocation.[3] In contrast to Rubin's (2017) view, the success of this project was not the result of Islam's doctrinal endowment or a critical juncture taken in Islam's first few decades. Rather it emerged from the historical circumstances of the 11th and 12th centuries, in particular the Sunni Revival (Kuru, 2019) and proceeded via a variety of channels – the madrassa institutions considered in this article (Makdisi, 1981; Chaney, 2016) but also demographic migration (Bulliet, 2009) and active suppression, such as book burning and banishment of Averroës. To summa-

[3]See Baumol (1990), Murphy et al. (1991) and David (2008) for how the allocation of talent and patronage affects long-term growth.

rize the theory schematically, ↑ Political Power of Religious Elites ⇒ Institutional Changes/Demographics/Supression ⇒ ↓ Payoff to Production of Science ⇒ ↓ Science. Sachau (1876), Huff (1993), Kuru (2019), Sayılı (1981) and Chaney (2016) support this causal framework, although they differ in the extent to which the process was gradual or sudden, of regional or general origin, and led by institutional path-dependencies crystalized in Islamic law or enduring class interests.

The bibliographic records of the Ar-Req repository and Çelebi's *Kashf al-Zanūn* presented in this article support some of the predictions of the Sunni Revival: the decline in Arabic science's status within the manuscript corpus indeed appears to take shape in the 11th and 12th centuries and correlates with the rising proportion of authors who identify with a Sunni school of law. Were we to actually read some of the religious texts found in the catalogues, the voices opposing an empirical or secular worldview ring loud and clear – Al-Ghazzli (d. 1111), Ibn al-Jawzi (d. 1201), Ibn Taymiyya (d. 1328) come to mind for instance. In addition, a paradigm of conflict centering conservative religious authorities may help us make legible specific patterns of Islamic history that held science back, such as the Ottoman Empire's delay in adopting the printing press (Coşgel et al. 2012) or the longevity of Islamic taboos on human dissection (Fahmy, 2018).

Moreover, the notion of an ascendant religious elite resonates with a literature of broader thematic and temporal interest. Zahra Ayubi (2019) for instance shows how the Qur'an and Sunnah's radical potential to articulate gender equality was not fully realized because medieval Islamic figures such as al-Ghazzali and al-Tusi chose to establish "an edifice of hierarchical virtue ethics" rooted in elite masculinity. Shehadi (1995) elaborates how mainstream medieval jurists came to rule wind and string instruments as *haram* in almost all circumstances and saw the Sufi practice of *sama* chant and dance as suspicious. He juxtaposes these developments with the musical theory and mystical celebration of melody, cadence and rhythm embodied by the works of Al-Kindi, Al-Farabi and the Brethren of Purity. In the 19th century, Yalçinkaya (2015) documents that Ottoman literati who located the roots of Western ascendance with the "new sciences" of the Europeans were not worried so much with the meaning and merits of science itself as an epistemological orientation nor as a practical manual for recovering the glory of a faded and sick empire. Rather, the greater ferment

and anxiety concerned whether science would fashion "learned patriots" or corrupt the young Turks. In this sense, the idea of a conservative religious establishment is helpful.

However the Sunni Revival thesis as a causal model of Arabic science's decline suffers from a number of conceptual deficiencies, while the data cast doubt on some of the institutional vehicles alleged to be at work more generally. First, as Gutas (1998) has taken pains to illustrate, the target of traditionalist attack is not always clear, and when it is, the target is not always what modern readers would call science. Magic, astrology, and Aristotelian dogma suffused the Greek canon, while some of the most scathing critiques of that Greek canon came not from fundamentalist quarters but the most celebrated figures of Islamic science. Ibn al-Haytham's *Doubts Concerning Ptolemy* (1028) takes issue with Ptolemy's tables in *Almagest* and his equant device, which failed to satisfy the physical requirement of uniform circular motion. Al-Razi in *Doubts About Galen* (935) exorciates the Greek physician Galen along with Aristotle for advocating a theory of humors and four elements insufficiently grounded in experimental evidence. These critiques were written in an ideological climate in which the Greek or "foreign" sciences were suspect, and scholars were under constant scrutiny from religious authorities to prove their orthodox bona fides. Could it be that such scrutiny helped cleanse and progress science, rather than arrest it? In Saliba's (2007) words:

> "With the pressure from the anti-astrological quarters, usually religious in nature or allied with religious forces, astronomy had to re-orient itself to become more of a discipline that aimed at a phenomenological description of the behavior of the physical world, and steer away from investigating the influences its spheres exert on the sublunar region as astrology would require" (186).

The Islamic rituals and social laws promoted by religious authorities also stimulated new fields of scientific inquiry, such as the new astronomy of *hay'a* to accurately determine Muslim holy days on the lunar calendar, *'ilm al-farā'id* to divide inheritances, and *'ilm al-mīqāt* to determine prayer times based on the position of the sun. As Islam expanded into more distant latitudes, the *qibla* problem – defined as determining the direction one must face during prayer – became an increasingly non-trivial mat-

ter, since the curvature of the earth required one to solve the angle his local horizon made with the circle that intersects his own zenith and the zenith of Mecca (Saliba, p. 186). Existing trigonometry from Indian and Greek tradition was cumbersome for that task, so new identities were developed, such as the spherical sine and cosine laws.

