

Tolerance, Religious Competition and the Rise and Fall of Muslim Science

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Abstract

This paper investigates how medieval Islam encouraged scientific innovation. By granting non-Muslims a degree of religious freedom, Muslim law created competition between religions for converts and social standing. Institutionalized tolerance, coupled with initial disadvantages in the number of adherents and sophistication of theological scholarship, encouraged Muslim religious elites to promote the study of logic. The study of logic for inter-religious debates, in turn, created an environment in which science flourished. Results suggest that competition, tolerance and non-religious intellectual enterprise decreased as the societies under Muslim rule became increasingly religiously homogeneous. The results highlight the role of tolerance in Islam's medieval development and stress the importance of diversity in constraining elements resistant to innovation.

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“[T]he exceeding distance [of Northern Europeans] from the sun thickens the air making their dispositions cold, their natures rude, their skin color white and their hair straight. Thus [...] dullness and ignorance overpower them.” **Abū al-Qāsim Sa’id (1068)**¹

Northern Europe’s rise to world economic dominance after the 18th century took many by surprise. Europe’s Muslim neighbors were among the most surprised. For centuries Muslims had viewed their European counterparts as technologically and economically backward. The most prominent European thinkers echoed this attitude until at least the 16th century. They sometimes referred to the Arab thinkers that invented the scientific method and pioneered research in countless fields as their “Arab masters.”

In their search for an explanation for Europe’s Industrial Revolution, scholars have sought to understand why Europe, instead of other technologically advanced societies like China, industrialized first.² Yet economists have often overlooked Europe’s Muslim neighbors.³ For centuries, Europeans trailed Muslim societies along the path that ultimately led to a European rather than an Islamic industrial revolution. Bernard Lewis, a prominent historian of Islam, has recently stressed this point by noting that “one might reasonably have expected [the industrial revolution to have occurred], in the richer, more advanced, and in most respects more enlightened realm of Islam.”⁴

This paper investigates how medieval Islam encouraged scientific innovation and examines the factors that led to Muslim science’s decline. Understanding why Muslim scientific progress stagnated, in turn, sheds light on why sustained economic growth first emerged in Europe rather than in Muslim lands.

The results suggest, as has been argued by Moykr (1990), the importance of constraining authorities and individuals that are opposed to technological and scientific progress. Muslim

¹p. 8-9.

²E.g. Pommeranz (2001).

³Exceptions include Greif (1994) and Kuran (2003).

⁴Lewis (2003), p. 156.

science and the fledgling Muslim enlightenment seem to have fallen victim to the forces of religious reaction. European science, when confronted with similar religious opposition, emerged victorious.⁵ Mokyr (2005) has recently argued that this enlightenment “unlocked the path to cumulative growth in the West”.⁶

The results highlight how religious groups –like their secular counterparts– can block innovation when they regard it as a threat to their interests. The evidence suggests that religious diversity and competition between religions mitigated the opposition of Muslim religious forces to scientific inquiry for centuries by both constraining these elites and providing incentives for them to tolerate the study of logic. When religious competition decreased after Islam emerged as the dominant majority, the religious authorities moved to eliminate scientific enterprise. Understanding how the European enlightenment avoided the fate of Muslim science may provide important insights into why sustained economic growth first emerged in Europe.

Muslim religious authorities were wary of the study of the “foreign” or rational sciences immediately following the conquests of the Middle East and North Africa (632-732 C.E.).⁷ They viewed these rational sciences as unnecessary additions to the Islamic or “Arab” sciences and a potential danger to the faith.⁸

The religious authorities, constrained from forcefully converting the non-Muslim populations (which were initially the vast majority), became interested in the study of logic as non-Muslim populations objected to Islamic proselytizing in logical terms. These authorities encouraged the widespread study of logic for the purpose of religious debate which in turn created an environment in which scientific progress flourished.⁹

⁵Israel (2006).

⁶Mokyr (2005), p. 324.

⁷The rational sciences cultivated during this period primarily consisted of philosophy, mathematics and astronomy.

⁸The Islamic sciences consisted of, among other things, the study of Islamic law (*shar'ia*). The term Islamic science is not to be confused with Muslim science, the term which we use to refer to all intellectual activity (irrespective of the religious affiliation of the author) under Muslim rule.

⁹We will refer to the study of logic for religious debate and science interchangeably, the link between the two is established more precisely in section 2.2.3.

Medieval sources show how the widespread study of logic led an increasing subset of the Muslim population to turn to logic and philosophy –not religion– as the ultimate arbiter of truth. I argue that once the majority of the conquered populations converted to Islam, the costs associated with allowing the study of logic dominated the benefits for religious elites. When this occurred, the religious authorities withdrew their support for the study of the rational sciences. They burned books, discouraged questions, pressured leaders to eliminate the institutions of “secular” learning and branded students of the rational sciences heretics. Although a few leaders and individuals continued to support these sciences, the costs of doing so had considerably increased.

This hypothesis implies that as Muslims became increasingly numerically dominant in a given area, one would expect to see production of the rational sciences decrease as the religious authorities increased their opposition to the study of these sciences. I test these implications using data on scientific production from a book catalog from the thirteenth century Levant. The data show an abrupt decline in Muslim scientific production that roughly coincides with the advent of the Muslim population as the dominant majority in each region. Qualitative evidence from medieval sources stresses the role of Muslim religious elites in bringing about this drop.

The evidence suggests that the decline of Muslim science contributed to Muslim technological stagnation. This technological stagnation, in turn, negatively affected the growth prospects of the Muslim Middle East and North Africa. The experience of medieval Islam suggests that diversity -when combined with tolerance- can help encourage innovation and growth by preventing the dominance of innovation-resistant groups.

The remainder of the paper proceeds as follows. Section 1 starts by giving a broad overview of Muslim scientific and technological advances in the Middle Ages and examines the extent to which these had the potential to influence economic growth. Section 2 briefly explains previous hypotheses regarding the rise and fall of Muslim science and then uses the historical record to outline both the incentives and disincentives the religious authorities

faced when deciding whether to permit the study of logic. Section 3 develops a formal model that investigates the relationship between the number of non-Muslims, the opposition of religious elites to science and the political authority’s tolerance of both the non-Muslim population and the rational sciences. Section 4 provides both qualitative and quantitative evidence from medieval sources and investigates alternative explanations for the results. Section 5 concludes.

1 Muslim Science, Technology and Economic Growth

1.1 Muslim Scientific and Technological Achievements

A cursory examination of a list of English words derived from Arabic indicates the extent of Muslim medieval scientific¹⁰ development. Among other scientific loan words from Arabic that continue to be used today, Muslim scientists gave English alcohol, algebra, algorithm, amalgam, almanac, azimuth, chemistry and zero.

Muslim medieval scientific advances included the development of algebra, trigonometry and chemistry, the widespread use of the experimental method and the development of the astronomical models used by Copernicus.¹¹ In many fields Muslim scientific accomplishments greatly surpassed those achieved in China.¹²

Islam’s medieval scientific development is all the more striking because it appeared so “European.”¹³ Muslims pioneered many of the empirical and mathematical techniques that proved central to European scientific development, and Muslim thinkers even had their own “enlightenment” (Israel (2006), p. 634). European thinkers did not surpass 11th century Muslim scientific and technological developments until well into the Renaissance after more than 300 years of continuous study of translated Muslim scientific works.¹⁴

¹⁰The use of the term science is, admittedly, anachronistic. For the purposes of this paper, “science” will refer to “natural philosophy” or the precursor to modern science.

¹¹Saliba (2007).

¹²See, for example, Huff (1993) pp. 50-51.

¹³Or perhaps more precisely because European development appeared so Muslim.

¹⁴It is difficult to overestimate the amount European technological and scientific development in the

Muslim thinkers did not limit themselves to theoretical considerations. Muslim technicians developed machinery similar to that used in a double-acting steam engine,¹⁵ invented a device that led to the first recorded episode of human flight¹⁶ and made substantial advances in the development of the mechanical clock.¹⁷

Bernard Lewis sums up medieval scientific and technological developments in the Muslim world. He notes that

[f]or most of the Middle Ages, it was neither the older cultures of the Orient nor the newer cultures of the West that were the majors centers of civilization and progress, but the world of Islam in the middle. It was there that old sciences were recovered and developed and new sciences created.¹⁸

For centuries, Muslim science and technology were in many respects the world's most advanced.

1.2 Linking Science, Technology and Economic Growth

Economists widely agree that technological innovation is necessary for sustained economic growth.¹⁹ Inasmuch as Muslim scientific stagnation explains long-term Muslim technological stagnation, understanding why Muslim science stagnated helps us understand why sustained growth first emerged in Europe and not in the Middle East.

While the mapping between scientific and technological progress is clear today, before the 19th century the link between science and technology was at best indirect. Many European technological advances came from individuals with little formal training, and many scientists did not consider or were not interested in the practical implications of their discoveries.

Renaissance and Enlightenment owe to previous Islamic discoveries. It is widely believed that the translation of the Muslim scientific corpus into European languages in the Middle Ages set the stage for the Renaissance and Enlightenment.

¹⁵Hill (1979), p. 235.

¹⁶White (1961), pp. 100-101.

¹⁷Hill (1994), p. 234.

¹⁸Lewis (2003), p. 156.

¹⁹For an overview the importance of technological innovation for economic growth see Helpman (2004), section 4.

Recent work by Joel Mokyr, however, has argued that despite this apparent disconnect, theoretical scientific developments played an important role in the ultimate success of the Industrial Revolution. He notes that technological progress “would have eventually run into diminishing returns and fizzled out” in the absence of continued scientific progress.²⁰

Scientific development, while perhaps not the short-term engine of pre-industrial technological development²¹ seems to have defined the feasible frontier of long-term technological progress. In other words, although scientific progress was not a sufficient condition for long-term economic growth it was a necessary one.

Although an Islamic industrial revolution was not the necessary outcome of the counterfactual world in which Muslim science did not stagnate, Muslim scientific stagnation nonetheless contains important insights into understanding the roots of modern economic growth.²² Understanding where Muslim science “went wrong” may shed light on where European scientific development –fundamental to the ultimate success of the Industrial Revolution– “went right.”

2 Religious Competition and the Rise and Fall of Muslim Science

2.1 The Rise and Fall: Previous Hypotheses

The reasons behind the sudden flowering of Muslim science in the 8th century have perplexed generations of modern scholars. The past decade, however, has seen a flurry of research

²⁰Mokyr (2005), p. 289.

