The Cost of Orthodoxy:
The Inquisition and the Decline of Science in Spain

Gary W. Cox*
Department of Political Science
Stanford University

Valentin Figueroa
Instituto de Ciencia Política
Pontificia Universidad Católica de Chile

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Abstract

A traditional argument that the Spanish Inquisition did *not* depress scientific research is that Spain experienced its Golden Age (1492-1657) after the Inquisition was formed (1478). Yet the arts, rather than the sciences, flourished; and we argue that the Inquisition had important chilling effects on the latter. After providing difference-in-differences evidence of Spain's relative decline in STEM fields, we provide the first systematic evidence on scholarly interactions among early modern Spanish book authors, documenting an immediate reduction in interactions after an abrupt increase in inquisitorial activity in 1559. We also document significant reversals in previously upward trends in university affiliation and entry into STEM occupations circa 1559. Our work helps explain the puzzling disjuncture between the glory of Spanish literary and visual arts during the Golden Age, on the one hand, and the poverty of its contributions to science, on the other.

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1 Introduction

A burgeoning recent literature explores the historical political economy of religion (e.g., Johnson and Koyama 2019; Møller and Doucette 2022; Grzymala-Busse 2023). Part of this literature considers the extent to which religious elites' enforcement of orthodoxy hindered progress in scientific and technological fields (Huff 2003; Mokyr 2017, ch. 16; Chaney 2023). Relatedly, recent formal models of competition between secular and religious elites seek to explain the differing equilibria — ranging from theocracy to secularism — observable in the modern world (Bénabou et al. 2022; Bisin et al. 2024).

In this paper, we study the Spanish Inquisition, a long-lasting program of religious censorship that enforced Catholic orthodoxy and coincided with the decline of Spanish science in the 16th century. Although historians of science agree on the fact of decline — "so complete was the collapse that it is difficult to find any [Spanish] contribution to the Scientific Revolution in the 17th century" (Goodman 1992, p. 171) — no consensus exists on the Inquisition's role. In particular, revisionist historians have recently argued that the Inquisition's targeting and punishment of scientists has been grossly exaggerated (Baldini and Spruit 2009); that it lacked the capacity to enforce its book bans (Kamen 2014); and that it likely had little effect, given that Spain's Golden Age (1492-1657) began after the Inquisition was founded (1478) and co-existed with it for over 150 years.

We reconsider the Inquisition's role in the decline of science in Spain.[1] We argue that the Inquisition's direct targeting of specific scholars, theories, and books was less important than the chilling effects that such efforts produced: inducing scholars to reduce their interactions with anyone the Inquisition might scrutinize; and prompting various forms of self-censorship. To study these difficult-to-observe behaviors, we exploit two large datasets that have only recently become available in machine-readable form for the early modern period: dictionaries of national biography; and comprehensive catalogs of published works. We briefly describe the data we use before each empirical test (providing fuller explanations in Table A1 in the Supplementary Appendix).

To leverage these data, our empirical investigation focuses on a sharp increase in inquisitorial

[1]Portugal was ruled by the Spanish monarch from 1580 to 1640; and we use the terms Spain and Iberia interchangeably here.

activity following the discovery of a circle of Protestants in Valladolid in 1559. This discovery led to a ban on travel to foreign universities; the publication of an expanded index of banned books; the announcement that possessing or reading these books was punishable by death; the burning at the stake of fourteen people in Valladolid; and an immense increase in inquisitorial activity (Drelichman et al. 2021).

To set the stage for our case study of Spain, we begin by studying how inquisitorial persecution affected scientific research in Europe more broadly. We use data from the Universal Short Title Catalogue (USTC) to explore the output of scientific books across eight regions of Europe. Taking a difference-in-differences approach, we show that increases in inquisitorial activity led to reductions in the output of books in STEM (science, technology, engineering and mathematics) fields.

We then explore the mechanisms that may have depressed STEM research in Spain. For this, we build a new panel database with annual information on the intellectual interactions, institutional affiliations, and publications of all Spanish authors listed in *Iberian Books* over the period 1472-1700. Restricting attention to the 411 authors with complete residential histories in the *Diccionario Biográfico Español*, we use interrupted time-series analyses to examine how their behavior changed after the policy shock of 1559. First we show that the share of Spanish authors who interacted closely with another scholar (via mentorships, collaborations, and intellectual circles), as well as the share attending foreign universities, declined abruptly after 1559. Then we document reversals in previously upward trends of university affiliation and entry into STEM occupations, also occurring in 1559.

Another, indirect measure of intellectual interaction is the extent to which scholars became more productive when co-residing in the same city. To investigate such "urban agglomeration" benefits, we rely on author-level panel data from Spain and England from 1500 to 1700. We show that Spanish scholars who moved into Madrid during the century 1550-1650 became substantially more productive. By 1650-1700, however, the Madrid premium had declined and was statistically insignificant. Analogous results for British authors moving to London, in contrast, show persistently positive and significant agglomeration effects.

We argue that the ups and downs of the Madrid premium reflected the expected value of scholarly interactions. Madrid in the century 1550-1650 experienced two opposite trends. First, Spanish elites flocked to Madrid after Philip II made it his capital in 1561, with the share of elites in the capital peaking around 1650. Second, as noted above, rates of interaction among scholarly elites declined after 1559. The expected number of interactions (number of potential interactors times rate of interaction) increased in the 16th and early 17th century but then began to decline during the half-century in which we detect a decline in the Madrid premium.

Our work relates closely to two streams of recent scholarship. To the literature on the political economy of religion (cited above) we contribute a case study of the dynamic interplay between science and religion during the Scientific Revolution. Our work looks at the details of how religious censorship operated, and the mechanisms through which it affected scientific research, thus complementing more abstract theories (Bénabou et al. 2022; Bisin et al. 2024) and broader characterizations of the aggregate result of imposed orthodoxy (Huff 2003; Mokyr 2017, ch. 16; Chaney 2023).

We also relate to a recent literature in historical political economy that focuses specifically on the effects of the Catholic Inquisition. This literature has thus far focused on how the Spanish and Roman Inquisitions affected (1) entry into, and pursuit of, scientific careers (Anderson 2015; Blasutto and De la Croix 2023; Dewitte et al. 2022; Cabello 2023); and (2) rates of publication of banned books (Becker et al. 2021; Comino et al. 2021). Our contribution is to assemble the data necessary to document, for the first time, how much the Inquisition affected scholars' rates of interaction and their choice of educational institutions. In addition, we provide new evidence on how the Inquisition affected scholars' scientific output. Our work helps to explain how Spain could have experienced a Golden Age despite the Inquisition; and why that Golden Age was restricted to the literary, performing and visual arts, leaving Spain largely out of the Scientific Revolution.

2 Inquisitions and their effects

As noted in the introduction, some scholars dismiss claims that the Inquisition substantially depressed creative output in Spain. In part, this is because early commentators often harbored anti-Catholic biases and grossly exaggerated the Inquisition's use of judicial torture and death penalties, as well as the extent to which it sought to suppress scientific research. Recent corrective scholarship points out that, although the Inquisition targeted a few specific ideas — most prominently heliocentrism, magic, and divination — it did not comment on, much less try to ban, most scientific theories, experiments and discussions (Baldini and Spruit 2009, Tome 1, pp. 85-90). Moreover, most scientists whom the Inquisition tried received relatively mild punishments (Baldini and Spruit 2009, Tome 1, pp. 69-71).