Real conflict did occur – made manifest by such historical events as the Great Inquisition or *Miḥna* in 833 CE, the burning of Averroës' books in 1195, Al-Ghazālī's treatise *The Incoherence of the Philosophers* in 1091 – but it did not usually concern such prosaic affairs as the validity of the experimental method or algebra. More precisely, the struggle between the adherents to tradition (*ahl al-hadīth*) and the disciples of rationalism (the *Mu'tazila*) was first and foremost ideological – controversies about overall worldview, sectarian power, and value system. As Sonja Brentjes (2004) notes, these antinomies do not map well onto a narratives about the victory of Enlightenment over the church. Goldziher (1916) and the older Orientalists may thus misunderstand the issue, projecting the political agitations of their era – say, the Wahhabīs of the Sa'ud house against Ottoman Turks – on to the Hanbali-Mu'tazilite conflicts of the 9th to 12th centuries. We should thus be worried that the ideological intransigence alleged by the Sunni Revival mechanism is the products of simplistic nineteenth century historiography.

In fact, the polarization of the traditional concept of *'ilm* ("knowledge") into *'ilm* ("modern science") and *dīn* ("religion") has a short philological history indeed. As Akkach (2019) observes, "Emerging awareness of the conflict between *'ilm* and *dīn* can [only] be traced back to the early decades of the 19th century" (3), when Draper and White's books on the conflict thesis, Copernicus' heliocentric theory, and Darwin's theory of evolution by natural selection provoked vociferous debate in such journals as *al-Jinān* (The Gardens, 1870-86), *al-Muqṭataf* (The Snippets, 1876-1952), and *Wādī al-Nīl* (Nile Valley, 1867 - 1878). Before this time, many scientific developments did not arouse the ideological antics which embroiled Western Europe. As İhsanoğlu (2004) writes about the early modern Ottomans:

> The matter of the Sun's location at the centre of the universe and the Earth's motion – the basic elements of this new understanding of astronomy introduced by Copernicus which caused great controversy in Europe – was treated on the level of a secondary technical detail by the Ot-

> toman astronomers. One of the reasons for this indifference may be the absence of a religious dogma which would cause disputes among Muslim astronomers on the subject of geocentric and heliocentric systems" (10).

Moreover, the history of Islamic science documents an array of famous physicians, chemists, and astronomers who held religious positions of great authority. Thus Ibn al-Nafīs (d. 1288) who wrote the critical commentary on Avicenna's *Cannon* and discovered the pulmonary movement of the blood was also a practicing Shāfi'i lawyer who gave lectures at the Masrūrīya madrassa. The prolific astronomer al-Tūsī (d. 1274), author of the famous Tūsī Couple is remembered first as a great Ismā'ili Sufi scholar, while Ibn al-Shātir (d. 1375), popularizer of the minaret sundial, derived his income as a *muwaqqit* (Timekeeper) at the Umayyad mosque in Damascus. All these figures held formal religious titles and identified with a school of law. Even within the ultra-traditionalist camp, astronomy and algebra were often spared attack, since their value to the practice of Islamic law and ritual were obvious. Significant difference in attitude also existed; Ibn Taymiyya (d. 1328) famously disliked Greek logic because he saw it as a gateway to apostasy. But Ibn Hazm (d. 1064), the Andalusian literalist used it in his legal rulings. For these reasons, Saliba (2007) concludes, "it becomes very difficult to document a paradigm of conflict between religion and science in Islamic society" (191).

Moreover, even if political actors gave a hearing to the conservative religious elite, and we accept that this elite is in some way responsible for the stagnation of the Arabic scientific enterprise, it is not clear why the shift happened in the 11th and 12th centuries and then endured. Why weren't the traditionalists ignored in the same way Abbasid Caliph al-Ma'mun in Baghdad ignored the traditionalists and embraced the Mu'tazila? Or the way the Almohad caliph Abu Yaqub Yusuf appointed Averroes the chief judge of Córdoba despite the protestations of Maliki jurists? In any event, the Ar-Req and Çelebi data do not indicate that 'ulema religious scholars were exactly successful in their campaign to stifle scientific output since a rise in religious studies did not coincide with an absolute decline in science texts. A more accurate characterization is that science was "overshadowed" by its epistemic peers, not actively stifled. This feature remains to be explained by the Sunni Revival hypothesis.