²¹It is interesting to note, however, that in both Islam and the Christian west technological and scientific development have gone hand in hand. This suggests that the intellectual ferment that led some to science led others to “tinker.”

²²It must be noted that many of the institutional and organizational arrangements considered fundamental to the ultimate success of the Industrial Revolution were themselves innovations. Thus, it may be the case that uninterrupted scientific development would have led to these innovations in Islam even if these were not present earlier.

suggesting that competition between Muslim conquerors and their conquered²³ non-Muslim subjects played an important role in spurring initial scientific advances.

Gutas (1998) suggests that Islam's poor performance in inter-faith debates²⁴ led Muslim elites to translate Greek works on logic and physics to respond to theological arguments advanced by non-Muslim populations. These translations were the start of the great translation movement of Greek knowledge into Arabic²⁵ and a factor in the initial surge in Muslim scientific production.²⁶

The abrupt decline in Muslim scientific production that appears to have occurred between the 11th and 13th centuries has similarly perplexed scholars.²⁷ Possible explanations for this stagnation include a sudden increase in resistance by the religious authorities to the study of the sciences, the start of the first crusade (1095) and the Mongol invasions of the 13th century.

The following sections focus on the role the religious elites played in both the rise and fall of Muslim science. I argue that competition between Islam and the religions in the lands it conquered can both explain the sudden rise in interest of the religious elites towards the rational sciences as well as their abrupt change in interest in these science after the 11th century. Section 4.3 shows that the evidence does not support other widely held explanations for Muslim scientific stagnation.

2.2 Tolerance, Religious Competition and Science

This subsection uses the historical record to outline the process that led Muslim religious elites to tolerate the widespread study of the sciences. It can be summarized schematically

²³Between 632 and 732 C.E. Muslim armies conquered lands from modern day France to Pakistan.

²⁴Between Muslims and their non-Muslim subjects, see section 2.2.2 for details.

²⁵From the middle of the eighth century to the end of the tenth, scholars working in the Muslim world (primarily the Abbasid Caliphate (758-1258)) translated the vast majority of secular Greek works into Arabic. The Abbasid Caliphs supported this movement to varying degrees, as did wealthy individuals. For additional information on the translation movement, see Gutas (1998) and O'Leary (1949).

²⁶Saliba (2007) similarly suggests the importance of competition between Muslim and non-Muslim bureaucrats in the rise of Muslim scientific activity.

²⁷A recent book by Saliba (2007) argues that Muslim science did not decline. His conclusions, however, have been seriously disputed.

as follows: rapid Muslim conquest→institutionalized tolerance of non-Muslims→religious competition (+Hellenistic heritage)→study of logic for debates→science. As the population converted to Islam, I argue that religious competition decreased as did the study of logic and science.²⁸

2.2.1 Tolerance

When the prophet Muhammad (570-632) first encountered opposition to his message, he encouraged his followers to convince non-believers by persuasion rather than by force.²⁹ Muslims were told to “invite (all) to the Way of thy Lord with wisdom and beautiful preaching; and [to] argue with them in ways that are best and most gracious” (*Qur‘ān* (16:125)). The *Qur‘ān* (2:256) explicitly forbade the forced conversion of other monotheists.

After Muhammad’s death and the first wave of Muslim conquests (632-732), the conquered populations³⁰ were allowed to retain their original creeds, in exchange for the payment of an annual poll tax (*jizya*). A non-Muslim living under Muslim rule who had paid the *jizya* was referred to as a *dhimmī* (protected person), and enjoyed legal protection. Although treatment of the non-Muslim populations varied, these communities were generally treated with “a degree of tolerance without precedent or parallel in Christian Europe” (Lewis 2003, pp. 33-34).³¹

Constrained from forced conversion by numerical realities and Muslim law, Muslim authorities interested in converting their non-Muslim subjects were forced to resort to persuasion.³² Tax breaks and the societal status that came with conversion to Islam were un-

²⁸The hypothesis of a link between the proportion of non-Muslims, conversion to Islam and scientific development is not new. See, for example, Huff (1993, p. 47) or Kuran (2004, p. 125).

²⁹This was undoubtedly partly due to Islam’s weak numerical and political position (Bosworth 1979, pp. 13-14).

³⁰The majority of the conquered populations had been under the Sassanid (roughly modern Iran, Iraq and Afghanistan) or Byzantine Empires (modern Syria, Israel, Jordan and Egypt).

³¹There were violent exceptions such as the forced conversion and expulsion of non-Muslims in North Africa and the Iberian peninsula under Almohades (1121-1269).

³²Muslim authorities did not immediately encourage conversion to Islam. Large scale conversion does not appear to have been pursued until the Abbasid Empire (750-1258).

doubtedly the most effective means of encouraging the non-Muslim populations to convert.³³ These incentives, however, worked slowly. In the meantime, representatives of the numerically dominant non-Muslim creeds used logical arguments to embarrass Muslim religious scholars in debates and to discourage conversion to Islam.³⁴

2.2.2 Religious Competition

Because Muslim religious authorities³⁵ could not use force to silence the theological counter-attacks of non-Muslims, inter-faith debates emerged as a means of demonstrating religious superiority. These debates appear to have initially been instigated by non-Muslims in response to Muslim proselytizing.³⁶ Non-Muslim communities seem to have realized that they would have a distinct advantage in these debates. Non-Muslims had more systematically developed theologies (due to the fact that Islam had recently been founded) and had access to the tools of Hellenistic learning that Muslims initially did not.³⁷

Non-Muslim religious authorities successfully exploited this comparative advantage. Muslims initially performed poorly in inter-faith debates.³⁸ Islam, in turn, was “guided by its opponent in the method of attack and fell [...] under its influences” (Fueck (1939), p. 107). Inter-faith debates were based on logical arguments and appear to have been quite widespread.

Although Hellenistic heritage seems to have been a necessary condition for the emergence

³³Once one converted to Islam, conversion to another religion was prohibited.

³⁴For one example, see Edde et al. (1997), p. 209.

³⁵These religious authorities are perhaps best identified with what would eventually be known as the *‘ulamā’* or religious scholars. In the early centuries of Islam, these authorities were often divided on many issues. These early divisions, which proved beneficial to the development of Muslim science (as argued below) make a more precise definition of these authorities difficult.

³⁶The intra-Christian and anti-Jewish polemics of the early seventh century in the Byzantine empire meant that Christian and Jewish authors were well trained in the art of debating when Islam arrived (Cameron (1991) especially p. 302).

³⁷It is interesting to note that Christian elites in Byzantium seem to have been generally hostile to this Hellenistic heritage before the arrival of Islam. Despite this general hostility, they did allow the use of logic as “a dialectical weapon to be used against heresies” (Kazhdan (1991), p. 1660). Christian religious elites found a renewed interest in logical methods after Islam arrived.

³⁸The Abbasid Caliph al-Ma’mūn (786-833) supposedly lamented following one debate: “how I wish that I had never seen this day, nor seen the failure of the Muslims and their lack of argument on behalf of their religion!” (cited in Thomas (2003), p. 66).

of logic as the lingua-franca in religious debates, the distance between the religious beliefs of Muslims and non-Muslims was also important. Since Muslims believed that non-Muslim scripture had been distorted and non-Muslims did not believe in Muhammad or the *Qur'ān*, inter-faith debates could not rely on revealed truth.³⁹ An excerpt from one such debate in the 11th century stresses this point. In this debate, the head of the court stated that

‘you have gathered to debate, so let not the Muslims use their book or the sayings of their prophet as evidence, because we do not believe in these things nor do we admit them, instead we debate using proofs of the mind, and that which allows comparison and examination.’⁴⁰

Constrained from forced conversion by numerical realities and Muslim law, many Muslim religious elites supported the translation of Hellenistic knowledge into Arabic and the development of *‘ilm al-kalām*, a rational branch of Muslim theology.⁴¹ The primary function of *kalām* was to “rationalise the basic beliefs of the Muslims as they are given in the Koran and the Sunna”.⁴² Although some religious authorities objected to this introduction of rational elements into Muslim theology, they tolerated its use to defend Islam from the “challenge by other monotheists” (Hodgson (1977) pp. 437-438).

³⁹The importance of a wide “distance” between doctrines for the emergence of logic as a lingua franca in debates is exemplified by the follow excerpt from Thomas Aquinas’s (1225-1274) *Summa Contra Gentiles* (written, by many accounts, to aid in the conversion of Muslims in the Iberian peninsula). Aquinas explains that “the Mohammedans [...] do not agree with us as to the authority of any Scripture whereby they may be convinced, in the same way as we are able to dispute with the Jews by means of the Old Testament, and with heretics by means of the New: whereas the former accept neither. Wherefore it is **necessary to have recourse to natural reason, to which all are compelled to assent**” (Aquinas (1264), p. 4 emphasis added).

⁴⁰Al-Andalusī (1095), p. 96.

⁴¹The historian al-Mas‘ūdī (d. 957) stresses the importance of “religious competition” for the broad acceptance of rational methods in Muslim theology. He states that “[i]n this fashion Manichaeans [a non-Muslim creed] increased in number and their opinions came out in the open among people. Al-Mahdī [775-785 C.E.] was the first caliph to command the theologians who used dialectic disputation [...] to compose books against heretics [...]. The theologians then produced demonstrative proofs against the disputers [and] eliminated the problems posed by the heretics (cited by Gutas (1998), p. 65).

⁴²Frank (1992), p. 22.

2.2.3 Science

Following the Muslim conquests, many Muslim religious elites were suspicious of Hellenistic learning.⁴³ They viewed science using rational methods as an unnecessary addition to the Islamic sciences.⁴⁴ The study of these rational sciences soon came to be associated with religious apostasy and doubt.⁴⁵ This attitude—hardly unique to Muslim religious authorities—was echoed centuries later by Christian religious elites during the Renaissance and Enlightenment.

Despite this aversion to the rational sciences, Muslim religious elites tolerated and even encouraged the study of rational methods to support Islam in debates with non-Muslims.⁴⁶ The study of rational methods for religious debates, in turn, created an environment in which scientific progress could obtain. Although such an environment was not sufficient for scientific advancement, it was necessary.

Religious debates and religious competition created a science-friendly environment through two channels.

First, religious debates gave Muslim religious elites (of whatever persuasion) an incentive to allow the study of logical methods (*‘ilm al-kalām*) to perform well in debates. Muslims who studied these logical methods “did not distinguish theology from philosophy.”⁴⁷ Consequently the line between studying works such as Aristotle’s *Topics*⁴⁸ to improve debating skills and

⁴³Huff (1993, pp. 68); Sabra (1987, pp. 231); Goldziher (1916).