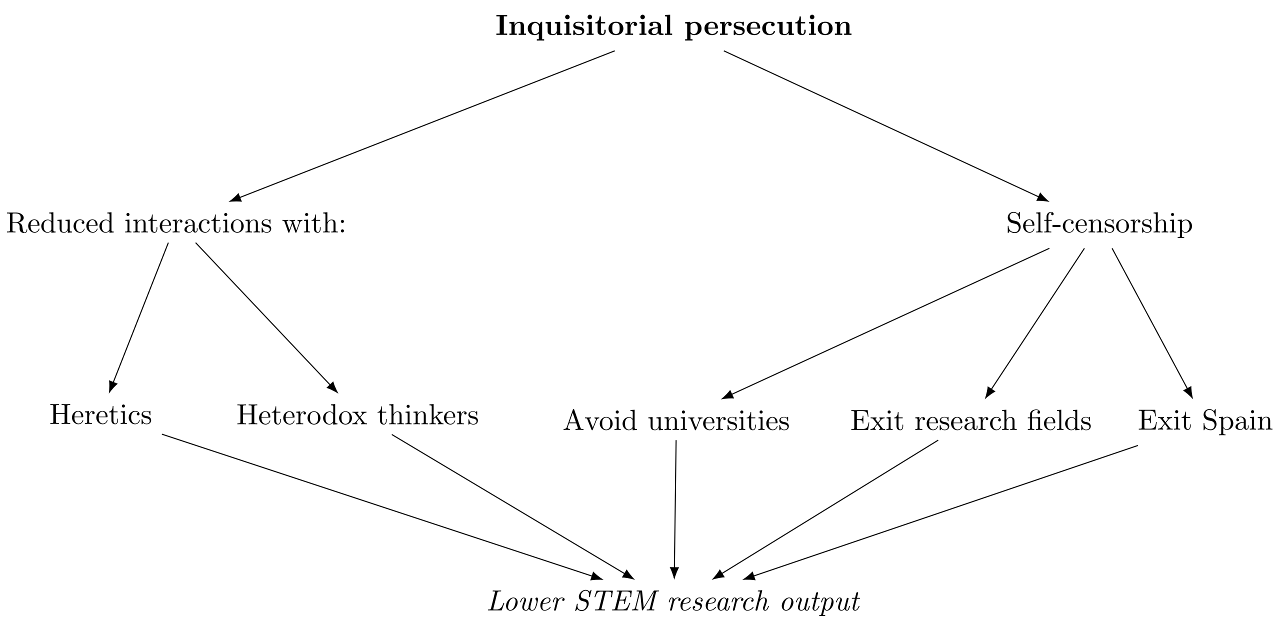
That said, Hassner (2020, pp. 473-474) reports that 12% of those whom the Inquisition prosecuted in Toledo (whether scholars or not) were tortured, with 30% receiving heavy sentences. Moreover, as Baldini and Spruit (2009, Tome 1, p. 88) put it, "Trials, prohibitions and preventive control. . . of books. . . possibly sowed terror, and surely created a widespread climate of intimidation..." Since the dividing lines between alchemy and chemistry, or between magic and natural philosophy, were not yet agreed upon, the various STEM-adjacent ideas that the Inquisition censured likely raised concerns among a wide range of STEM researchers.

Here, we focus on two chilling effects that the Inquisition plausibly had — scholars reducing their interactions with others and self-censoring their works in order to avoid inquisitorial attention. We study how these behaviors changed in the aftermath of an abrupt expansion of the level and scope of inquisitorial activity in 1559 (on which more below).

Scholarly withdrawal from interactions would have meant that scholars took on fewer students; engaged in fewer collaborative projects; formed fewer intellectual circles and learned societies; and were less willing to discuss some of their ideas. Scholars would have had the strongest incentives to reduce their interactions with anyone who might be suspected of heresy (including Protestants, *moriscos*, and *conversos*) or heterodox beliefs (e.g., astronomers familiar with heliocentrism). Incentives to reduce interactions would have been intensified by the Inquisition's use of an army of lay spies to discover prosecutable offenses; and by its natural desire to target, among heretical and heterodox thinkers, those who were more central in the emerging network of European scholars (Ormerod and Roach 2004; Bergeman 2017).

Scholarly self-censoring was probably widespread; as one contemporary put it in 1559: "the times are such that one should think carefully before writing books" (Kamen 2014, p. 118). The types of self-censoring we are interested in are displayed in Figure 1 and include avoiding secular institutions of higher education (i.e., universities), exiting (or never entering) certain fields, and exiting Spain.

Figure 1: Diagrammatic representation of the Inquisition's chilling effects



How might these chilling effects have affected scholarship? A prominent model argues that innovation occurs mostly when people recombine existing ideas in novel ways (Weitzman 1998; Uzzi et al. 2013). Thus, the larger and more diverse the flow of ideas in a particular location is, the greater the volume of innovation in that location will be. The Inquisition, by *reducing* and *homogenizing* the flow of information, could have substantially reduced recombinant discoveries in certain fields. In particular, as suggested in Figure 1, we argue that the Inquisition had especially large effects on STEM research.

Our theoretical expectations are not novel; many have suggested that the Inquisition had one or more of the chilling effects depicted in Figure 1. Until recently, however, most contributors to the debate have relied on qualitative evidence and contextual characterizations of the Inquisition's motivations (e.g., Baldini and Spruit 2009; Kamen 2014).

Some progress in assembling systematic evidence on *self-censorship*, the right branch in Figure

1, has recently been made. Cabello (2023) studies elites across Europe, showing abrupt departures of Catholic elites from STEM fields whenever inquisitorial activity increased. Blasutto and de la Croix (2023) show that Italian university professors during the Inquisition became more likely to pursue research in "compliant" fields. Some progress has also been made in documenting the Inquisition's effectiveness in dissuading printers from trafficking in banned books (Becker et al. 2021; Comino et al. 2021).

No one has previously attempted to provide systematic evidence on *scholarly interactions*, the left branch in Figure 1. Such interactions are extremely hard to measure for any given case, let alone cross-nationally. We take a two-pronged approach here. First, we exploit scholars' biographies to code whether and when they engaged in three specific forms of intellectual interaction: close teacher-student or other mentorship relationships, collaborations on books or projects, and participation in intellectual circles and learned societies. Second, to complement this direct evidence on relatively intensive interactions, we indirectly assess a wider range of more mundane interactions by studying the agglomeration benefits that scholars derived from residing in Madrid.

3 The policy shock of 1559 in Spain

A group of Protestants were discovered in Valladolid in 1559, leading to great alarm in church and royal circles and sharp shifts in inquisitorial and royal policy. Travel to all but a few foreign universities was banned; the death penalty was put on the table for possessing any book on a newly-published index of banned books; repentance would no longer suffice to escape death penalties (Edwards 2012, p. 47); and the estimated number of trials doubled over the period 1540-60, peaking at over 1,000 per annum circa 1559 (Drelichman et al. 2021, Supplementary Appendix, p. 2).[2]

Roughly coinciding with the policy shift in 1559, the range of the Inquisition's targets expanded. When founded in 1478, the Spanish Inquisition focused specifically on ending crypto-Judaism among the *converso* population. Over the first half century of its operation, 90% - 99% of its victims were

[2]The ban on travel to foreign universities originally applied to the Crown of Castile and was extended to the Crown of Aragon in 1568 (Kamen 2014, ch. 6).

conversos. The Inquisition expanded its mission thereafter, seeking to ensure that a set of dogmas and morals — formally articulated at the Council of Trent in 1545-1563 — were followed by all Spaniards (Bennassar 1987, p. 177).