If these previous theories appear in tatters, or at least inadequate to explaining the trends seen in the Çelebi and Ar-Req, perhaps salvaging elements of them can help reconstruct a causal story of the medieval decline. This final theory I consider is highly speculative but explains my findings better than any other one evaluated so far. It may also serve as an avenue for future research because many of the claims can be empirically tested. It goes like this. The 11th to 14th centuries witnessed (1) dwindling rates of conversion to Islam as higher proportions of the demographic base became Muslim. Bulliet (2013) shows this quantitatively by tracing the *nisba* and naming conventions of medieval genealogies. Those centuries also witnessed (2) the demise of the old Abbasid and (Cordoban) Ummayyad caliphs in status and military strength. Trends (1) and (2) increased (3) the legitimating power of the religious scholarly class over time via the formation of mass Muslim publics that could be mobilized for war or rebellion. These trends also led to (4) a succession of outside political dynasties from the periphery, such as the Almoravids, Almohads, Seljuks, Mamluks, and Mongol Ilkhanates anxious to prove their bona fide right to power.

As Rubin (2017) and Bueno de Mesquita (2005) argued, the religious elite played a legitimizing role useful to the sovereign's "logic of political survival." Here we are on familiar territory. However contra Rubin, I argue this shift was *not* the culmination of a centuries-long process of institutional path dependence, in which Christian authorities inherited the legal apparatus of the Roman Empire and benefited from an assertive merchant elite whose class interests inadvertently helped Europe prosper. His foil in this story is Islam's expanding ambitions as a military project with an institutional framework that had to be forged rather than inherited, and he says this framework eventually became self-limiting in its capacity to generate economic growth. As noted before, such static features of Islam would have difficulty explaining the rise of the Arabic scientific tradition in the first place. Rather, the legitimating power of the clerical establishment was more precisely a byproduct of the unique historical circumstances of the Sunni Revival, its demographic transition, and the demise of a central caliph authority.

Unlike previous rulers, the new dynasties arrived with Muslim-majority populations waiting for them, and so the legitimating advantage of the religious elite grew over time, particularly after the 11th century. Kuru (2019, 2020) aptly describes the

resulting socio-economic structure as the "ulema-state alliance," but he does not adequately document the demographic basis for this transition, nor the unique forms of state militarism that took root in subsequent centuries. As Blaydes and Chaney (2013) argue, the Almoravid, Almohad, Seljuk, Mamluk, Mongol, and later Ottoman state were dominated by (5) a novel form of military recruitment, in which Berber and Central Asian tribesmen, Circassians, and Balkan peoples were conscripted, enslaved, and trained in the arts of war. To pay their salaries, (6) the monetary economy was gradually replaced by a new system of the state allocation of land revenues. Arbitrary taxation, pastoralism and land absenteeism grew, which discouraged agricultural innovations and deflated the need for new technical expertise.

The impact on science was two-fold. Far from displacing scientific knowledge, the 'ulema scholars made their peace with it. As Sabra (1987) argues, the Greek sciences were "naturalized," replacing the philosophers' view of knowledge with the instrumentalist view proposed by Ghazali: that "Knowledge is a virtue in itself, absolutely and without relation [to something else]" (1067). However, non-revealed knowledge must be subordinated to the more worthy pursuit of the revealed knowledge of God. The instrument is not the end to itself; medicine assists in the preservation of health, arithmetic in the execution of wills and inheritances in accordance with the revealed law, and so on. Under this limited basis, science was actually admitted into the madrassa, the mosque, and hospital. The institution of madrassa thus did not stifle science per sé, but did tend to direct productivity gains or "extra" human talent or patronage into religious output, relegating scientific research to a more narrow, essentially unprogressive area where the pressures to innovate were not great. Sabra (1987) calls this the final stage in science's assimilation to Islamic life:

> "The third stage is that in which *falsafa*, the type of thought and discourse found in the writings of philosophers like Farabi and Avicenna, began to be practised in the context of *kalām*; and in which the philosopher-physician (represented by Rāzī) was replaced by the jurist-physician (represented by Ibn al-Nafīs), the mathematician (*ta'līmi*) by the *faradi* [executor of wills], and the astronomer- astrologer by the *muwaqqit* [mosque timekeeper]" (237).

Coupled with the replacement of the monetary economy with land absenteeism, no-

madic herding, and tax farming, the technical needs that had propelled scientific research forward in earlier centuries attenuated. This emphasis on science's practical function in expanding the realm of useful knowledge is, I think, a crucial one. As Engels wrote in 1894:

> "If society has a technical need, that helps science forward more than ten universities. The whole of hydrostatics (Torricelli etc.) was called forth by the necessity for regulating the mountain streams of Italy in the sixteenth and seventeenth centuries. We have only known anything reasonable about electricity since its technical applicability was discovered. But unfortunately it has become the custom in Germany to write the history of the sciences as if it had fallen from the skies" (457).

This working model can be summarized in schemmatic fashion: $\uparrow$ Muslim proportions + $\downarrow$ caliph status $\Rightarrow$ $\uparrow$ outside political dynasty + $\uparrow$ conscripts and slaves from periphery + $\uparrow$ power of religious elite $\Rightarrow$ institutional/cultural changes $\Rightarrow$ $\downarrow$ societal payoffs to science $\Rightarrow$ $\downarrow$ science. However the medieval decline in science was not so much driven by the madrassa as an institutional vehicle nor by the active opposition of the religious elite. It involved, paradoxically, their acceptance of scientific research into the fabric of Islamic life.