⁴⁴The “rational sciences” refer to most pre-modern science. The Islamic sciences referred, primarily, to the study of religion.

⁴⁵To be more precise, those who studied these sciences seem to have had a greater propensity to reject the authority of Muslim religious elites. These individuals seem to have been in their majority deists although a few were atheists. Their attitude is summed up by al-Ghazālī (1058-1111) “[f]or I have witnessed a group who see themselves as superior to the rest [...] who have ceased to perform the duties of Islam [...] and belittle the rites of religion [...] and the source of their unbelief [...] comes from] Socrates, Hippocrates, Plato, Aristotle and the likes” (al-Ghazālī (1095), pp. 41-42).

⁴⁶It should be noted that while for ease of exposition we limit the notion of religious competition to logical debates, religions appear to have competed on other dimensions as well. ‘Abū ‘Uthmān ‘Amr Ibn Baḥr al-Jāḥiẓ (d. 869) noted that “the [Muslim] commoners prefer Christians [...] [because] there are philosophers and doctors and astrologers [among them]” (al-Jāḥiẓ (868), pp. 14-16). This suggests that religions also competed for “prestigious positions.” In addition, there is evidence faiths used architecture to compete (see Bosworth (1992), p. 19).

⁴⁷Frank (1992), p. 19.

⁴⁸The *Topics* teaches the art of debate using logic and commonly held beliefs.

other “secular” works was poorly defined. Muslim political and religious authorities seem to have recognized that the study of logic for debates went hand in hand with philosophy and scientific study.⁴⁹

Second, religious competition made it difficult to define and enforce religious orthodoxy. The definition of orthodoxy in Islam relies on agreement between Muslim religious elites (*ijma'*).⁵⁰ Muslim religious leaders immersed in rationalistic methods to defend their beliefs, however, often came up with “heterodox” interpretations and founded spin-off groups.⁵¹ These groups, in turn, bickered amongst themselves.⁵² Ibn al-Faqih al-Hamadani in 903 noticed how intra-Muslim religious debate impeded the emergence of “orthodoxy.” He observed how “each [religious] group holds the other one in check and prevents it from setting itself up as leader”.⁵³

Inter-faith competition constrained the emergence of an influential anti-scientific religious orthodoxy by a) giving the religious authorities an incentive to support logical methods and b) preventing the agreement of Muslim religious authorities on an anti-rationalistic orthodoxy.

The lack of religious dogma combined with Smithian growth and the region’s Hellenistic heritage to create an environment in many ways similar to the European Enlightenment. Muslim political authorities, as well as wealthy merchants, supported the establishment of large libraries for the study of secular science. As time progressed, competition emerged between different Islamic kingdoms to attract and support the most gifted scholars. The result was probably the largest upsurge in formal scientific activity in the pre-modern era.

⁴⁹For an example of this see Makdisi (1981) pp. 136-137. Al-Ghazālī (1058-1111), one of the most famous (although moderate) medieval opponents of rationalistic methods, linked the study of logical methods to the other rational sciences and to apostasy. He states that “often he who admires logic [...] believes the rest of their [philosophers’] teachings [...] and hastens to unbelief” al-Ghazālī (1100), p. 36.

⁵⁰Islam during this period had no equivalent to the priesthood, Pope, or other such centralized authority.

⁵¹This is perhaps best represented by the proliferation of “Sunni” law schools which numbered over 500 before the 9th century (Makdisi (1981) p. 2).

⁵²The proliferation of Muslim sects seems to have been a function of inter-faith religious competition and the conversion process itself. In a detailed study of Iran during the conversion period, Bulliet (1994, p.106) argues that “[w]ith thousands of people [potential and recent converts] asking questions about Islam, the marketplace of answers [i.e. interpretations and sects] was wild and colorful.”

⁵³Cited by Gutas (1998), p. 190.

2.3 Religious Uniformity, the Emergence of Orthodoxy and the Fall of Muslim Science

Muslim religious authorities soon found their initial mistrust of the study of the rational sciences justified. The intellectual ferment and fledgling Muslim enlightenment produced figures like Abū 'Ala al-Ma'arī (1057) who claimed that “[t]he people of this earth are two; those with a mind and no religion and those with religion and no mind.”⁵⁴ Ibn al-Haytham (965-1039) stated that as a youth he “saw that [he] would not reach the truth unless it was through [...the teachings of] Aristotle”⁵⁵ and al-Ghazālī (1058-1111) studied “until the tie of tradition was undone and the inherited beliefs were broken”.⁵⁶

The widespread use of logic that proved so useful in combating the doubts and attacks of non-Muslims did not come without costs. This study led to disagreements between Muslims themselves and led some Muslims to doubt and turn to philosophy rather than religion for answers. This increasingly led the religious elites to view the use of rational methods as “a serious threat to [...] religious doctrine” (Goldziher 1916, p. 198) and to the welfare of the religious elites themselves.⁵⁷

While Muslim sects remained divided and the non-Muslim majority large, Muslim religious elites were both ill-positioned and did not have incentives to eliminate the widespread study of the rational sciences. Once the vast majority of the population converted to Islam, Muslim religious elites would have little reason to tolerate the study of the sciences. Unless the remaining Muslim sects themselves remained divided, we would expect Muslim religious authorities to unite in their anti-science campaign and to pressure both the populace and the political authorities to eliminate the study of these sciences.

⁵⁴Cited in Makdisi (1981) p. 139 (with a slightly different translation).

⁵⁵Ibn Abī Uṣaybi'a (1268), pp. 506-507.

⁵⁶Al-Ghazālī (1100), p. 3.

⁵⁷While there is substantial evidence that Muslim religious elites saw the study of the rational sciences as a threat to their welfare, the exact mechanism that led to this resistance remains (at least in my mind) unclear. Perhaps these elites derived utility or extracted additional rents from uniformity or from never being questioned.

3 Political Elites, Tolerance and Scientific Production

The previous discussion suggests that Muslim religious authorities should have encouraged (or at the very least not actively discourage) the study of the sciences as long as the non-Muslim population remained sufficiently large. This section takes the behavior of the religious elites as given and considers the implications of the size of the non-Muslim population for both the level of support of the sciences by the political authorities⁵⁸ and the tolerance with which the political authorities treated the non-Muslim population.

Consider a finitely lived Muslim political leader who seeks to maximize the income generated from the non-Muslim population over his lifetime. Let $N(t)$ denote the size of the non-Muslim population at time t (we assume that the total population is fixed) and $\tau(t)$ the tax rate (this could also be interpreted as the tolerance with which the non-Muslim populations are treated) at time t . We normalize production per worker to one (for simplicity we assume productivity is independent of the tax rate) so that the revenue flow at time t is given by τN .

The leader does not keep all of the revenues obtained from the taxation of his non-Muslim subjects.⁵⁹ He has to maintain a standing army to discourage and/or quell revolts. The size (and the associated cost) of this army depends on the propensity of the population to revolt. We consider here the costs of revolt imposed on the ruler by the non-Muslim population. For clarity, I have broken this cost into two expressions.

The first expression represents the propensity of the non-Muslim population to revolt and is given by $q(\tau, N)$. We assume $q_1 > 0, q_{11} > 0$ (where subscripts denote partial derivatives with respect to a given argument) since a higher tax rate should increase the propensity of the population to rebel. In addition, we assume $q_2 > 0, q_{22} > 0$ since a higher non-Muslim

⁵⁸Political and religious authorities in Islam were separate for the vast majority of the period considered in this paper. While religious authorities often wielded considerable political authority (as in Christianity) political leaders almost always determined the final policies. Politicians could (and often did) go against the dictates of the religious authorities.

⁵⁹Non-Muslims were always taxed at a higher rate than Muslims. See section 2.2.1.

population level should also increase rebellions.⁶⁰

The second expression represents the propensity of the Muslim religious authorities to rebel⁶¹ and is given by $q_R(A, N, A_c)$, where $A(t)$ is the Muslim secular knowledge “stock”⁶² and A_c is the Christian knowledge stock (which we assume constant).⁶³ We assume that $q_{R11} > 0$ since an increase in the secular knowledge stock weakens the religious authorities’ position as previously discussed. In addition we assume that $q_{R12} < 0$ since a larger stock of non-Muslims lowers the opposition to the study of the sciences for competition purposes. Finally, we assume that $q_{R2} > 0, q_{R22} > 0$ since the religious authorities do not like large populations of non-Muslims.

The leader sets the amount of secular knowledge⁶⁴ in the Muslim community in each period A as well as the tax rate τ to:

$$\underset{\tau, A_m}{Max} \int_0^T [\tau N - q(\tau, N) - q_R(A, N, A_c)] dt \quad (1)$$

subject to the equation of motion of the non-Muslim population

$$\dot{N} = -\xi(\tau, N, A_c) \quad (2)$$

Equation (2) shows that the non-Muslim population only converts to Islam to escape high tax rates.⁶⁵ We assume $\xi_1 > 0, \xi_{11} > 0$ and $\xi_2 > 0, \xi_{22} > 0$. In other words, a rise in the tax rate increases the number of converts as does an increase in the population (since

⁶⁰There are many examples of non-Muslim revolts while they remained a numerical presence. See, for example, Bulliet (1994, p. 39).

⁶¹More precisely that part of the propensity caused by the non-Muslim population.

⁶²We will assume that the “stock” needs to be renewed each period.

⁶³These stocks are defined at the individual level and thus are the same (within religion) regardless of the total population in a given religion. In other words, I define the aggregate knowledge stock as the union of the identical knowledge sets of the individual members of each religion.

⁶⁴We assume that the leader had negligible interest in supporting the sciences (i.e. simple curiosity or the demonstration of royal power). This assumption is justified since during the pre-modern era, the potential economic and military benefits of the use of logic and formal science were poorly understood. Consequently, rulers and other elites primarily saw these sciences as a “luxury,” to be patronized when convenient.

⁶⁵While there is evidence that a few individuals converted because Islam was more “rationally” convincing, these were probably a small minority.

there is a larger “stock” from which converts can come). Finally, we assume that $\xi > 0$ since there were always incentives to convert to Islam and conversion was irreversible.⁶⁶

The Hamiltonian is

$$H = \tau N - q(\tau, N) - q_R(A, N, A_c) - \lambda \xi(\tau, N, A_c)$$

and the necessary conditions⁶⁷ for a maximum are:

$$\lambda' = -\tau + q_2 + q_{R2} + \lambda \xi_2 \quad (3)$$

$$\frac{\partial H}{\partial \tau} = N - q_1 - \lambda \xi_1 = 0 \quad (4)$$

$$\frac{\partial H}{\partial A} = -q_{R1} = 0 \quad (5)$$

in addition to the transversality condition $\lambda(T) = 0$.