In addition, the church increasingly adopted Thomas Aquinas' doctrine on the superiority of theological over philosophical reasoning:

> According to Aquinas, the higher level of certainty possessed by theology instantiated a hierarchy of disciplines. He [argued] that if a theologian and a philosopher reached differing conclusions, ...then this implied the falsity of the philosopher's arguments. Consequently, if any such disagreements should occur, then it was incumbent upon the philosopher to reconsider his arguments until he had reached a conclusion that was in accordance with that established in theology (Tarrant 2014, pp. 14-15).

Aquinas's doctrine was formally endorsed in 1516 by the Fifth Lateran Council's decree *Apostolici regiminis* (Tarrant 2014, p. 15). Moreover, those committed to *enforcing* the Aquinian hierarchy of knowledge gained control over the Inquisition in the mid-16th century; and the Council of Castile (an Inquisition ally) gained centralized control over book licensing in the period 1554-1558 (Tofiño-Quesada 2002; Kamen 2014, p. 120). At this point, STEM researchers should have recognized that any work viewed by church theologians as challenging their beliefs — a vaguely defined but potentially vast field — would attract inquisitorial attention.

The intensification of inquisitorial activity, the widening range of its targets, and its increasing influence over censorship would likely have deepened its chilling effects. While *conversos* would have been lying low even before the policy shock of 1559, Old Christians would have gained an additional incentive to avoid interacting with (known or suspected) *conversos*, lest they appear sympathetic to any heresies the latter might eventually be accused of. Since *conversos* were over-represented in several scientific fields (Goodman 1992, pp. 161-163; Navarro 2014, p. 29), the Inquisition's chilling of *converso*-Old Christian interactions would have particularly affected STEM fields.

4 The Inquisition and the decline of STEM research

In this section, we investigate the effect of the Inquisition on STEM output across eight European regions. Our results show a divergence in STEM output between Spain and places free from inquisitorial persecution occurring around the policy shock of 1559.

4.1 Europe: difference-in-differences study

We use the Universal Short Title Catalogue (USTC) to measure, for eight European regions, the proportion of books on STEM topics published in each decade from 1470 to 1700. The USTC has comprehensive bibliographic data for the British Isles, France, the Holy Roman Empire, the Italian states, the Northern Netherlands, the Southern Netherlands, Spain, and the Swiss Confederacy.[3] We classify as STEM those books that focused on medicine, science, mathematics, astrology and cosmography, and agriculture. Our balanced panel dataset has 184 observations (8 regions observed over 23 decades). For each region i in each decade d, we compute $\%\ \text{STEM}_{id}$, which equals the number of STEM books published, divided by the total number of books published.

To estimate the effect of the Inquisition on %STEM output, we take advantage of the fact that the intensity of inquisitorial persecution varied both across regions and over time within regions. Some regions, like the Holy Roman Empire, France, and the Swiss Confederacy, were never exposed to *high levels* of inquisitorial persecution; other cases had short spells of high inquisitorial persecution, like England under Mary I (1555-1558) or the Northern Netherlands (1523-1566); and others, like Italy (since the 1540s) and Spain (since the 1560s), experienced persistently high levels of inquisitorial persecution beginning in the middle of the sixteenth century.

In our baseline specification, we leverage this variation to estimate the following two-way fixed effects model:

$$\%\ \text{STEM}_{id} = \beta_1 \text{Inquisition}_{id} + \theta_i + \lambda_d + u_{id}$$

where Inquisition_{id} is an indicator that the Inquisition was active in region i in decade d; and θ_i and λ_d are region and decade fixed effects. We estimate the model with OLS and cluster standard errors

[3] We exclude regions in which book production was substantially lower than in the cases we include: Hungary, Poland, Portugal, and Scandinavia.

by region. To account for the small number of clusters — which might lead us to underestimate standard errors — we also present p-values calculated using a wild cluster bootstrap procedure (Cameron et al. 2008).

As different units in our panel become exposed to inquisitorial persecution in different periods (e.g., Italy in the 1540s and Spain in the 1560s), and because this variable also features reversals (e.g., persecution stops in the Northern Netherlands after 1566), we also estimate the average treatment effect of the Inquisition on STEM publications using Liu et al.'s (2024) fixed effects counterfactual estimator (FEct). This estimator — one of several that methodologists have recently devised to address short-comings in traditional two-way fixed effects regressions — uses observations in the control group to impute counterfactuals for treated units, and then estimates treatment effects by comparing the observed treated units with the imputed counterfactuals.

We present our baseline results in Column 1 of Table 1. On average, region-decades with an active Inquisition published a lower proportion of STEM books. This effect is substantively large, representing 66 percent of the average of the outcome variable. Column 2 shows that we obtain a similar estimate when we use the FEct counterfactual estimator.

The Inquisition also affected *total* STEM output. Using the total number of STEM books published in each region-decade as the outcome variable, we estimate that the Inquisition, on average, reduced the number of STEM publications by 386 books (wild cluster bootstrap p-value = 0.03) (results shown in Table A2).

Panel B of Table 1 studies the effect of the Inquisition on literary publications (poetry, drama, and literature). The estimated effects are small, representing only 12 percent of the average of the outcome variable, and statistically indistinguishable from zero. This suggests that the Inquisition did not affect all non-religious intellectual pursuits equally but, rather, had particularly pronounced effects on STEM fields.

To our knowledge, no existing study focuses on decadal research output in scientific fields across different regions of Europe. Some studies consider how the number of STEM researchers per capita evolved over time (Anderson 2015; Cabello 2023) but do not examine researchers' outputs. Blasutto and De la Croix (2023) examine a sample of Italian scholars from all fields, finding a decline

Table 1: Inquisitorial persecution and % STEM publications, 1470-1700

	% STEM	
	(1)	(2)
Panel A:	Two-way fixed effects model	Liu et al's (2024) FEct estimator
Inquisition	-0.032***	$\widehat{ATT}$ = -0.0399***
	(0.007)	95% CI = [-0.060,-0.017]
		Treated region-decades = 54
Wild cluster bootstrap p-value	0.007	
Mean outcome	0.0484	
Observations	184	
R-squared	0.324	

	% Literary	
	(3)	(4)
Panel B:	Two-way fixed effects model	Liu et al's (2024) FEct estimator
Inquisition	-0.011	$\widehat{ATT}$ = -0.0126
	(0.010)	95% CI = [-0.042,0.0115]
		Treated region-decades = 54
Wild cluster bootstrap p-value	0.257	
Mean outcome	0.0875	
Observations	184	
R-squared	0.371	

Notes: Robust standard errors clustered by region in parentheses. *p<0.1, **p<0.05, ***p<0.01. Inquisitorial persecution is coded as follows: Spain (1560-1700), Italian States (1540-1700), Northern Netherlands (1520-1560), Southern Netherlands (1520-1700), and British Isles (1550).