6 Conclusion

The data and modeling presented in this paper delivers some important findings. I show that the proportion of books in the Islamic world dedicated to scientific topics such as astronomy, mathematics, chemistry, engineering, and anatomy declined over the medieval period, while the proportion of books about theological topics rose. These two trends were most acute in the 11^{th} to 14^{th} centuries. By mapping the birth and death places of authors, I also show that the decline exhibits an interesting geographic feature – concurrence in population centers in the East such as Baghdad and Mosul, the Levantine belt of Beirut, Istanbul, Cairo, and Alexandria, and the Western region of Andalusian Spain and Morocco. These findings are consistent with the Cantoni and Yuchtman's (2013) view that religious establishments tend to favor institutional and political arrangements that encourage public piety and centralize clerical authority at the expense of human capital accumulation. I also build upon the work

of Chaney (2016) and Buringh and van Zanden (2009) in quantifying manuscript production across the Old World as an illuminating guide to the long-term evolution of scientific, scholarly production. Future, careful scholarly work will have to tease apart the causal mechanisms behind these patterns.

Finally, my results cast doubt on theories attributing the Islamic world's decline to the Mongol invasions, the Crusades, soil exhaustion and declining agricultural yields, climatic events, or modern European colonialism. Preliminary evidence shows that religious leaders discouraged rationalistic interpretations in favor of a new 'orthodoxy' premised on obedience to authority, mysticism and faith, which came to overshadow research into the workings of the material world. This process unfolded in the context of the assimilation of the "foreign sciences" into the fabric of Islamic religious life, not their expulsion. As such, my study challenges the view that Islam is intrinsically anti-science and situates scientific production within the political equilibrium of medieval Islamic society. These findings enrich the scholarly literature on religion in politics, the politics of innovation, Islamic history, and the proximate causes for disparate intellectual trajectories across human society.

7 Bibliography

'Abduh, Muḥammad. *Risālat Al-tawḥīd*. [al-Qāhirah]: Dār al-Hilāl, 1963 [1897].

Abu-Lughod, Janet L. *Before European Hegemony: The World System A.D. 1250-1350.* New York: Oxford University Press, 1989.

Acemoglu, Daron, and James A. Robinson. *Economic origins of dictatorship and democracy.* Cambridge University Press, 2006.

Acemoglu, Daron, Simon Johnson, and James A. Robinson. "Institutions as a fundamental cause of long-run growth." *Handbook of economic growth* 1 (2005): 385-472.

Adonis. V*iolence and Islam: Conversations with Houria Abdelouahed.* Polity Press, 2016.

Afghānī, Jamāl al-Dīn, Muḥammad ʿAbduh, and Muḥammad ʿAbd al-Raḥmān ʿAwaḍ. *Al-Radd ʿalá Al-dahrīyīn*. [Cairo]: Maktabat al-Salām al-ʿĀlamīyah, 1983 [1883].

Akkach, Samer. *ʿIlm: Science, Religion and Art in Islam.* South Australia: University of Adelaide Press, 2019.

Alexander, Bryan, Adeela Arshad-Ayaz, Fatima Badry, Thorsten Botz-Bornstein,

Janel Curry, Boufeldja Ghiat, Michael Gow et al. *Western higher education in Asia and the Middle East: Politics, economics, and pedagogy.* Lexington Books, 2016.

Al-Ghazali, *The Incoherence of the Philosophers [Tahafut al-Falasifa].* Translated by Michael E. Marmura. Provo, UT: Brigham Young University Press. 2000 [1095].

Al-Rundi, Abu al-Baqa'. *Lament for the Fall of Seville.* Translated by James T. Monroe in *Hispano-Arabic Poetry: A Student Anthology.* Berkeley: University of California Press, 1974 [1297].

Ali, Syed Ameer. 2019 [1891]. *The Spirit of Islam or the Life and Teachings of Mohammed.* San Bernardino: Forgotten Books.

Anwar, Mohammad, and A. Abu Bakar. "Current state of science and technology in the Muslim world." *Scientometrics* 40, no. 1 (1997): 23-44.

Arnaldez, Roger. *Averroës: A Rationalist in Islam.* Notre Dame, IN: University of Notre Dame Press. 2000.

Ayubi, Zahra MS. *Gendered morality: classical Islamic ethics of the self, family, and society.* Columbia University Press, 2019.

Azzam, Abdel Rahman. "Sources of the Sunni Revival: Nizam u-Mulk and the Nizamiyya: An 11th Century response to Sectarianism." *The Muslim World* 106, no. 1 (2016): 97-108.

Bacon, Roger. *The Opus Majus of Roger Bacon: A Translation of Robert Belle Burke. Vol. 1.* University of Pennsylvania Press, 1928 [1267].

Bai, Jushan, and Pierre Perron. "Estimating and testing linear models with multiple structural changes." *Econometrica* (1998): 47-78.

Bai, Jushan, and Pierre Perron. "Computation and analysis of multiple structural change models." Journal of applied econometrics 18, no. 1 (2003): 1-22.