Since conversion does not depend on the Muslim knowledge stock, the leader sets $q_{R1} = 0$ and the rate of change of the Muslim knowledge stock is given by:

$$\dot{A} = \frac{q_{R12}}{q_{R11}} \xi \quad (6)$$

If $q_{R12} < 0$ as we would expect if the religious authorities dislike secular knowledge less when there is a larger non-Muslim population (for competition purposes), then the level of Muslim secular knowledge should decrease over time.⁶⁸ If we assume that q_{R11} is constant, then the largest decreases in scientific activity should be concentrated around points where

⁶⁶We assume that all functions are “smooth” and that the necessary derivatives exist.

⁶⁷The conditions $\xi_{11} > 0, \xi_{22} > 0, \xi_{11}\xi_{22} > \xi_{12}^2$ guarantee the joint concavity of ξ . Assuming $q_{11} > 0$ as well as $\frac{q_{R21}^2}{q_{R11}} + \frac{(1-q_{21})^2}{q_{11}} < q_{22} + q_{R22}$ ensures that $\tau N - q - q_R$ is jointly concave. If in addition $\lambda = \frac{N-q_1}{\xi_1} \geq 0$ then the necessary conditions are also sufficient. We assume these below.

⁶⁸Note that for the level of secular science to be positive, it must be the case that $q_{R1} < 0$ for some values of $A > 0$.

$q_{R12}\xi$ is “large” or when non-Muslims cease to pose a threat to the religious authorities.

The first order condition $q_{R1}(A, N, A_c) = 0$ coupled with the implicit function theorem⁶⁹ allows us to conclude that $\frac{\partial A}{\partial N} = -\frac{q_{R11}}{q_{R12}} > 0$, or that an increase in the non-Muslim population will increase the stock of knowledge. If in addition we assume that an increase in the non-Muslim knowledge stock lowers the resistance of the Muslim religious authorities to secular knowledge (again for competition) then $\frac{\partial A}{\partial A_c} = -\frac{q_{R11}}{q_{R13}} > 0$, and an increase in the non-Muslim knowledge stock increases the level of Muslim secular science.

The change in the tax rate (tolerance) over time is given by the expression

$$\dot{\tau} = \frac{\frac{\partial H}{\partial N}\xi_1 - \frac{\partial^2 H}{\partial \tau \partial N}\xi}{q_{11} + \lambda\xi_{11}} \quad (7)$$

and the tax rate will increase if $\frac{\partial H}{\partial N}\xi_1 > \frac{\partial^2 H}{\partial \tau \partial N}\xi$.

To better understand the $\frac{\partial H}{\partial N}\xi_1$ term, recall that $\lambda' = -\frac{\partial H}{\partial N}$ on the optimal path. As the ruler increases the tax rate, he accelerates conversion to Islam. For this discussion assume that $\lambda' > 0$, where λ' is the rate of change in the leader’s marginal valuation of the non-Muslim population stock (N) at time t . Since the non-Muslim population is becoming more valuable, a faster conversion rate decreases the leader’s income. The leader will want to slow conversion and decrease the tax rate τ . Thus, the first factor in (7) pulls the leader to decrease taxes if $\frac{\partial H}{\partial N} < 0$ since $\lambda' > 0$.

To better understand the second term $(\frac{\partial^2 H}{\partial \tau \partial N}\xi)$ commute derivatives to obtain $\frac{\partial^2 H}{\partial \tau \partial N} = \frac{\partial}{\partial N}[\frac{\partial f}{\partial \tau} - \frac{\partial g}{\partial \tau}]$ (where f represents the “flow” revenue $(\tau N - q - q_R)$ and g the loss in “future” revenue $\lambda\xi$). As the population declines, the first order condition for maximizing revenue $\frac{\partial f}{\partial \tau} = \frac{\partial g}{\partial \tau}$ becomes unbalanced. Assume for this discussion that $\frac{\partial^2 f}{\partial N \partial \tau} < \frac{\partial^2 g}{\partial N \partial \tau}$. Since our assumptions⁷⁰ imply $\frac{\partial g}{\partial \tau} > 0$, $\frac{\partial^2 g}{\partial N \partial \tau} > 0$ we know that as the non-Muslim population converts to Islam, $\frac{\partial g}{\partial \tau}$ is getting smaller. Unless $\frac{\partial f}{\partial \tau}$ is shrinking at a faster rate, this will imply that $\frac{\partial f}{\partial \tau} > \frac{\partial g}{\partial \tau}$ and an increase in tax rate will yield more revenue today than the losses such a rate

⁶⁹We assume that $q_{R13} \neq 0$.

⁷⁰Assume that $\xi_{12} > 0$.

increase produces in the future. This will cause the leader to move to increase tax rates. This is reflected in the second term of (7) since $\frac{\partial^2 f}{\partial N \partial \tau} < \frac{\partial^2 g}{\partial N \partial \tau}$ implies $\frac{\partial^2 H}{\partial \tau \partial N} < 0$ which will, in and of itself, cause the leader to increase taxes.

For the purposes of the paper, we are interested in observing the leader's behavior around the point when non-Muslims cease to pose a numerical "threat." Points at which non-Muslims are rapidly losing their cohesion and ability to impose a "threat" correspond to points where $q_2, q_{R2}, \xi_2, q_{12}$ and ξ_{12} are "large."

As the non-Muslim population ceases to be a threat the Muslim ruler is pulled in two directions.

First: the leader wants to slow conversion (and drop the tax rate) since the "spread" $(\tau N - q - q_R)$ is increasing ($\frac{\partial H}{\partial N} = \tau - q_2 - q_{R2} - \lambda \xi_2 < 0$) and the leader gets more from the non-Muslim population ($\lambda' > 0$).

Second: the costs from increasing the tax rate on the non-Muslim population are rapidly decreasing ($\frac{\partial^2 H}{\partial \tau \partial N} = 1 - q_{12} - \lambda \xi_{12} < 0$) which will push the leader to increase the tax rate. Intuitively, this is because if he leaves the tax rate constant $\frac{\partial f}{\partial \tau}$ will be greater than $\frac{\partial g}{\partial \tau}$ and the "flow" gain of raising tax rates today will be larger than "future" losses and he can increase income by raising taxes.

Whether the leader raises the tax rate (becomes less tolerant) depends on the magnitude of these two effects. If the losses from increasing the tax rate ($\frac{\partial H}{\partial N} \xi_1$) are greater (in absolute value) than the benefits ($\frac{\partial^2 H}{\partial \tau \partial N} \xi$) the leader will decrease taxes (become more tolerant). If the gains dominate, he will raise taxes.

If the gains dominate the losses and $q_{21} \approx q_{R21}$ (large decreases in the ability of non-Muslims to rebel correspond with large increases in the religious authority's dislike of rational methods) then we can conclude that large decreases in scientific output should correspond with decreases in the tolerance shown towards the non-Muslim populations.

In sum, the model generates two main predictions. First: the leader will support the production of the sciences only inasmuch as the religious authorities do not oppose these

activities. Large drops in scientific activity should be concentrated around points when non-Muslim populations cease to pose a “threat.” Second: under a few plausible assumptions the model predicts that large decreases in scientific output by the Muslim population should be accompanied by decreases in tolerance ($\dot{\tau} > 0$) towards the non-Muslim population.

4 The Evidence

4.1 Qualitative Evidence

The model predicts that scientific output should decline as the non-Muslim populations convert to Islam. This drop should be most pronounced around the level of non-Muslim population when these populations cease to pose a threat to the Muslim community (large q_{R21}). At this point, we would expect to see the religious authorities pressure the political authorities to eliminate the study of the sciences (prediction 1). If at this point q_{21} is also large the drop in science should be accompanied by a decrease in tolerance towards the non-Muslim population (prediction 2).

An ideal test would examine the attitudes of the religious elites towards the rational sciences before and after non-Muslims ceased to pose a threat. Although it is impossible to measure the exact date at which this occurred, it is possible to concentrate on the general period when Muslims emerged as the dominant majority in a given region.

4.1.1 The Emergence of Orthodoxy, Intolerance and the Decline of Science

Muslims became the majority at different times across the Islamic world. In Iraq and Iran, scholars estimate that this occurred between the eleventh and twelfth centuries. According to Lapidus, “by the eleventh century, as far as we can tell from exceedingly fragmentary evidence, Islam was no longer the faith of a dominant minority, but was the majority faith of Iraq and Iran”.⁷¹ Bulliet (1979, pp. 82-83) confirms this timing, estimating that the

⁷¹Lapidus (2002), p. 143.

conversion process in Iraq was largely complete by the start of the twelfth century.

The hypothesis predicts that during this period, individual Muslim religious elites should begin to systematically oppose the study of logic and the rational sciences. If religious authorities from individual sects were united in this opposition, they would have incentives to combine forces to better oppose the widespread use of logical methods.

Decline in the Constraints: Fall in Competition and the Emergence of Orthodoxy

Sunni Islam itself rapidly moved, from the twelfth century on, towards theological uniformity (Bulliet 1994, p. 153). During this period religious authorities began to systematically discourage both questions from individual Muslims and the exercise of independent judgement in legal matters.⁷² These authorities encouraged, in place of debate and reasoning, a reliance on tradition and “approved” knowledge.⁷³

Marshall Hodgson, a prominent historian of Islam, links this emergence of religious orthodoxy to the emergence of Islam as the dominant religion. In his view “in a population turned predominantly Muslim [...] the temptation to try to enforce conformity in opinions became strong.”⁷⁴

Our framework explains why the “temptation” to achieve conformity became large once Islam emerged as a majority faith. After Islam emerged as the dominant majority, Muslim religious elites could choose to agree or continue to bicker amongst themselves. If they continued to debate amongst themselves, they would incur costs (such as continued doubts and challenges to their authority).⁷⁵ Unless the loss from agreeing to agree was larger

⁷²While there are a host of sources that demonstrate this trend, al-Ghazālī’s “*Iljām al-‘Awām*” (Bridling of the Common Man) embodies this spirit well. He suggests that the common man “not ask its meaning (of religious doctrines) and not delve into these matters and he should know that his questioning is apostasy” (al-Ghazālī (1111), p. 54).