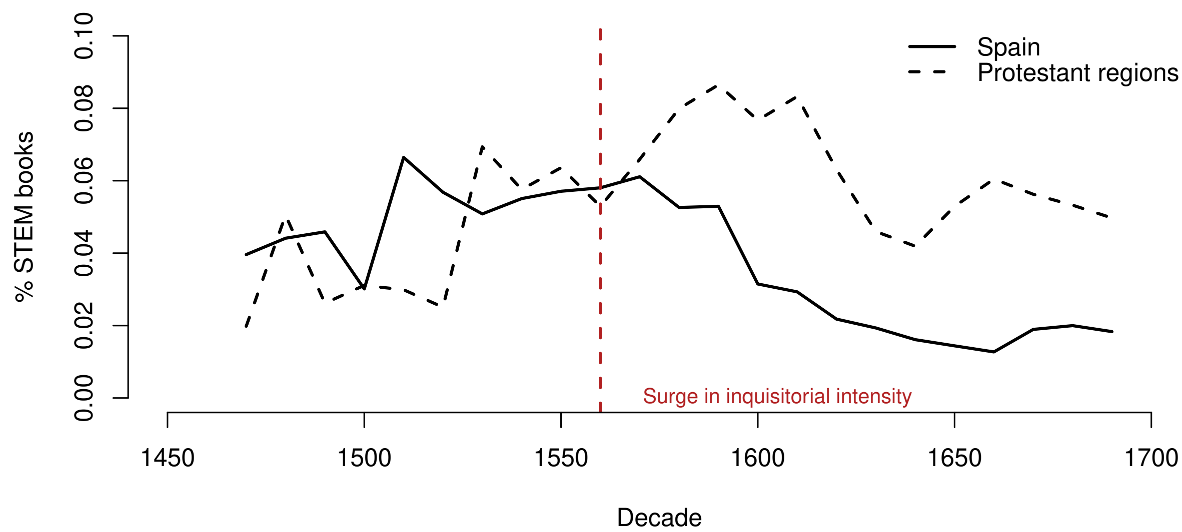
over time in per-scholar publications relative to other European countries. However, they do not comment on whether Italian scientists in particular were declining relative to those elsewhere.

4.2 The case of Spain

The output of STEM books in Spain responded to inquisitorial activity similarly to the pooled estimates given in Table 1. If we include a separate indicator for the onset of the Spanish Inquisition's period of intense activity, we find no significant divergence from the overall estimate.

To illustrate Spain's relative performance, Figure 2 shows the proportion of STEM publications in Spain compared with the average proportion across Protestant regions (the Holy Roman Empire, England, the Northern Netherlands, and the Swiss Confederacy).[4] We envision Protestant regions as the closest we can get to "pure control" cases within our sample — where inquisitorial persecution was least likely to be a concern for authors. The evolution of STEM publications in Spain is similar to that in Protestant regions until the 1560s, when a relative decline of Spanish science begins.

Figure 2: The Inquisition and the decline of Spanish science



5 Studying mechanisms: chilling effects

In this section, we investigate the mechanisms driving the decline of Spanish science after 1559. For this, we identified the 411 persons who have biographies in the DBE with full residential histories and published at least one item listed in the *Iberian Books* catalogue during their adult lives (from 15 until death). We used the DBE to code whether each author engaged in intellectual interactions during each year of their life, looking in particular for close teacher-student relationships (often

[4] The Holy Roman Empire and the Swiss Confederacy had both Protestant and Catholic regions. For this analysis, we focus on books printed in Protestant towns. We only study the cities in the HRE that Cantoni (2012) identifies as Protestant, and only consider Basel, Bern, Biel, Geneva, Neuchatel, Schaffhausen, St Gallen, and Zurich in the Swiss Confederacy.

corresponding to schools of thought), collaborations on books or projects, and participation in intellectual circles and learned societies. We also used the DBE to code the institutions of higher learning (convents and universities) that authors attended in each year of their lives.

Using our longitudinal database, we investigate whether the likelihood of scholarly interactions, affiliation with secular institutions of higher learning, and pursuit of STEM occupations changed after the intensity of inquisitorial persecution increased in 1559. We model changes in behavior after the 1559 policy shock using an interrupted time series model:

$$Y_t = \beta_0 + \beta_1 \mathit{Years}_t + \beta_2 \mathit{After\ 1559}_t + \beta_3 \mathit{Years\ After\ 1559}_t + u_t \tag{1}$$

$$u_t = \rho u_{t-k} + z_t \tag{2}$$

Here, Y_t represents the value of a particular response variable averaged over scholars active in year t. $Years_t$ is the number of years elapsed since the beginning of the time series. $After1559_t$ is a dummy variable that takes a value of 0 before the policy shock of 1559 and 1 afterwards. Finally, $YearsAfter1559_t$ is zero before 1559 and then counts the number of years elapsed since 1559. The coefficient β_1 represents how the outcome variable trended before 1559, β_2 represents how much the outcome variable changed immediately after 1559, and β_3 represents how the trend changed after 1559. To account for serial correlation, the error term u_t is a Newey-West standard error with lag k chosen following Newey and West's (1984) procedure.

5.1 Chilling effects: Declining interactions

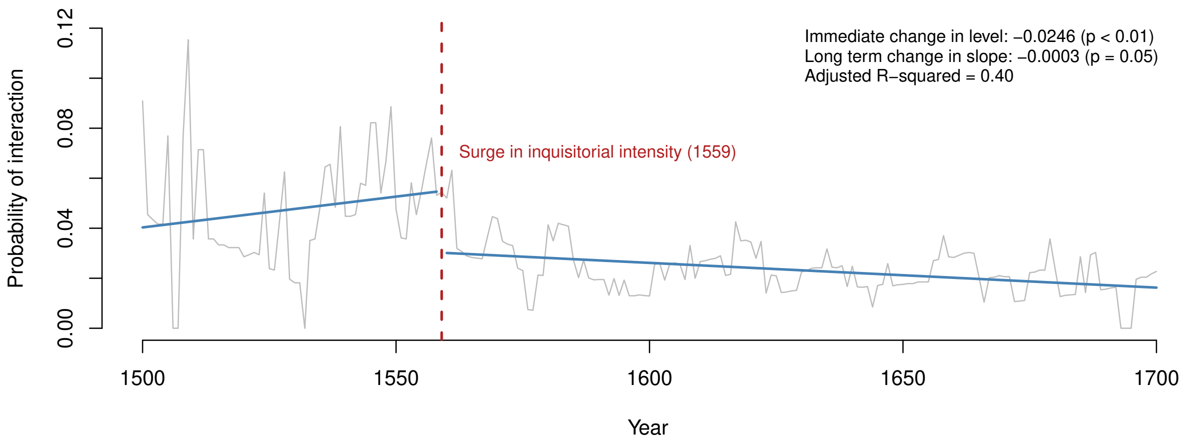
5.1.1 Interaction

Figure 3 plots the share of authors who interacted intellectually in each year between 1500 and 1700. The vertical line indicates the year 1559.

As can be seen, the share of Spanish authors who interacted was trending *upward* in the sixty years before the policy shock. In 1559, however, the share of interacting authors dropped abruptly and the trend reversed. Both effects are statistically and substantively significant. The shift in intercept, for example, indicates that the rate of interaction was cut roughly in half.

It is remarkable that the interactivity of Spanish scholars declined so much in the middle of

Figure 3: Interaction rates over time



Spain's Golden Age (1492-1657). Our explanation for this decline is as follows. After the Council of Trent in 1545-1563, the centralization of book censorship in the hands of the Council of Castile in 1554-1558, and the policy shock of 1559, educated Spaniards would have known the following. First, the Inquisition sought to enforce a set of dogmas and morals in the entire Spanish population (Bennassar 1987, p. 177). Second, trials began when one of the Inquisition's vast network of lay collaborators (including formally appointed commissioners and "familiars") accused someone (Kamen 2014, ch. 10). Third, judicial procedures could involve torture and punishments could include death. In this context, prudence enjoined avoiding topics that, and persons who, might run afoul of the inquisitors. Scholars after 1559 thus became significantly more cautious in interacting than their predecessors had been.