Barthold, Wilhelm. *Turkestan Down to the Mongol Invasion.* Translated from Russian by T. Minorsky. London: E. J. W. Gibb Memorial Trust. 1977 [1900].

Baumol, William J. "Entrepreneurship: Productive, unproductive, and destructive." *Journal of business venturing* 11, no. 1 (1996): 3-22.

Bénabou, Roland, Davide Ticchi, and Andrea Vindigni. Forbidden fruits: the political economy of science, religion, and growth. No. 21105. *National Bureau of Economic Research*, 2015.

Berkey, Jonathan P. *The formation of Islam: Religion and society in the Near East, 600–1800.* Vol. 2. Cambridge University Press, 2002.

Berman, Harold J. *Law and Revolution II: The Impact of the Protestant Reformations on the Western Legal Tradition.* Cambridge, Mass: The Belknap Press of Harvard University Press, 2003.

Bisin, Alberto, Jared Rubin, Avner Seror, and Thierry Verdier. Culture, Institutions the Long Divergence. No. w28488. *National Bureau of Economic Research*, 2021.

Bloch, Marc. *Feudal Society*. Chicago: University of Chicago Press, 1964.

Borsch, Stuart J. *The Black Death in Egypt and England: a comparative study.* University of Texas Press, 2005.

Bīrūnī, Muḥammad ibn Aḥmad, and Eduard Sachau. *Chronologie Orientalischer Völker*. Leipzig: Deutsche Morgenl. Gesellschaft, 1923 [1876].

Blaydes, Lisa, and Eric Chaney. "The feudal revolution and Europe's rise." *American Political Science Review* 107, no. 1 (2013): 16-34.

Brentjes, Sonja. *"Orthodoxy", Ancient Sciences, Power, and the Madrasa (" college") in Ayyubid and Early Mamluk Damascus.* Max-Planck-Institut für Wissenschaftsgeschichte, 1997.

Brentjes, Sonja. "Oversimplifying the Islamic Scientific Tradition." Metascience 13, no. 1 (2004): 83-86.

Brentjes, Sonja. "Patronage of the mathematical sciences in Islamic societies." *The Oxford handbook of the history of mathematics* (2009): 301-328.

Brentjes, Sonja. *Teaching and learning the Sciences in Islamicate Societies (800-1700).* Turnhout: Brepols, 2018.

Bueno de Mesquita, Bruce, and Ethan Bueno de Mesquita. "From Investiture to Worms: A Political Economy of European Development and the Rise of Secular Authority." (2018). Working Paper.

Bueno De Mesquita, Bruce, Alastair Smith, Randolph M. Siverson, and James D. Morrow. *The logic of political survival.* MIT press, 2005.

Bulliet, Richard W. *Cotton, Climate, and Camels in Early Islamic Iran: A Moment in World History.* New York: Columbia University Press, 2009.

Bulliet, Richard W., Gerhard Endress, Carole Hillenbrand, Nadia Marzouki, and Olivier Roy. *Islam: The view from the edge.* Columbia University Press, 1994.

Bulliet, Richard W. *Conversion to Islam in the Medieval Period.* Harvard University Press, 2013.

Buringh, Eltjo, and Jan Luiten Van Zanden. "Charting the "Rise of the West": Manuscripts and Printed Books in Europe, a long-term Perspective from the Sixth through Eighteenth Centuries." *Journal of Economic History* 69, no. 2 (2009): 409-445.

Butterfield, Herbert. *The Origins of Modern Science, 1300-1800.* New York: Macmillan Company, 1951.

Campbell, B. M. S. *The Great Transition: Climate, Disease and Society in the Late-*

medieval World. Cambridge, United Kingdom: Cambridge University Press, 2016.

Cantoni, Davide, and Noam Yuchtman. "The political economy of educational content and development: Lessons from history." *Journal of Development Economics* 104 (2013): 233-244.

Chaney, Eric. "Religion and the rise and fall of Islamic science." Work. Pap., Dep. Econ., Harvard Univ., Cambridge, MA (2016).

Chow, Gregory C. "Tests of Equality Between Sets of Coefficients in Two Linear Regressions." Econometrica 28, no. 3 (1960): 591–605.

Christensen, Peter. *The decline of Iranshahr: irrigation and environments in the history of the Middle East, 500 BC to AD 1500.* Museum Tusculanum Press, 1993.

Condorcet, Jean-Antoine-Nicolas de Caritat. *Sketch for a Historical Picture of the Progress of the Human Mind.* London: Weidenfeld and Nicolson, 1955 [1795].

Conroy-Krutz, Emily. *Christian Imperialism: Converting the World in the Early American Republic.* Ithaca: Cornell University Press, 2015.

Coşgel, Metin M., Thomas J. Miceli, and Jared Rubin. "The political economy of mass printing: Legitimacy and technological change in the Ottoman Empire." *Journal of Comparative Economics* 40, no. 3 (2012): 357-371.

Dallal, Ahmad. *Islam, science, and the challenge of history.* Yale University Press, 2010.