⁷³Al-Ghazālī states that “it is necessary to discourage mankind from reading their (the philosophers’) books since these are filled with danger and deception [for one’s religious belief] [...] mankind [must] be kept from reading these books” (al-Ghazālī (1100), p. 31).

⁷⁴Hodgson (1974), p. 192.

⁷⁵It should be noted, however, that intra-Islamic debates seem to have been considerably less “philosophical” than inter-faith debates. Intra-Islamic debates were based on “premises [...] [such as agreed on Islamic beliefs], or the consensus of the community [of Muslims], or acceptance of the *Qur’ān* and traditions [of the Prophet]” al-Ghazālī (1100), p. 14.

than that of continuing to bicker, these elites would move toward a “loose” theological uniformity.⁷⁶ By 1300 Sunni Islam had coalesced around an “orthodoxy” that appears to have generally agreed to oppose the open study of the rational sciences.⁷⁷

Decline of Science (prediction 1) As the religious elites coalesced around a religious “orthodoxy,” we observe a rapid decline in the study of logic and the rational sciences. ‘*Ilm al-Kalām*’ (a logically intensive branch of Muslim theology) fell into disfavor and religious authorities began to pressure political leaders to establish *madrasas* or religiously based centers of learning during this period. According to George Makdisi, a prominent scholar of Muslim institutions of learning, the religious authorities created these madrasas to “achieve strength [...] against the forces of rationalism” (Makdisi 1981, p. 52). Since madrasas were run by the religious elites and governed by Muslim law, these elites completely controlled the curriculum. Consequently, the madrasas

excluded any and all things that were considered to be inimical to the tenets of Islam. Hence the exclusion of the [rational sciences] from the curriculum [since] [p]hilosophical doctrines clashed with [...] monotheistic doctrines”⁷⁸

Institutions where the rational sciences were studied began a rapid decline in this period. By the 12th century these had become extinct.⁷⁹

In addition to eliminating the institutions in which the rational sciences were studied, religious elites began to pressure individuals who continued to study the sciences.

The Muslim historian al-Qiftī provides detailed accounts of changing attitudes toward those who studied the sciences in the Baghdad suburb of Karkh in his *Ta’rīkh al-Hukamā’* (1248). His commentary, beginning in 1080 and concluding in 1193, reveals a distinct change

⁷⁶This prediction is supported across the Muslim world and particularly in Iran. Bulliet (1994 p. 110) notes that intra-Islamic religious debates became less dramatic “in the twelfth century as part of a broader recentring and homogenization of Islamic thought.”

⁷⁷Makdisi (1981), p. 2. Shi’a Islam did not emerge as a mass movement until a later period.

⁷⁸Makdisi (1981), p. 78

⁷⁹Makdisi (1981), p. 10.

in the attitudes of the religious elites towards the use of logic. The timing of the change roughly coincides with the emergence of Islam as a clear majority.⁸⁰

Qiftī begins by relating that sometime around 1080: “Yahyā bin ‘Isā bin Jazla, [...] a Christian doctor in Baghdad, studied medicine under his contemporary Christians in Karkh. Desirous to study logic, but not finding any renowned Christian logician in his community, he studied under [...] Ibn al-Walīd who was an expert in ‘*ilm al-kalām* and logical terms. Ibn al-Walīd persisted in inviting him to become Muslim by using clear evidence and proofs until he responded and became Muslim” (Qiftī 1248, p. 239).

In 1080 Yahya bin Isa bin Jazla turned to a Muslim scholar for instruction since there were no “renowned” Christian logicians. The Muslim scholar was so convincing in his use of logic that the Christian doctor himself converted to Islam under his tutelage.

By 1174, however, the atmosphere had changed. Qiftī reported that the Muslim student ‘Alī bin ‘Alī, “learned the science of the ancients [including philosophy and logic] from a group of Christians and Jews of Karkh. After he made his knowledge public, the *fuqahā*’ [religious scholars] shunned him, avoided him and questioned his belief [i.e. religious orthodoxy], after this he left Iraq” (Qiftī 1248, p. 161). Unlike the Christian doctor in 1080, ‘Alī bin ‘Alī had to study with Christians and Jews, and when he did, Muslim religious elites shunned him. As Islam emerged as the dominant majority during the start of the twelfth century, religious elites who resisted the study of the rational sciences seem to have gained power.

As these religious elites gained influence, they began to take extreme measures to prevent the study of the rational sciences. In 1193, Qiftī (citing al-Ḥakīm Yūsuf al-Sabtī al-Isrā’īlī) relates that al-Isrā’īlī was present “in Baghdad that day [of the burning of books] on business [...] and heard the words of Ibn al-Māristāniya and saw in his hand *Kitāb al-Hay’a* by Ibn Haytham and he [Ibn al-Māristāniya] was pointing to a circle in which the author represented the universe, and he [...] ripped it up and threw it in the fire” (Qiftī 1248, p. 154). By 1193 a powerful anti-scientific religious orthodoxy seems to have emerged. This orthodoxy

⁸⁰ Empirical analysis in the subsequent section suggests that the decline in scientific production may have started before 1080.

burned books, persecuted those who studied the sciences and closed the institutions where these had been studied.

The pattern of Islam emerging as the dominant religion and a decline in the study of the rational sciences was not confined to Iraq. Writing in fourteenth century North Africa, Ibn Khaldūn reflected on the reason logic was no longer a necessary topic of study across the Muslim world. He stated that, “*ilm al-kalām* is not necessary [...] since **apostasy and heresy have become extinct**, and the religious leaders [...] have **written and recorded more than sufficient** for our needs [...] **mental proofs were needed only when they defended and supported** [their beliefs]” (Ibn Khaldūn 1377, p. 214 emphasis added). According to Ibn Khaldūn, once “apostasy and heresy” had been eliminated and the majority of the population converted to Islam, there was no reason for the study of logic.⁸¹

While many Muslim religious authorities might have liked to repress the study of subjects based on reason from the start, large and relatively well-educated non-Muslim populations under their control prevented this repression. As the non-Muslim population decreased, however, so did the tolerance constraints (towards the rational sciences) on Muslim religious elites.⁸² While isolated individuals continued to study these sciences, the widespread study of the sciences ceased.⁸³

Increase in Intolerance (prediction 2) The decrease in religious competition, the emergence of orthodoxy and the decline in scientific activity corresponded with a decrease in the tolerance of the non-Muslim population. During this period, there “was a general hardening against *dhimīs* (non-Muslims) in Muslim countries, helped materially and morally by the change in numerical proportions”.⁸⁴

⁸¹Such examples are not isolated. See Makdisi (1981) pp. 136-137, 257.

⁸²While a detailed investigation of the effects of Muslim expansion (and concomitant large non-Muslim populations) is beyond the scope of this paper, there is some evidence that the theory holds in both India and Asia minor following the Muslim conquest. See Hodgson (1974 (2)) pp. 72-73, 111 and Gutas (1998) pp. 173-174.

⁸³There were a few important discoveries made in later periods. These were accomplished, however, almost universally by the religious authorities (Saliba (2007)) and the results were not widely disseminated.

⁸⁴Cahen, Cl. “Dhimma.” Encyclopaedia of Islam http://www.brillonline.nl/subscriber/entry?entry=islam_SIM-1823

Despite this increase in intolerance, Muslim political and religious authorities almost never resorted to forced conversions and expulsions.⁸⁵ Tolerance –originally a function of numerical realities– seems to have become sufficiently institutionalized in Muslim law so as to prevent the most extreme forms of persecution and intolerance.

4.2 Quantitative Evidence

4.2.1 Measuring Scientific Achievement

The Data The data we use to measure scientific output come from Ibn Abī Uṣaybi‘a’s biographical catalogue: *‘Uyūn al-Anbā’ fī Ṭabaqāt al-Aṭibbā’* (Sources of News on the Generations of Physicians). Ibn Abī Uṣaybi‘a was a physician and bibliographer born in Damascus after 1194. He studied medicine and after completing his studies practiced in Damascus and Cairo. He died in 1270.

Ibn Abī Uṣaybi‘a’s catalogue, completed in 1268, is his most important work. It is “a collection of 380 biographies which are of inestimable value for the history of Arabic science.”⁸⁶ His catalogue is part of the medieval *Ṭabaqāt* genre which sought to document all individuals who had devoted themselves to a given field of study. The catalogue’s focus on physicians is especially informative since most students of the rational sciences either wrote at least one work on medicine or earned their living by practicing medicine.⁸⁷

Ibn Abī Uṣaybi‘a borrowed from the work of previous *Ṭabaqāt* writers, adding authors that had lived between the completion of the previous works and his own. The catalog can be viewed as a compilation of catalogs from different periods and locations.⁸⁸

Ibn Abī Uṣaybi‘a divided his book into 14 sections, by region and period. Within a given section Ibn Abī Uṣaybi‘a provides the author’s date and place of birth, the titles of

⁸⁵Except for a few violent exceptions as previously noted.

⁸⁶Vernet, J. “Ibn Abī Uṣaybi‘a.” *Encyclopaedia of Islam*.
http://www.brillonline.nl/subscriber/entry?entry=islam_SIM-3058

⁸⁷Huff (1993), p. 171.

⁸⁸We need to assume that each catalog attempted to document every book a given author wrote. There is no evidence to suggest otherwise.

his writings, his religious affiliation, his death date and a biographical sketch.⁸⁹ We focus on the sections detailing scientists who wrote after or around the emergence of Islam. These biographies form the lion’s share of the book.

I divided the books by discipline based on their titles concentrating on the scientific disciplines outlined in Ibn al-Nadīm’s (d. 995) *fihrist*. I then divided intellectual production into two broad categories: intellectual production that posed a threat to the religious authorities (philosophy, astronomy-mathematics⁹⁰ and other sciences⁹¹) and those that did not (primarily books written on religious subjects and medicine).⁹²

The most productive authors in the catalog include the most famous Muslim scientists such as al-Rāzī (Rhazes), Ibn al-Haytham (Alhazen, Avennathan and Avenetan), Abū Naṣr al-Fārābī (Alfarabius and Avennasar), Ibn Sīnā (Avicenna) and Ibn Rushd (Averroes).⁹³

Summary statistics of variables of interest are in table 1. The first group of variables details the “region” in which each author was born. While the first 5 regions clearly correspond to geographic areas, the last 2 correspond to a time period (*Early*) and ethnic group (*Syriac*). The following group of variables shows that of the reported authors, over 25% were either Christian or Jewish.⁹⁴ The remaining statistics measure the productivity of authors, the era in which they lived and the level of political support they received.