Many scholars have cited anecdotal evidence of the Inquisition's chilling effects. For example, the Inquisitor General's son, Rodrigo Manrique, warned that "silence has been imposed on the learned, and a tremendous terror has been inspired in those who would have called themselves scholars" by the risk that their writings would be judged to deviate from orthodoxy (quoted in Alcalá 1987, p. 327). René Descartes, although he lived beyond the reach of the Inquisition, "almost [took] the decision to burn all [his] papers, or at least to let no-one see them" after Galileo's trial (Parker, 2013, p. 654). Our results provide the first systematic evidence that these sorts of reactions were widespread among Spanish scholars and coincided with the policy shock of 1559.

5.1.2 Comparison with multiple placebo cutoffs

While the patterns shown in Figure 3 suggest chilling effects, they could also be influenced by random fluctuations in the time series. To address this concern, we conduct a falsification check.

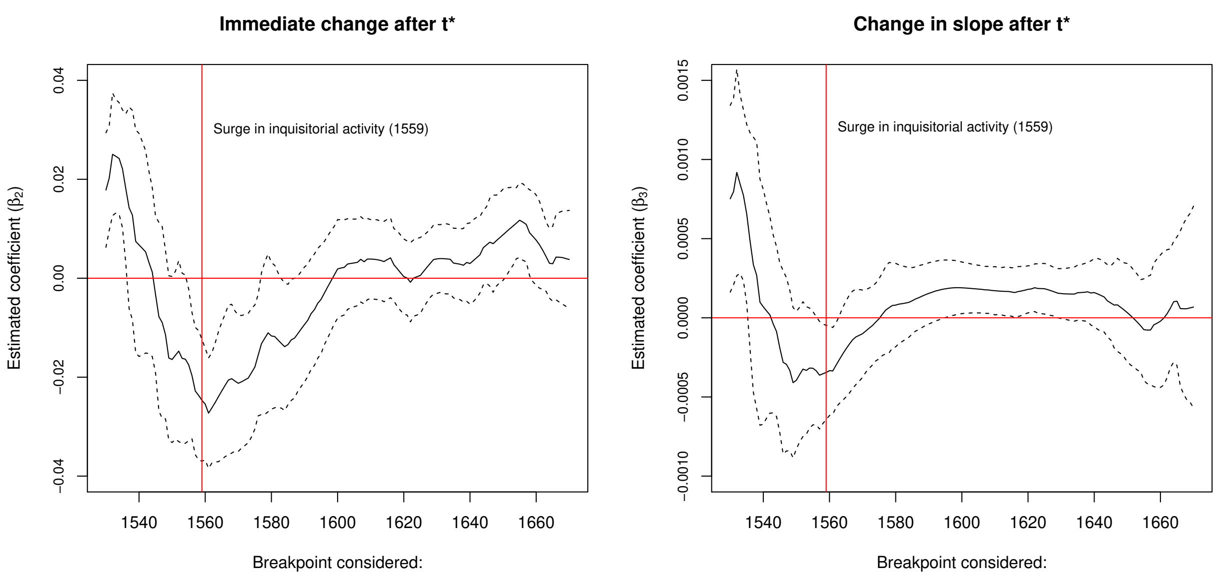
For each placebo cutoff $t* \in [1530, 1680]$, we perform an interrupted time series regression as follows:

$$\text{Interacts}_t = \beta_0 + \beta_1 \text{Years}_t + \beta_2 \text{After t*}_t + \beta_3 \text{Years After t*}_t + u_t$$

where u_t represents a Newey-West error term. This falsification check enables us to compare the estimated immediate and long-term changes in 1559 with estimates derived from 150 placebo cutoffs.

Figure 4 illustrates the results for each cutoff $t*$. Each subplot displays the estimated immediate change after the cutoff (left) and the estimated change in slope after the cutoff (right) with 90% confidence intervals. Vertical lines represent the "true" cutoff in 1559, while horizontal lines indicate zero change.

Figure 4: Comparing 1559 with 150 placebo cutoffs



We see that most placebo cutoffs yield effects that are statistically indistinguishable from zero.

Only cutoffs near 1559 yield statistically significant effects. Of these, the largest drop occurs with a cutoff in 1561, just two years after the policy change in 1559. Similarly, the largest negative change in slope, among those that are statistically discernible from zero, occurs in 1557, just two years before the events of 1559.

5.1.3 Short-term changes in interaction with foreign universities

In 1559, the Crown of Castile banned travel to most foreign universities — the only exceptions being the Catholic universities in Rome, Bologna, Naples, and Coimbra. Previous research has shown that this ban had an immediate effect. Kamen (2014, p. 123), examining a sample "of 228 Spanish scientific authors from the early sixteenth century," finds that "some 11 percent had taught in foreign universities and 25 percent had studied abroad" but "after 1560 the proportion was negligible." López Piñero (1979, p. 141), studying a different sample, finds that about half of Spanish researchers had visited foreign universities before 1559, while afterwards the share fell to virtually zero. Cabello (2023, Table A.2), examining yet a third sample, again finds substantial travel to foreign universities before 1559, falling to negligible levels afterward.[5]

At a time when traveling to other cities was an important way to learn, the cessation of inter-university visits plausibly had deleterious effects on Spanish research (Pardo 1991, pp. 109, 347).[6] Consistent with this idea, De la Croix and Morault (2022, p. 1) show that the number of publications per university was strongly correlated with the number of their professors who spent time at other universities, concluding that "the loss of connectedness of the Southern European universities after the (Counter-)Reformation was important in triggering their scientific demise."

5.2 Chilling effects: Increasing self-censorship

We know that there was a massive exodus of Jews after their expulsion in 1492 and a smaller exodus of *moriscos* after their expulsion in 1609. Recent DNA evidence suggests that there was a

[5] We see a similar, albeit less pronounced, pattern in our sample of book authors. Among authors who ever attended a Spanish university, 9.3% of those coming of age prior to 1559 visited a foreign university, versus 1.6% of those coming of age afterward.

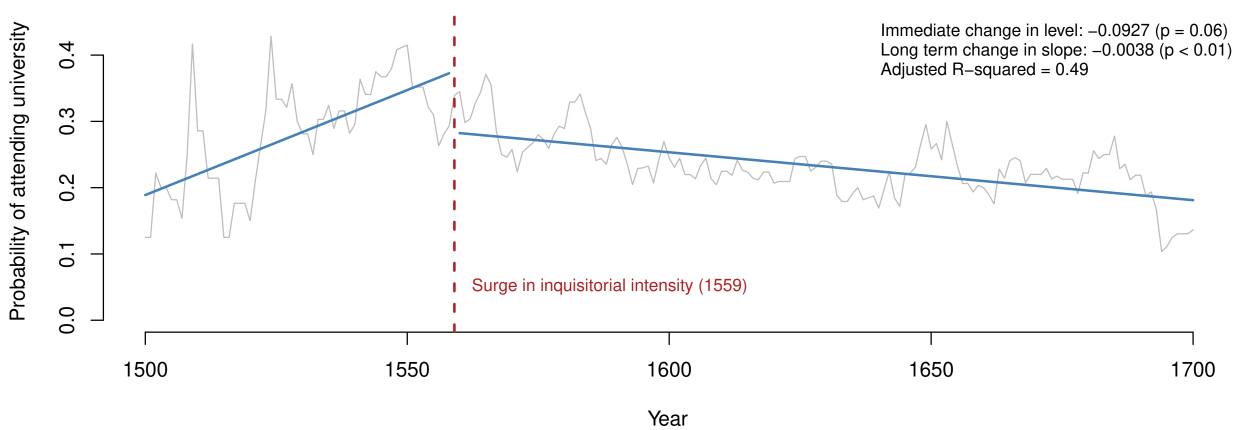
[6] A similar point has been made concerning the sharp reduction in research cooperation between the US and China circa 2018. See Jia et al. 2024.

large exodus of *conversos* to the New World as well (Chacón-Duque et al. 2018), although precisely when this occurred is unknown. In this section, we investigate self-censorship among those who remained in Spain.