David, Paul A. "The Historical Origins of 'Open Science': an essay on patronage, reputation and common agency contracting in the scientific revolution." *Capitalism and Society* 3, no. 2 (2008).

Diamond, Jared. G*uns, germs and steel: a short history of everybody for the last 13,000 years.* Random House, 2013.

Dols, Michael W. (Michael Walters). *The Black Death in the Middle East.* Princeton, N.J.: Princeton University Press, 1977.

El-Abbadi, Mostafa, Omnia Fathallah, and Ismail Serageldin, eds. *What happened to the ancient library of Alexandria?.* Brill, 2008.

Ellenblum, Roni. *The Collapse of the Eastern Mediterranean: Climate Change and the Decline of the East, 950-1072.* Cambridge: Cambridge University Press, 2012.

Engels, Friedrich in Marx, Karl, and Friedrich, Engels. "Selected Works in Two vols." London: Lawrence Wishart, 1950.

Fakhry, Majid. *Averroës (Ibn Rushd): His Life, Works and Influence*. Oxford: Oneworld, 2001.

Fahmy, Khaled. *In quest of justice: Islamic law and forensic medicine in modern Egypt.* Univ of California Press, 2018.

Francisco, Adam. *Martin Luther and Islam: a study in sixteenth-century polemics and*

apologetics. Vol. 8. Brill, 2007.

Gilbert, Joan E. "Institutionalization of Muslim scholarship and professionalization of the 'ulamā' in Medieval Damascus." *Studia Islamica* (1980): 105-134.

Goldziher, Ignaz. "The Attitude of Orthodox Islam toward the Ancient Sciences." In Swartz, Merlin L. *Studies on Islam.* New York: Oxford University Press, 1981 [1916]: 185-215.

Greif, Avner, and David D. Laitin. "A theory of endogenous institutional change." *American political science review* 98, no. 4 (2004): 633-652.

Greif, Avner. *Institutions and the Path to the Modern Economy: Lessons From Medieval Trade.* Cambridge. New York: Cambridge University Press, 2006.

Gutas, Dimitri. *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early ʿAbbāsid Society*. New York: Routledge, 1998.

Hodgson, Marshall G. S. *The Venture of Islam: Conscience and History in a World Civilization.* Chicago: University of Chicago Press, 1974.

Hoodbhoy, P. A. (2007). Science and the Islamic world—The quest for rapprochement. *Physics Today*, 60(8), 49–55.

Huff, Toby E. *The rise of early modern science: Islam, China, and the West.* Cambridge University Press, 2017.

Ibn al-Nadīm and Bayard Dodge, and *The Fihrist of Al-Nadīm: A Tenth-century Survey of Muslim Culture.* New York: Columbia University Press, 1970.

İhsanoğlu, Ekmelddin in. *Science, Technology, and Learning in the Ottoman Empire: Western Influence, Local Institutions, and the Transfer of Knowledge.* Aldershot, Hampshire ; Burlington, VT: Ashgate/Variorum, 2004.

Ibn Khaldun. *Muqaddimat Ibn Khaldūn*, 3 vols., ed. ʿAlī ʿAbd al- Wāḥid Wāfī. Cairo: Nahḍat Miṣr, 2004 [1377].

Iqbal, Muhammed. "Islam as an Ethical and a Political Ideal" (1908) cited in Charles Kurzman and Michaelle Browers –, et al. *An Islamic Reformation?* Lanham, Md.: Lexington Books, 2004.

Jābirī, Muḥammad ʿĀbid. *Ḥiwār al-Mashriq wa-al-Maghrib*. Cairo: Maktabat Madbūlī, 1990.

Kearney, Hugh Francis. "Puritanism, capitalism and the scientific revolution." *Past Present* 28 (1964): 81-101.

Koestler, Arthur. *The Sleepwalkers: A History of Man's Changing Vision of the Universe.* New York: Grosset Dunlap, 1963.

Koyré, Alexandre. *Études Galiléennes*. Paris: Hermann, 1939.

Khomeini, Ruhollah. "Islamic Government." In *Islam and Revolution: Writings and Declarations of Imam Khomeini.* Translated from Persian by Hamid Algar. Berkeley: Mizan Press. 1981 [1970].

Kuran, Timur. "The provision of public goods under Islamic law: Origins, impact, and limitations of the waqf system." *Law and Society* Review (2001): 841-898.

Kuran, Timur. *The Long Divergence: How Islamic Law Held Back the Middle East.* Princeton, Oxford: Princeton University Press, 2011.

Kuru, Ahmet T. *Islam, authoritarianism, and underdevelopment: A global and historical comparison.* Cambridge University Press, 2019.

Kuru, Ahmet T. "Islam, Catholicism, and Religion-State Separation: An Essential or Historical Difference?." *International Journal of Religion* 1, no. 1 (2020): 91-104.

Lambton, Ann K. S. *Landlord and Peasant in Persia: A Study of Land Tenure and Land Revenue Administration.* [1st ed.] London: Oxford U.P., 1969.

Lapidus, Ira M. (Ira Marvin). *A History of Islamic Societies.* 3rd ed. Cambridge ; New York: Cambridge University Press, 2014.