⁸⁹ Although some birth dates and death dates are missing, Ibn Abī Uṣaybi’a organizes the authors in each section by the era in which they lived, from earliest to latest. This allows us to impute the birth dates (when not given) with a reasonable degree of accuracy. If either the birth date or death date is missing I add or subtract the average life span in the data set (70 *hiḡrī* years or approximately 68 solar years).

⁹⁰ Al-Ghazālī (1100, pp. 21-22) states of the mathematical sciences “he who studies these sciences admires their precision [...] leading to an admiring for philosophy [...] and to apostasy and rejection of religion.”

⁹¹ See footnote [45] for a characteristic statement linking the study of any science based on logical methods with apostasy.

⁹² Medicine was seen in a favorable light since there was a clear benefit to the study of medicine and the study of medicine is mentioned in the Qur’ān. Al-Ghazālī (1100, p. 25) considered that “religion does not reject the study of medicine.” This does not mean that the method of study of medicine did not change as religious orthodoxy emerged (centers of study of medicine were also incorporated under the religious authorities see Makdisi (1981), p. 38).

⁹³ To investigate the extent to which the total number of books written corresponds with the quality of intellectual production, I looked up every author in the encyclopedia of Islam and created a dummy variable (ENCY) equal to 1 if that author has an encyclopedia entry. The two measures (total number of books and ENCY) are highly correlated and seem to do a good job of measuring the general quality of intellectual production.

⁹⁴ Although a detailed discussion of the relative productivity of Muslim and non-Muslim scientists is not possible here, Muslim scientists seem to have been both more productive and creative.

Map 1 presents the geographical distribution of the birthplaces of scientists in the catalog.⁹⁵ For clarity I have grouped the scientists into 2 chronological bins: those born before and after Islam emerged as the dominant majority in each region. The geographic distribution of scientists shows that Islamic intellectual production was concentrated in the regions Iraq and Ajam, and records the decline in scientific output after Islam emerged as the dominant majority.

Figure 1 shows the evolution of intellectual output by time since conquest (grouped into 25 year bins) and by region. The upper right hand corner details the average time elapsed between time since conquest and the emergence of Islam as the dominant majority (where an estimate of this date is provided by Bulliet (1979)). The fall in the production of the rational sciences is striking, while disciplines that did not pose a threat do not show a clear downward trend.

4.2.2 Empirical Strategy

Using the Data to Test the Hypothesis In the ideal world, the data would provide a random sample of authors who wrote on the rational sciences. Instead, we have a measure of the composition and intensity of the intellectual production of physicians. If every author who wrote on the rational sciences also was a physician, then physicians are the population of interest. While this correspondence is not one to one, there is evidence that most scientists wrote on or practiced medicine.⁹⁶

This fact allows us to use variation in the intellectual production of physicians to make statements regarding the overall evolution of science over the period covered by the catalog. The assumption we are making is that over the entire period, if an author was a student of the rational sciences he also practiced medicine.

As Islam emerged as the dominant majority, we would expect physicians to cease to

⁹⁵ Authors in a given region lacking a birthplace are assigned to the region’s “capital.” The few entries in what is today Saudi Arabia were coded as before Islam became the majority since these occurred soon after the conquest.

⁹⁶See footnote [87].

produce works on the rational sciences (since the costs of producing these had significantly increased). Under the previous assumptions, if we observe physicians writing less on the rational sciences we can conclude that scientific activity declined.⁹⁷

Testing Prediction 1 Prediction 1 states that production of the rational sciences should decline over time and that this drop should be most pronounced around the level of the non-Muslim population when these populations ceased to pose a threat to the Muslim community.

In the ideal world, we would have a yearly panel on scientific production at the author level. In addition, we would observe when Islam became a large enough numerical presence that the religious authorities began to oppose rational inquiry. Equipped with this data, we would run the regression:

$$rational_{ijt} = \gamma_i + \beta opposition_{jt} + \varepsilon_{ijt}$$

where i would index author, j “region” and t year. The coefficient β would measure the average effect of an increase in the opposition of the religious authorities on the production of the rational sciences. We could also include time dummies to control for yearly or “dynasty” effects to productivity.

Unfortunately, these data do not exist. We do possess, however, data on the productivity of a given author over his lifetime. We possess one observation for each author i born in region j at time t. Let $rational_{ij}$ denote the number of books written on the rational sciences over the lifetime of a given author.

The weighted mean comparison β in the regression

$$rational_{ij} = \gamma_j + \beta opposition_{ij} + \varepsilon_{ij}$$

compares the change in intellectual production before and after the religious authorities

⁹⁷Unless we believe that reporting systematically changed over the period covered by the data, see section 4.3 for a discussion.

began to oppose the production of the rational sciences. Instead of comparing intellectual production within a given author, we compare this production within a given region.

The identifying assumption is that within a given region authors born before and after Islam emerged as a majority were on average identical and were subject to identical forces except those changes brought on by the increased resistance of the religious authorities to the study of the rational sciences. This assumption will be increasingly plausible as we restrict comparisons to a smaller time frame within region.

We again do not observe the date when Muslim religious authorities began to oppose the production of science in a given region. Instead we have an estimate of when Islam emerged as the dominant majority.⁹⁸ Let the binary variable $majority_{ij}$ denote whether a given author was born after the estimated date that Islam emerged as the dominant majority. Then consider the coefficient β in the regression

$$rational_{ij} = \gamma_j + \beta majority_{ij} + \xi_{ij} \quad (8)$$

where $\xi_{ij} = \beta(opposition_{ij} - majority_{ij}) + \varepsilon_{ij}$. Given that majority is a dummy variable measured with error, β is biased. It can be shown that

$$\hat{\beta} \xrightarrow{p} \beta(E[opposition|majority = 1] - E[opposition|majority = 0]) \in [-\beta, \beta]$$

Unless the misclassification induced by mismeasurement of the date the religious authorities began to oppose the sciences is such that over half the observations are spuriously attributed to the wrong group then $\hat{\beta}$ will have the same sign as β and will suffer from attenuation bias.

The results of (8) are reported in table 2⁹⁹ and show that, consistent with the hypothesis,

⁹⁸These data are provided in Bulliet (1979).

⁹⁹We have dropped the “regions” Maghrib, Syriac and Early from the analysis since the Maghrib was very different from the other regions (it had a Latin heritage) and we do not have estimates for the date Islam emerged as the dominant majority for the regions Syriac and Early. The results are qualitatively similar if we include the Maghrib.

the average author wrote fewer books on the rational sciences after Islam emerged as the dominant majority. The historical evidence suggests that this was due to the fact that authors born after this date faced primarily two factors that discouraged the study of these sciences. First, it was harder to find a location to study these sciences. Second, the costs from openly writing on the rational sciences had substantially increased.

Column (2) shows that when we compare within regions the average author wrote approximately 9 books less on the rational sciences after Islam emerged as the dominant majority.¹⁰⁰ Column (4) compares the mean number of books written on the rational sciences before and after Islam emerged as the majority “within-dynasty.”¹⁰¹ Although the point estimate drops, the fall in intellectual production remains statistically significant (at the 10% level). Column (5) compares “before and after” within 25 year bins (starting at time since conquest by Muslim forces=0). The large standard errors show that the data are not fine enough to make informative comparisons at this level of detail, although the point estimate is still negative.

Column (6) reports the within-region comparison for books written on subjects the religious authorities did not consider to be a threat. The point estimate is not statistically different from 0 (but is statistically different from the coefficient reported in columns (2) and (3)). Columns (7) and (8) fit a negative-binomial specification.¹⁰²

As an additional test, table 3 analyzes the data aggregating variables within 25 year bins (where time is again measured by time since conquest by Muslim forces) by region (creating a “panel” of intellectual production). In addition to the problem of deciding how finely to aggregate the data, there is the problem of deciding what to do with the time-region bins that do not have data.¹⁰³ We can either assume that the variables of interest are missing in

¹⁰⁰Standard errors are clustered at the region-time level (where time is divided into 25 year bins) to allow for arbitrary correlation of intellectual production with region and time bin (there are 62 clusters).

¹⁰¹The “dynasty” variables for Iraq, for example, are 4 dummies set to 1 if the author was born in one of the following periods. If the author was born between 39-135 (*hijri*) the Ummayyad dummy is set to one, from 135-328 Iraq Abbasid dummy is equal to one, from 328-441 the Buyid dummy is set to one and from 441- the Seljuq dummy is set equal to one.

¹⁰²In general, the results are stronger if modeled using an exponential mean.

¹⁰³I omitted the Maghrib (for previously discussed reasons) and the Arabian peninsula (due to the small number of scientists). The results do not substantially change if these regions are included.

these bins (raising concerns associated with an unbalanced panel¹⁰⁴) or we can assume that variables of interest are 0 in these bins.¹⁰⁵

The aggregated results are presented in table 3 where the variables of interest are regressed on time (where time is measured in 0.25 century intervals since conquest by Muslim forces) and region dummies. Columns (1) and (2) show that the number of authors and the number of books written on subjects not viewed as dangerous by the religious elites do not show downward trends. The number of books written on the rational sciences, however, show a statistically significant downward trend.¹⁰⁶ The point estimate suggests that a century increase in time since conquest by Muslim forces is associated with a decrease of 5-7 books (roughly 1/8 of a standard deviation¹⁰⁷) written on the rational sciences. If the only changes over time that systematically affect intellectual production are driven by the conversion process to Islam, then the downward trend identifies the effect of the decrease in the Muslim population on secular intellectual production.

In sum, while the 800 year old data limit the extent of statistical analysis, the trends are consistent with the hypothesis. The production of the rational sciences decreased over the period. This drop roughly coincides with the date Islam emerged as the dominant majority. Writings on sciences that did not present a danger to the religious authorities did not decrease.

4.3 Confounding Factors

This paper has claimed that rapid conquest by Muslim forces led to tolerance which in turn led to religious competition and scientific development. The empirical test of this hypothesis has relied on the assumption that the emergence of Islam as the dominant majority

¹⁰⁴Consistency requires $E(\varepsilon_{it}|\mathbf{x}_i, \mathbf{s}_i, c_i) = 0, \forall t$. Where i indexes region, $\mathbf{x}_i$ is a vector of controls, $\mathbf{s}_i$ is the region “selection” vector (0 if observed, 1 else) and c_i is the region specific effect.

¹⁰⁵There is also the problem of deciding when to start and end the panel. I decided to start at the first year after which data is available for some region without gaps (175 *hijrī* years after conquest) and end in the last year such data is available (625 *hijrī* years after conquest).