5.2.1 Avoiding secular institutions

Higher education in early modern Spain had a secular sector made up of universities and a religious sector made up of convents, monasteries, and religious colleges. Using our biographical data, we identified authors who ever attended an institution of higher education and computed the share who attended a secular institution in each year, either as a student or faculty member. This provides a rough indicator of the secularization of higher education in Spain.

Figure 5: Proportion of educated authors attending universities



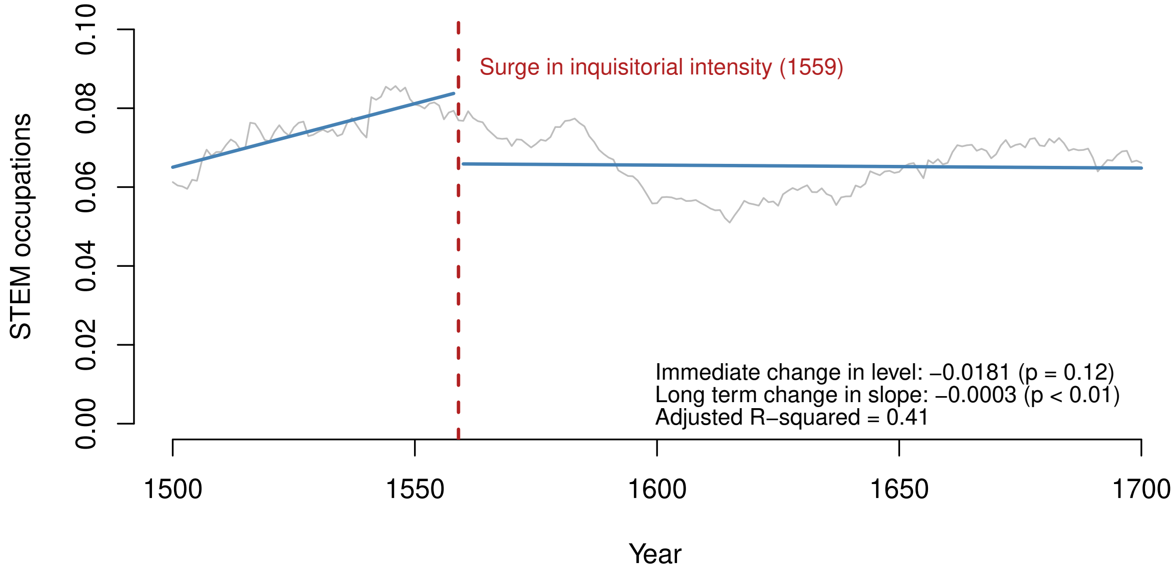
As can be seen in Figure 5, the share of educated Spanish elites attending secular institutions of higher education (i.e., universities) was trending up prior to 1559 but then we observe a statistically significant drop in level and reversal of slope. In the appendix, we run placebo tests in which the intervention is considered to have happened in a range of years. We find significant intercept downshifts for years between the mid-1540s and mid-1570s, with the single largest downshift estimated for 1567. Meanwhile, any year before 1590 yields a significant downturn in slope with the largest estimate being for 1553.

These patterns matter for current purposes in part because there was a strong association between which sector of higher education a person chose and their pursuit of STEM careers. Only 3.3% of those who trained exclusively at religious institutions entered STEM careers, versus 21.2% of those who trained exclusively at secular institutions.

5.2.2 Avoiding STEM occupations

In this section, we use the entire DBE (not just authors) and its classification of occupation(s) to calculate the share elites with STEM occupations in each year. This variable changes as elites die and others come of age — downward changes, for instance, indicate that "entering" cohorts are less likely to pursue STEM occupations than "exiting" cohorts.

Figure 6: STEM occupations in DBE



As can be seen in Figure 6, STEM careers increased until shortly before 1559, when they began to decline. An interrupted time series analysis shows an immediate drop in the STEM share of occupations circa 1559 (insignificant: p=0.12) and a reversal of trend (significant: p<0.01). Our results here corroborate previous works by Anderson (2015) and Cabello (2023) that study different samples of elites.

Placebo intervention tests show significant intercept downturns between the late 1540s and 1563 — roughly corresponding to the Council of Trent — and again in 1580-1600. Any year before 1590 shows a significant reversal in trend.

6 Robustness of results

In this section, we first discuss threats to the validity of interrupted time series analyses, following Baicker and Svoronos (2019). We then discuss another falsification test that we ran and summarize our results.

6.1 Concurrent events

Probably the most obvious threat to an interrupted time series analysis is the occurrence of other events at the same time as the posited intervention. In this section, we consider whether other events, occurring at about the same time as the policy shock of 1559, might have produced the syndrome of developmental reversals we have described.

We first looked at the significant European events of 1558-1560 listed in standard historical chronologies. Two events (a royal marriage and a treaty signing) involved Spain but no one has suggested that either had any effect on Spanish scholars' interactions or career choices. A third event — the arrest in 1558 of the Roman Catholic Archbishop of Toledo on the orders of the Grand Inquisitor — can be viewed as part of the policy shock on which we focus. The arrest made clear that no one living in Spain could think that they were beyond the reach of the Inquisition.

We next considered economic development. According to Prados de la Escosura et al. (2022) and Henriques and Palma (2023), Spain's economic decline began circa 1650. Thus — even if one believed that economic decline would have induced scholars to reduce their scholarly interactions, avoid secular institutions of higher education, and avoid STEM occupations — economic decline did not begin in 1559.

The nature of warfare was changing during Europe's military revolution but changes were gradual and would plausibly have generated greater demand for military-related STEM expertise.

So, one would have thought that STEM occupations in Spain should have trended upward, given its continual participation in warfare.

Was there a broader cultural decline in people's propensity to interact circa 1559? No one has argued this. Moreover, Drelichman et al. (2021) show that the more active the Inquisition was in a Spanish area, the greater the level of church attendance in that area is today. Thus, one form of interaction (attending church) seems to have been stimulated.

We cannot eliminate alternative explanations as effectively as one can in a randomized controlled trial. However, all the developmental reversals we have documented would be expected on the hypothesis that scholars took increasing pains to avoid becoming targets of the Inquisition after 1559, and no alternative explanation has been proposed.

6.2 Anticipation effects

Another well-known threat to interrupted time series analyses arises when actors anticipate the onset of treatment (in our case, a surge in inquisitorial activity) and adapt to it prior to actual onset. We would make two points about this concern. First, the policy shock of 1559 was precipitated by the discovery of a circle of Protestants in Valladolid, an unexpected event that few would have anticipated. Second, to the extent that contemporaries already perceived the shifts in inquisitorial policy entailed by the decree *Apostolici regiminis* in 1516 and the Council of Trent in 1545-1563, the likely effect would have been to reduce the impact of the policy shock on which we focus. In other words, our various analyses are likely biased downward by any anticipation effects.