Lowe, Roy, and Yoshihito Yasuhara. *The origins of higher learning: knowledge networks and the early development of universities.* Routledge, 2016.

Maalouf, Amin. *The Crusades through Arab Eyes.* Translated from French by Jon Rothschild. New York: Schocken Books, 1984.

Madkūr, Ibrāhīm. *Fī Al-falsafah Al-Islāmīyah: Manhaj Wa-taṭbīq*uh. Ṭab'ah 2, munaqqaḥah wa-mazīdah. Miṣr: Dār al-Ma'ārif, 1968.

Makdisi, George. *The Rise of Colleges: Institutions of Learning in Islam and the West.* Edinburgh: Edinburgh University Press, 1981.

Makdisi, George. "Muslim institutions of learning in eleventh-century Baghdad." *Bulletin of the School of Oriental and African Studies* 24, no. 1 (1961): 1-56.

Mokyr, Joel. "Cardwell's Law and the political economy of technological progress." *Research Policy* 23, no. 5 (1994): 561-574.

Mokyr, Joel. "The intellectual origins of modern economic growth." *Journal of Economic History* 65, no. 2 (2005): 285-351.

Mokyr, Joel. *The Enlightened Economy: An Economic History of Britain, 1700-1850.* New Haven: Yale University Press, 2009.

Mokyr, Joel. *The Gifts of Athena.* Princeton University Press, 2011.

Morkoç, Selen B. "In between the mind and the heart: Kātip Çelebi's concept of 'ilm." In Akkach, Samer. *'Ilm: Science, Religion and Art in Islam.* (2019): 113-124.

Murphy, Kevin M., Andrei Shleifer, and Robert W. Vishny. "The allocation of talent: Implications for growth." *The quarterly journal of economics* 106, no. 2 (1991): 503-

530.

Müteferrika, İbrahim. "The Usefulness of Printing." Translated from Ottoman Turkish by Christopher M. Murphy. In George N. Atiyeh, ed., *The Book in the Islamic World: The Written Word and Communication in the Middle East.* Albany: SUNY Press. 1995 [1726].

Najjar, Fauzi M. "Ibn Rushd (Averroes) and the Egyptian Enlightenment Movement." *British Journal of Middle Eastern Studies* 31, no. 2 (2004): 195–213.

Namık Kemal. *Renan Müdafaanamesi: (İslâmiyet Ve Maârif).* Ankara: Milî Kültür Yayınları, 1962 [1910].

Nasr, Seyyed Hossein, and Oliver Leaman. *History of Islamic philosophy.* Routledge, 2013.

Needham, Joseph, and K. G. Robinson. *Science and Civilisation in China.* Vol 7, Part 2. Cambridge [England]: University Press, 1954.

Needham, Joseph. *The Grand Titration: Science and Society in East and West.* London: Allen and Unwin, 1969.

North, Douglass C. (*Institutions, Institutional Change, and Economic Performance.* Cambridge ; New York: Cambridge University Press, 1990.

North, Douglass C, and Robert Paul Thomas. *The Rise of the Western World: A New Economic History.* Cambridge [Eng.]: University Press, 1973.

Nursi, Bediüzzaman Said. "Mektubat." In his Risale-i Nur Külliyatı. Istanbul: Nesil Yayıncılık. 1996 [1929–34].

Ó Gráda, Cormac. "Did science cause the industrial revolution?." *Journal of Economic Literature* 54, no. 1 (2016): 224-39.

Padgett, John Frederick, and Walter W. Powell. *The Emergence of Organizations and Markets.* Princeton: Princeton University Press, 2012.

Parray, Tauseef Ahmad. *Decadence of Muslim Intellectualism: Reason, Ramifications, and Remedies.* New Delhi: Viva books, 2021.

Petry, Carl F. "A paradox of patronage during the Later Mamluk Period." *The Muslim World* 73, no. 3-4 (1983): 182-207.

Pomerantz, Kenneth. *The Great Divergence: China, Europe, and the Making of the Modern World Economy.* Princeton: Princeton University Press, 2009.

Qutb, Sayyid. *Milestones.* Beirut: Holy Koran Publishing House, 1978 [1964].

Quṭb, Sayyid, and Ishaat-e-Islam Trust. *Islam, the Religion of the Future* [al-Mustaqbal Li-hādhā Al-dīn.]. Delhi: Markazi Maktaba Islami, 1974

Rashīd al-Dīn Ṭabīb, Muḥammad Rawshan, and Markaz-i Nashr-i Mīrās-i Maktūb. *Jāmiʿ Al-tavārīkh.* Tihrān: Markaz-i Pizhūhishī-i Mīrās̲-i Maktūb, 2013 [1314].

Rāshid, Rushdī, and Régis Morelon. *Encyclopedia of the History of Arabic Science.* London ; New York: Routledge, 1996.

Renan, Ernest. *L'Islamisme et la science: conférence faite à la Sorbonne, le 29 mars 1883.* Calmann Lévy, 1883.