¹⁰⁶At the 5% level if we assume homoskedastic errors, and at the 10% level allowing for heteroskedasticity.

¹⁰⁷This standard deviation is, of course, measured at the aggregate level.

(or the passage of time) was not systematically related to other events driving intellectual production.

While the historical record and the empirical results are consistent with this hypothesis, the data have limitations. This section briefly addresses some concerns and alternative hypotheses:

4.3.1 Trends: Political Fragmentation and the Crusades

Although it is impossible to prove that time since conquest (or the emergence of Islam as the dominant majority) is not correlated with other societal wide trends, the period covered by our sample shows no monotonic trend in economic or political “decline.”¹⁰⁸ While there is a trend towards political fragmentation during our sample, work by Moykr (1990, p. 264) suggests this should have encouraged scientific progress.¹⁰⁹

The start of the Crusades (1095), is probably the biggest threat to the validity of the identifying assumption since the beginning of the Crusades roughly coincides with the emergence of Islam as the dominant majority in some regions.

The data allow us to investigate this hypothesis empirically. These results are presented in table 4. Column (1) shows a decline if we compare means before and after the Crusades within region (not surprising since the Crusades occurred only a century after Islam emerged as the dominant majority in some regions). Column (2) shows that if we restrict this comparison to “within dynasty” the decline disappears, suggesting that the decline in scientific production occurred before the start of the Crusades. Column (3) presents the difference-in-difference estimates where we assume that the Sham region (the Levant) was treated (since this was the region invaded by Crusaders) and the other regions are controls. Column (4) limits this difference-in-difference comparison to “within” dynasty. Column (5) calculates the difference-in-difference estimates within-dynasty where the “control” is the

¹⁰⁸Analysis of the probability a given author received support of the political authority does not show a systematic decrease over time.

¹⁰⁹The Mongol conquests occurred after the end of the sample, and thus are not driving the results.

Ajam region (Iran and East). The Levant region does not show a large drop, nor does Iraq. While intellectual production in Egypt seems to have fallen, results from the other regions casts doubt on the importance of the Crusades for this decline. Finally, column (6) confirms that the drop in scientific production largely preceded the start of the first Crusade.

In sum, the data provide little evidence that the Crusades are responsible for the decline of secular intellectual production.

4.3.2 Reverse Causality

It may be the case that unobserved factors that led to the development of science also led to the “rationalization” of religion and thus to religious debates. Changes in these unobserved factors led to the decline of science which, in turn, led to a drop in inter-religious debate.

This would be a plausible alternative explanation if it were consistent with the historical record. The sources consistently stress the importance of religious competition in encouraging the rationalization of religion.

4.3.3 Data Quality

The empirical results use data from an 800 year-old book catalog providing information on scientific production over a period of 600 years from present-day Spain to Khazakstan. It may be that any trends in the data are due to systematic differences in reporting across time and region.

It is difficult to make a convincing case that systematic differences in reporting are driving the results. First of all, the presence of region dummies will absorb any region invariant biases in reporting. Second, one would expect any reporting bias to increase the number of books written closer to the date Ibn Abī Uṣaybi‘a wrote his catalog. This would work to produce an upward, not downward trend.

In sum, Ibn Abī Uṣaybi‘a’s book catalog coincides with independent sources documenting intellectual production in the period and much of the information provided in the catalog

has been proven accurate. Although these data have limitations, they appear to provide a remarkably reliable record of intellectual production.

4.3.4 Outliers

Although the results presented do hinge on including the most productive authors, inference without these authors often leads to similar qualitative conclusions (depending on the cutoff point). Moreover, much scientific and technological progress historically was accomplished by a small minority (Mokyr (2005), p. 301). Just as it would be hard to imagine the Renaissance without Galileo or Da Vinci, the Muslim “Golden Age” without Ibn Sīnā or Ibn Haytham is incomplete. Indeed, there are plausible arguments for giving the most productive scientists more weight than the rest of the observations.

At very least, we can conclude that after the emergence of Islam as the dominant religion the Muslim world stopped producing “Galileos.” This conclusion is quite important, since it was the most productive Muslim scientists who made most of the lasting scientific contributions.

5 Conclusion

This paper has argued that tolerance, diversity and religious competition were central to the development of Muslim science in the Middle Ages. It suggests that a decline in the proportion of non-Muslims led religious authorities to discourage the study of the rational sciences.

There is evidence that Muslim scientific stagnation affected the development of technological progress in subsequent centuries. Ibn Khaldūn (1332-1406), in his *Muqadimma* (1377) noted that the development of “mechanical devices” had ceased by the 14th century. He attributed this decline in technological progress to the fact that the development of these devices required understanding geometric and mathematical proofs that were no

longer understood (Ibn Khaldūn 1377, II, p. 258).

Similarly, Muslim institutional stagnation appears to have coincided with the stagnation of Muslim science. Although the factors that led to this institutional stagnation remain a topic for future research, it is likely that the emergence of Muslim religious orthodoxy and the stagnation of “freethinking” played a role.

In addition to informing our understanding of Muslim economic stagnation, the analysis suggests that tolerance can help channel between-group interactions towards productive ends. Although differences in religious beliefs have sometimes led to tragedy, medieval Islam used these differences to produce one of history’s most scientifically advanced civilizations. Competition between faiths ensured that no single orthodoxy could emerge and created an atmosphere conducive to “freethinking” and scientific progress.

The results suggest that religious elites, if unconstrained, will resist innovation when they do not see such progress in their interest. This opposition to innovation by religious authorities was hardly unique to the Muslim world. Indeed, during the Renaissance and Enlightenment Christian religious elites resisted many scientific advances (see, for example, Israel (2006)).

Although the application of this theory to Renaissance and Enlightenment Europe remains a topic for future research, there is suggestive evidence that religious competition encouraged religious authorities to allow thinkers to address a wide range of topics that would have otherwise been considered taboo. If religious competition facilitated Europe’s scientific development, understanding how Europe avoided the fate of the Islamic world can help answer why the Enlightenment, modern science and sustained economic growth first emerged in Europe.

Finally, the experience of medieval Muslim science may contain lessons for the Muslim world today. A recent survey of science in the Muslim world by Pakistani scientist Pervez Amirali Hoodbhoy suggests that many parts of the Muslim world remain in the “non-competitive equilibrium” that emerged in the Middle Ages. Years of teaching in Muslim

regions have led Dr. Hoodbhoy to conclude that

“[s]cience can prosper among Muslims once again, but only with a willingness to accept certain basic philosophical and attitudinal changes [...] The struggle to usher in science will have to go side-by-side with a much wider campaign to **elbow out rigid orthodoxy** and bring in modern thought, arts, **philosophy**, democracy and pluralism.”¹¹⁰

Abū Naṣr al-Fārābī, one of Islam’s greatest medieval scientists, would have been stunned to read Dr. Hoodbhoy’s assessment. In Fārābī’s day Christianity was identified with backwardness, Islam with reason and enlightenment. When analyzing the decline of science in Christian lands he noted that:

“Christianity came [during the late Roman Empire] to eliminate philosophic enquiry [...] because the bishops viewed its study dangerous [...they] only allowed the study of subjects that did not conflict with Christianity [...] philosophic enquiry then remained restrained [...] until the advent of Islam.”¹¹¹

Evidence from Fārābī’s day –one of Islam’s greatest eras– shows how diversity of beliefs, and Islam’s tolerance of this diversity, helped constrain Islam’s most conservative elements for centuries. Contrary to those who use the scientific advances of medieval Islam as justification for a “return” to Islamic “orthodoxy” the evidence suggests the importance of tolerance and personal freedoms. In absence of a return to these *Qur’ānic* principles, Muslim science will likely remain the victim of its own success.

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¹¹⁰Hoodbhoy (2007), p. 55 emphasis added.

¹¹¹Ibn Abī Uṣaybi’a (1268), p. 558.

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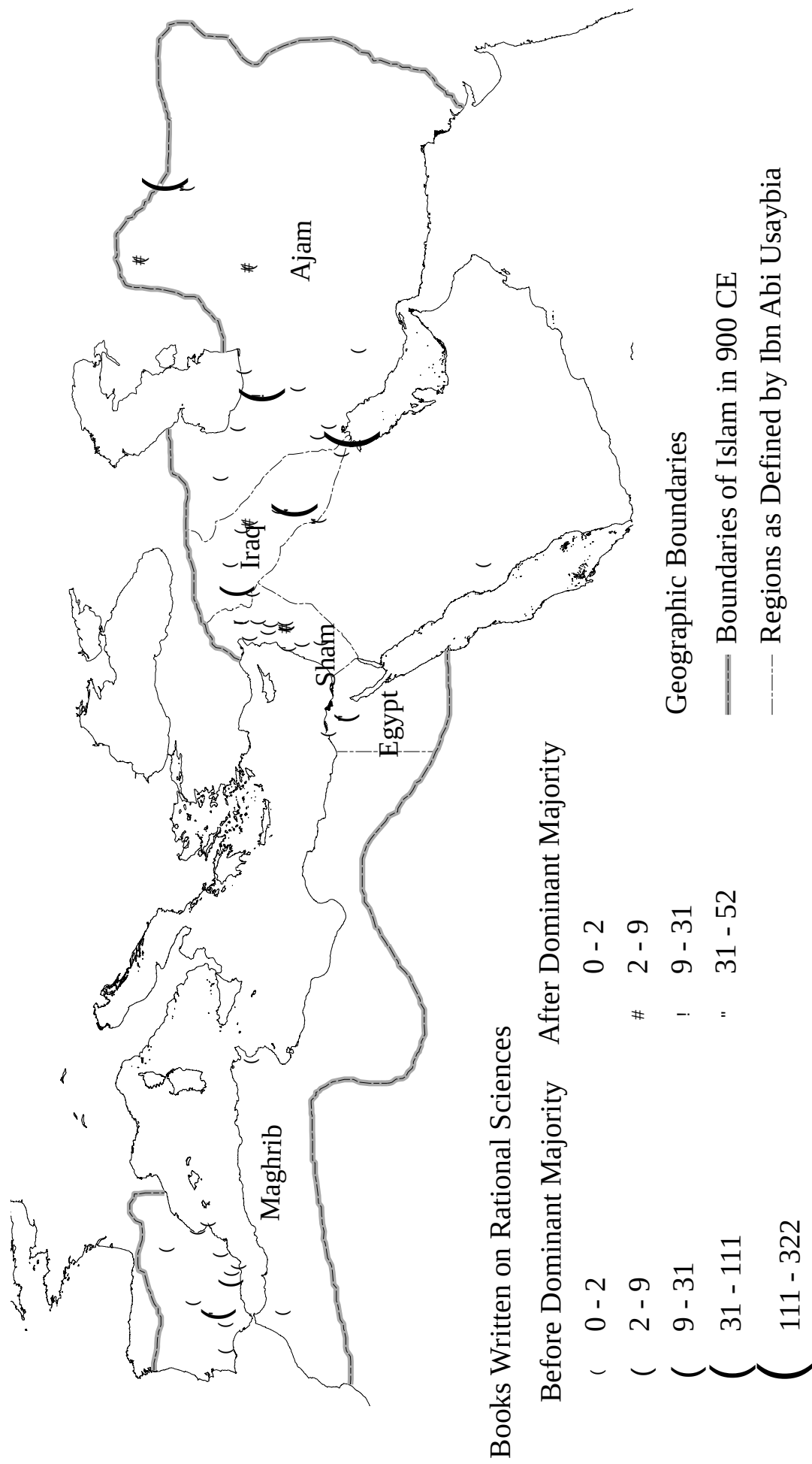
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Map 1: Geographic Location of Intellectual Production