6.3 Falsification test

Baicker and Svoronos (2019) propose a falsification test to complement interrupted time series analyses: an agnostic search for a structural break in the time series. If there is no such break, or if the most prominent break lies far from the intervention of interest, this suggests that the intervention was not so important. As can be seen in Table 1, agnostic searches find structural breaks in our time-varying response variables within a few years of the policy shock of 1559. For the one response variable that we code as an author fixed effect (occupation), the estimated structural break occurs about 30 years after the policy shock (in 1591).[7]

Table 2: Summary of main results on chilling effects

Response variable:	Figure:	Significant drop in 1559?	Reversal of trend in 1559?	Year of estimated structural break
Did author have a close mentorship, collaboration or circle?	3	Yes	Yes	1561
Did author attend secular institutions of higher education (conditional on any)?	5	Yes	Yes	1553
Did author enter a STEM occupation?	6	No	Yes	1591

Eventually, it will be possible to compare the trajectory of Spanish science to various "control" cases from Atlantic Europe where the Inquisition was less active. We anticipate that these additional studies will also show that Spain, and Spain alone, exhibited the behavioral downturns we have documented.

7 Indirect evidence of chilling effects: Agglomeration economies

In Section 5, we showed that Spanish authors' propensity to engage in several types of intensive interaction declined abruptly circa 1559. However, professors still taught classes and students still took them. Moreover, collaborations and conversations of which biographers never learned no doubt occurred. How can one measure the intensity of these less visible interactions?

7.1 Measurement approach

A burgeoning literature in urban economics measures the size of "agglomeration economies" using panel datasets on scholars' annual research output, such as articles and patents (see Eckert et al. 2022 for a recent review). The basic idea is to measure how much more productive researchers become, when they move into cities with large clusters of researchers in their own or related fields. One expects a productivity boost due to knowledge spillovers, the greater ease of finding appropriate

[7] These agnostic searches look for the best breakpoint in the time series, considering both the intercept and slope. Our previous placebo intervention tests are similar but explored possible breaks in the intercept and slope separately.

collaborators, and the greater availability of public goods such as libraries (Duranton and Puga 2004). Estimates of the size of these benefits in modern cities are in the 30%-50% range (e.g., De la Roca and Puga 2017; Eckert et al. 2022).

Recently, scholars have begun to apply the same panel-data approach to study agglomeration economies in early modern cities, using books, rather than articles and patents, to assess productivity (Mitchell 2019; Kuld et al. 2021; Cox and Figueroa 2023). Here, we provide the first comparable estimates of agglomeration economies for book authors in early modern London and Madrid.

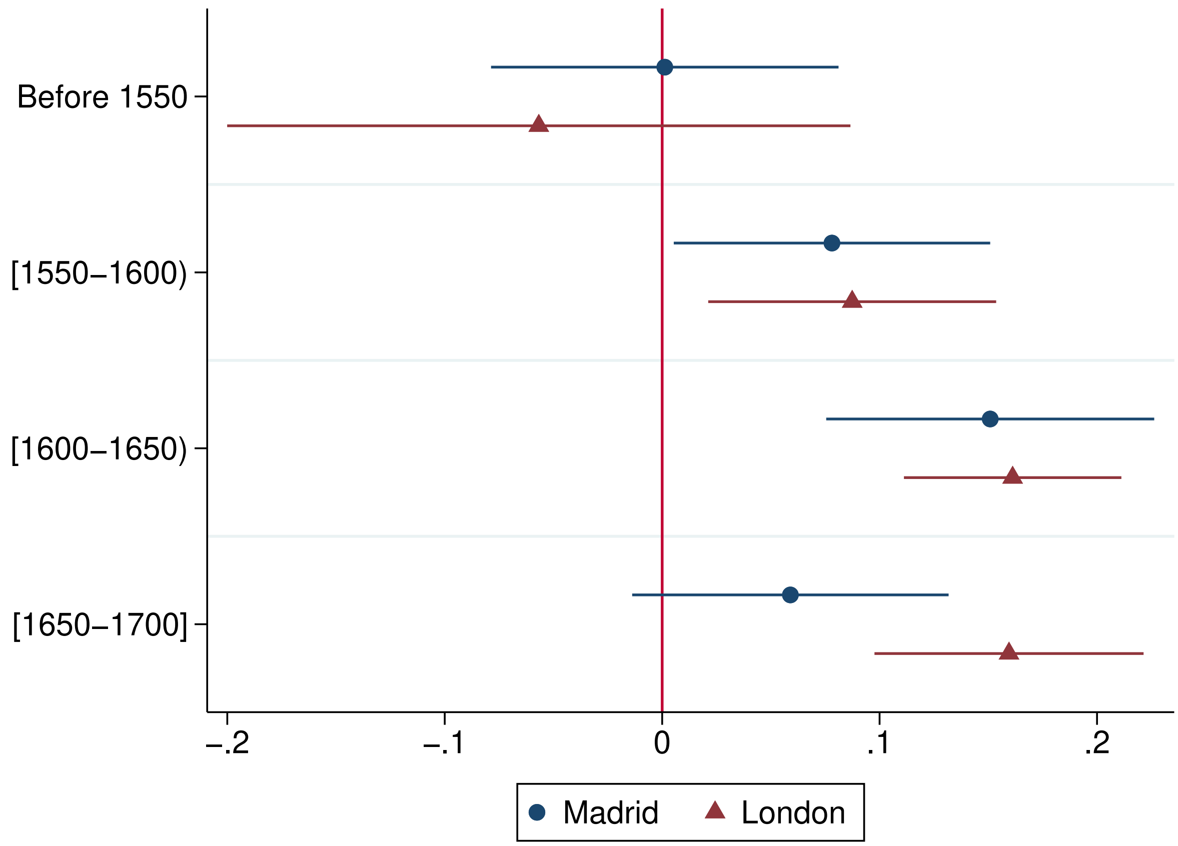
We continue to use our panel database of 411 authors with DBE biographies. For each year of each author's life, we code their place of residence and the number of books they published. We shall use this panel database, covering 19,975 observations from 1472 to 1700, to study temporal changes in spatial agglomeration and intellectual productivity. We combine these data with a similar database on prolific British authors. The panel of British authors, originally compiled by Cox and Figueroa (2023), includes all authors of at least five items in the English Short Title Catalogue (1473-1800) with full residential histories in the Oxford Dictionary of National Biography. To make it comparable to our panel of Iberian panel, we subset the British sample to those authors who published before 1700.

Following methods used in previous work (e.g., De la Roca and Puga 2017; Mitchell 2019), we examine the extent to which authors became more productive upon moving to Madrid and London — conditional on author, year, and age fixed effects. In particular, we estimate:

$$\textit{Publications}_{it} = \beta_1 \textit{Top Cluster}_{it} \times \textit{Time-period}_t + \lambda \textit{Age}_{it} + \theta_i + \alpha_t + \epsilon_{it} \tag{3}$$

where $\textit{Publications}_{it}$ is the number of works by author i printed in year t, $\textit{Top Cluster}_{it}$ is an indicator that i resided in the top cluster in his region in year t (Madrid or London), $\textit{Time-period}_t$ is a vector of dummy variables representing different half-century periods (before 1550, 1550-1600, 1600-1650, and 1650-1700), $\textit{Age}_{it}$ is a vector of age fixed effects, and θ_i and α_t are author and year fixed effects. We estimate this equation with OLS separately for the sample of Iberian and British authors. We cluster standard errors by author.

Figure 7: Agglomeration effects in Iberia and England



7.2 Results

Figure 7 shows the premium on productivity in Madrid and London, respectively, by half-century. Horizontal lines represent 90-percent confidence intervals. Both cities exhibited non-positive and non-significant agglomeration effects on productivity before 1550, small positive and significant effects in 1550-1600, and even bigger effects in 1600-1650. After 1650, however, Madrid's premium declined, becoming non-significant, whereas London's premium increased and remained significant.