Rubin, Jared T. *Rulers, Religion, and Riches: Why the West Got Rich and the Middle East Did Not.* New York, NY: Cambridge University Press, 2017.

Runciman, Steven. *The first crusade.* Cambridge University Press, 2005.

Sabra, Abdelhamid I. "The appropriation and subsequent naturalization of Greek science in medieval Islam: a preliminary statement." *History of Science* 25, no. 3 (1987): 223-243.

Safi, Omid. *The Politics of Knowledge in Premodern Islam: Negotiating Ideology and Religious Inquiry.* Univ of North Carolina Press, 2006.

Saleh, Mohamed. "On the road to heaven: Taxation, conversions, and the Coptic-Muslim socioeconomic gap in medieval Egypt." *Journal of Economic History* 78, no. 2 (2018): 394-434.

Saliba, George. *Islamic science and the making of the European Renaissance.* Mit Press, 2007.

Saunders, J. J. (John Joseph), and Geoffrey Rice. *Muslims and Mongols: Essays On Medieval Asia.* Christchurch: Whitcoulls for the University of Canterbury, 1977.

Sayılı, Aydın. "The observatory in Islam." New York: Arno Press (1981).

Seth, Sanjay. *Subject Lessons: The Western Education of Colonial India.* Durham: Duke University Press, 2007.

Shatzmiller, Maya. *Labour in the Medieval Islamic World.* Leiden [The Netherlands]; New York: E.J. Brill, 1994.

Shehadi, Fadlou. *Philosophies of music in medieval Islam.* Vol. 67. Brill, 1995.

Smith, John Masson. "Mongol manpower and Persian population." *Journal of the Economic and Social History of the Orient* (1975): 271-299.

Sorokin, Pitirim A., and Robert K. Merton. "The course of Arabian intellectual development, 700-1300 AD A study in method." *Isis* 22, no. 2 (1935): 516-524.

Starr, S. Frederick. *Lost Enlightenment: Central Asia's Golden Age From the Arab Conquest to Tamerlane.* Princeton: Princeton University Press, 2013.

Tierney, Brian. *The Crisis of Church and State, 1050-1300.* Englewood Cliffs, N.J.: Prentice-Hall, 1964.

Voltaire. An Essay on Universal History: The Manners, and Spirit of Nations, from the Reign of Charlemaign to the Age of Lewis XIV. Written in French by M. de Voltaire. Translated Into English, with Additional Notes and Chronological Tables,

by Mr. Nugent. S. Cotter, 1759.

Wallerstein, Immanuel. "The West, Capitalism, and the Modern World-System." *Review (Fernand Braudel Center)* 15, no. 4 (1992): 561–619.

Wild, Stefan. "Islamic Enlightenment and the Paradox of Averroes." *Die Welt Des Islams* 36, no. 3 (1996): 379–90.

Weber, Max, Guenther Roth, and Claus Wittich. *Economy and Society: An Outline of Interpretive Sociology.* Berkeley: University of California Press, 1978 [1921].

Weber, Max. *The Protestant Ethic and the Spirit of Captalism.* London ; New York: Routledge, 2001 [1930].

White, Sam. "The Real Little Ice Age." *Journal of Interdisciplinary History* 44, no. 3 (2014): 327–52.

Wickberg, Daniel. "Intellectual history vs. the social history of intellectuals." *Rethinking History* 5, no. 3 (2001): 383-395.

Yalçinkaya, M. Alper. *Learned Patriots: Debating Science, State, and Society in the Nineteenth-Century Ottoman Empire.* University of Chicago Press, 2015.

Zanden, J. L. van. *The Long Road to the Industrial Revolution: The European Economy in a Global Perspective, 1000-1800.* Leiden ; Boston: Brill, 2009.

8 Appendix I

Table 6: Rise of Legal Author Nisbas: 800 - 1500

	Ar-Req		Çelebi	
	East	Diff	East	Diff
	(1)	(2)	(3)	(4)
(1100, 1200]	−0.20	−0.99	10.68***	−9.61***
	(0.24)	(2.39)	(0.87)	(1.03)
(1200, 1300]	12.56***	−20.62***	2.30***	2.52***
	(0.98)	(2.10)	(0.59)	(0.82)
(1300, 1400]	41.85***	−45.47***	13.27***	−11.89***
	(2.30)	(2.97)	(0.59)	(0.94)
(1400, 1500]	15.16***	−5.15*	7.12***	−2.19*
	(0.64)	(2.99)	(0.66)	(1.18)
Baseline: (800, 1100]	1.93***	6.14***	14.52***	−6.85***
	(0.22)	(1.87)	(0.57)	(0.70)
Manuscripts	5,931		3,386	

Notes: Point estimates are calculated on the Al-Req and Çelebi sets, years [800, 1500). Columns 1 and 3 reports point estimates for the 50-year moving average of the proportion of authors who have *nisbas* that indicate an affiliation with one of the five Sunni schools of law. Columns 2 and 4 report the differences-in-differences estimates for the West. I present Newey-West standard errors in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Figure 9: Centers of Intellectual Production 650-1650 (Çelebi)