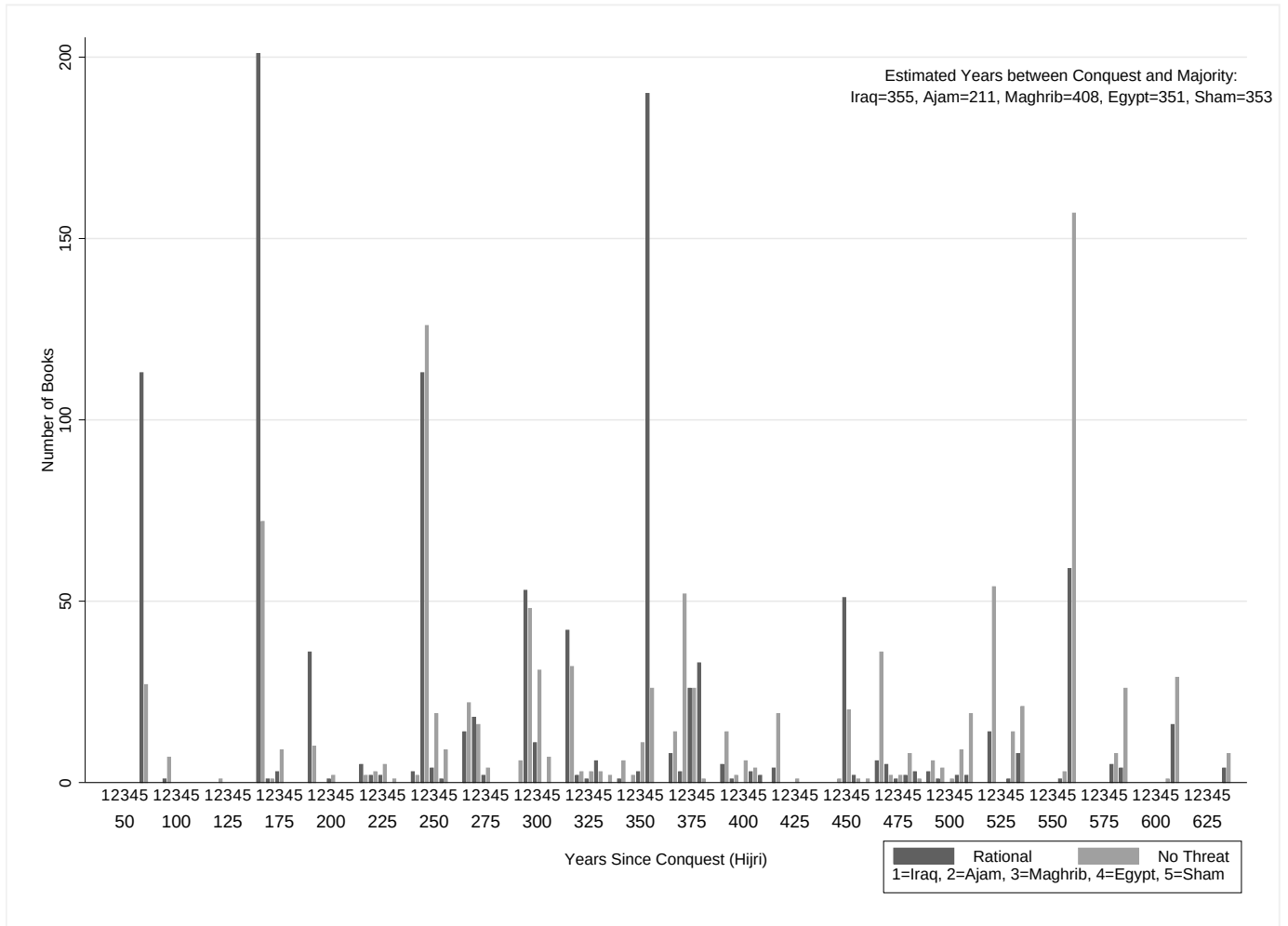


Figure 1: **Intellectual Development in the Lands Ruled by Islam**
By time since conquest by Muslim forces and region

Table 1: **Summary Statistics**

<i>Variable</i>	<i>Description</i>	<i>Mean</i>	<i>St.dev.</i>	<i>Min</i>	<i>Max</i>
		(1)	(2)	(3)	(4)
“Region”					
<i>Iraq</i>	Iraq	0.23	0.42	0	1
<i>Maghrib</i>	Spain or N. Africa	0.25	0.43	0	1
<i>Ajam</i>	Iran and East	0.07	0.25	0	1
<i>Egypt</i>	Egypt	0.16	0.37	0	1
<i>Sham</i>	Levant	0.17	0.37	0	1
<i>Early</i>	First Islamic Century	0.03	0.16	0	1
<i>Syriac</i>	Syriac	0.11	0.31	0	1
Religion					
	Jewish	0.09	0.29	0	1
	Christian	0.17	0.37	0	1
Productivity					
<i>Rational</i>	Rational Sciences	3.3	17.80	0	201
<i>NoThreat</i>	Religion and Med.	3.5	11.88	0	121
ENCY	Cited in Encyclopedia of Islam	0.15	0.36	0	1
Period (<i>Hijrī</i>)					
	0 = 622 C.E.				
Birth	Date of Birth	382.99	142.84	20	630
DateConquered	Date Place of Birth Conquered	41.34	34.25	6	225
Since	Birth - DateConquered	341.66	144.39	7	614
Majority	Born After Islam is Majority	0.52	0.50	0	1
Support					
Caliph	Political Patron	0.47	0.50	0	1

Notes: N=359

Table 2: **Scientific Production Before and After Majority**
Mean Comparison Before and After Muslim Majority

	<i>Rational</i> (1)	<i>Rational</i> (2)	<i>Rational</i> (3)	<i>Rational</i> (4)	<i>Rational</i> (5)	<i>NoThreat</i> (6)	<i>Rational</i> (7)	<i>Rational</i> (8)
<i>Majority</i>	-7.72 (3.06)	-9.30 (3.38)	-9.30 (4.76)	-5.40 (3.13)	-30.70 (34.09)	-2.04 (2.43)	-2.25 (0.52)	-2.14 (0.58)
<i>Region Dummies</i>	No	Yes	Yes	No	No	Yes	Yes	No
<i>Dynasty Dummies</i>	No	No	No	Yes	No	No	No	Yes
<i>Region * Year Dummies</i>	No	No	No	No	Yes	No	No	No
<i>Clustered SE's?</i>	No	No	Yes	Yes	Yes	Yes	Yes	Yes
<i>R²</i>	0.03	0.04	0.04	0.07	0.67	0.07	.	.

N=223

Standard errors are clustered at the region/year level where time is measured in 25 year intervals (62 clusters)

Columns (7) and (8) fit an exponential mean

NoThreat: number of books written on subjects that the religious authorities did not see as a threat

Rational: number of books written on the rational sciences

Majority: born after Islam became the dominant majority

Dynasty dummies vary at the region level

See text for additional details

Table 3: **Trends in Scientific Production**
 “Panel” created by aggregating variables in 25 year bins by region

	<i>DepVar</i>	<i>Authors</i>	<i>NoThreat</i>	<i>Rational</i>	<i>Rational</i>
		(1)	(2)	(3)	(4)
<i>Unbalanced</i>	<i>Time</i>	0.46	0.76	-7.37	-7.37
		(0.22)	(2.09)	(3.44)	(3.99)
	<i>N</i>	71	71	71	71
<i>Balanced</i>	<i>Time</i>	-0.10	-1.43	-4.92	-4.92
		(0.24)	(2.15)	(2.35)	(2.72)
	<i>N</i>	95	95	95	95
	<i>Robust SEs?</i>	Yes	Yes	No	Yes

Notes: Region dummies are included in all regressions
 Authors: number of authors
 NoThreat: number of books written on subjects that the religious authorities did not see as a threat
 Rational: number of books written on the rational sciences
 Unbalanced: assumes a given variable is missing if there are no entries in a given region-year bin.
 Balanced: assigns a value of zero to these bins.
 See text for additional details

Table 4: **The Crusades**
Mean Comparisons Before and After the Start of the First Crusade (1095 CE)

	<i>Rational</i>	<i>Rational</i>	<i>Rational</i>	<i>Rational</i>	<i>Rational</i>	<i>Rational</i>
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Crusades</i>	-6.76 (3.56)	-0.79 (1.34)	-5.70 (2.65)	-2.42 (1.72)	2.33 (1.49)	-0.79 (1.34)
<i>Majority</i>						-5.40 (3.13)
<i>Sham</i>			3.18 (10.24)			
<i>Sham * Crusades</i>			-1.89 (10.29)	4.19 (1.99)	-0.56 (1.80)	
<i>Iraq * Crusades</i>					-2.73 (1.55)	
<i>Egypt * Crusades</i>					-7.01 (3.24)	
<i>Region Dummies</i>	Yes	No	No	No	No	No
<i>Dynasty Dummies</i>	No	Yes	No	Yes	Yes	Yes
R^2	0.02	0.06	0.02	0.07	0.07	0.07

N=223

All standard errors are clustered at the region/year level where time is measured in 25 year intervals (62 clusters)
Rational: number of books written on the rational sciences
Majority: born after Islam became the dominant majority
Crusades: born after the start of the first Crusade
Sham: the Levant
Omitted region in column (5) is Ajam (Iran and East)
Dynasty dummies vary at the region level
See text for additional details