Why did agglomeration economies not decline immediately after 1559? Phillip II made Madrid his capital in 1561, attracting many famous elites. Although the post-1559 cohorts of these elites were less likely to take on students and collaborators or join intellectual circles than previous generations had been, there were enough pre- and post-1559 cohorts during the Golden Age so that the benefit of residing in Madrid was substantial for most scholars.

Why did agglomeration economies eventually decline? In 1627, the last scholar who had come of age before 1559 passed away, leaving only less interactive post-1559 cohorts. Moreover, the Spanish crown's ability to patronize the arts seems to have declined during the Thirty Years War; and the Spanish economy as a whole went into decline (de Pleijt and van Zanden 2016, 2020; Henriques and Palma 2023). The combination of fewer and less interactive elites with economic depression meant that Madrid's cluster of elites declined below a critical mass of size and activity, ending the Golden Age.[8]

8 Long-term effects of the Inquisition

8.1 Running behind in inter-state technological competition

We have argued that the Spanish Inquisition reduced and homogenized the flow of ideas within Spain's scholarly community, especially in STEM fields, and that this should have reduced the flow of recombinant discoveries. The evidence we have presented is consistent with such an account.

If Kremer's (1993) o-ring model of international competition in technological sectors is apt, then reducing and homogenizing the flow of ideas in Spain should have (a) pushed it into a subordinate position in the international pecking order in STEM sectors and (b) made it difficult to move up from that position. These two features — entirely consistent with the historical record — arise in theory because of strong complementarities across tasks and subfields, ensuring that if London, say, has assembled the best and brightest in an array of subfields, then it will have a substantial advantage in attracting talent in related subfields. Subordinate cities, meanwhile, must improve simultaneously across a broad range of subfields in order to compete for top talent successfully. From this perspective, the short-term effects of the Inquisition, upon which we have mostly focused, would have had negative long-term developmental consequences for Spain, contributing to the Little Divergence.

Looking beyond the particular case of censorship we study, one would expect that any successful

[8]The Supplemental Appendix compares the number of elite interactions scholars could expect in London and Madrid.

attempt to censor the flow of ideas in a research sector with substantial complementarities will not only produce chilling effects in the affected country but also worsen its standing in international competition. Given the intensity of competition for top talent, even relatively mild censorship might have outsized competitive effects.

8.2 Reduced generalized trust

The Inquisition's use of a network of lay collaborators would plausibly have eroded generalized trust among the general population. The Inquisition knew that elaborate public displays inspired fear in the broader public and its officials repeatedly stressed the value of doing so. In 1578, for example, one official reminded his colleagues that "we must remember that the essential aim of the trial and death sentence is...terrorizing the people" (quoted in Benassar 1987, p. 178).

Since generalized trust is highly correlated across generations (Wu 2022), it is plausible that the surge of inquisitorial activity after 1559 initially reduced trust, with parental socialization then entrenching the new, lower level. Consistent with this expectation, Drelichman et al. (2021) show that municipalities in Spain experiencing more intensive inquisitorial activity in the 16th-17th centuries have lower levels of trust even today.

9 Conclusion

In this paper, we have undertaken a case study of how religious enforcement of orthodoxy affected science in the early modern era, seeking to complement broader analyses of the political economy of religion (including Huff 2003; Mokyr 2017, ch. 16; Bénabou et al. 2022; Chaney 2023; Bisin et al. 2024) by providing detailed evidence on mechanisms. The case we study is the Spanish Inquisition.

A traditional argument against the hypothesis that the Spanish Inquisition substantially depressed scholarly activity in Spain is based on timing. The Inquisition was formed in 1478, and was most active in the period 1560-1620, yet Spain experienced its Golden Age 1492-1657.

We argue that a policy shock in 1559, which expanded the level and scope of inquisitorial activities, should have had important chilling effects, reducing scholars' willingness to interact with others and inducing them to divert their efforts away from STEM fields (or to pursue them outside

Spain). To support this thesis, we provide the first systematic evidence on interactions among early modern Spanish scholars, documenting a sharp reversal after the policy shock of 1559 in a previously upward trend in interactivity. We also document reversals in previous upward trends of university attendance and choice of STEM occupations. Finally, we document a reversal in trend of book output in STEM fields.

Activity and output declined in STEM fields, we argue, because STEM researchers were the most reliant on interactions with foreign universities and with Spain's *converso* population. Yet travel to the foreign universities most active in STEM research was banned in 1559; and Spain's *converso* population, over-represented in STEM fields, was the most likely to exit Iberia or to avoid publishing books that might run afoul of the inquisitors. The negative effect of the Inquisition thus fell heaviest, and soonest, upon STEM fields.

In contrast, Spain's efflorescence in the literary, performing and visual arts continued well after 1559 for two basic reasons. First, the arts were less reliant on interactions with foreign universities and the *converso* population. Second, the huge influx into Madrid after it became the capital compensated for lower rates of scholarly interaction. Thus, the collapse of the arts was much delayed but swift when it came.

In addition to explaining the puzzling disjuncture between the glory of Spanish literary and visual arts, on the one hand, and the poverty of its contributions to science, on the other, our account resonates with prominent models of why cities foster creative activities (Jacobs 1969; Lucas 1988). The gist of most models of agglomeration economies is that getting large numbers of educated people together allows them to more efficiently share knowledge and collaborate (Duranton and Puga 2004). The Inquisition reduced precisely these activities. The attractiveness of Madrid still increased, after it became the capital in 1561, because the interactions an in-migrating scholar experienced depended on both sheer numbers (inclining after 1561) and rates of interaction (declining after 1559). Once economic decline set in after the Thirty Years War, however, Madrid was no longer the kind of intellectual hub that it had been during the Golden Age.

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Supplementary Appendix [under construction]

9.1 Description of Data

Table A1: Description of variables and sources

Figure or table	**Summary and data**
Table 1	Difference-in-differences study of the effect of the Inquisition on STEM publications. We used the USTC to construct a panel tracing the % of STEM publications each decade in the British Isles, France, the Holy Roman Empire, Italian States, Northern Netherlands, Southern Netherlands, Spain, and the Swiss Confederacy. STEM books include those on medicine, science, mathematics, astrology and cosmography, and agriculture. Regions exposed to the Inquisition are the British Isles in 1550, Italian States from 1540 to 1700, Spain from 1560 to 1700, Northern Netherlands from 1520 to 1560, and Southern Netherlands from 1520 to 1700.
Figure 2	Time series plot comparing the evolution of % STEM in Spain with the average % STEM in the four Protestant regions in our sample (Holy Roman Empire, England, Swiss Confederacy, and Northern Netherlands). The figure uses the same database as Table 1, the only difference being that for this figure we only consider the Protestant towns of the Holy Roman Empire and Swiss Confederacy.
Figure 3	Time series plot of the proportion of Spanish authors who interacted with other scholars each year from 1500 to 1700. Our sample includes all Spanish persons who (i) published at least one book available in the *Iberian Books* catalogue during their adult lives, (ii) have a biography with a full residential history in *Diccionario Biográfico Español*. Our sample has 411 authors, whom we observe over 19,975 author-years.
Figure 4	Placebo tests of the interrupted time series in Figure 3; uses the same data as Figure 3.
Figure 5	Time series plot of the proportion of Spanish authors who attended a university each year. This figure uses the same data as Figure 3, but restricted to the 227 authors who attended an institution of higher learning at some point of their adult lives (either a university or a religious institution).

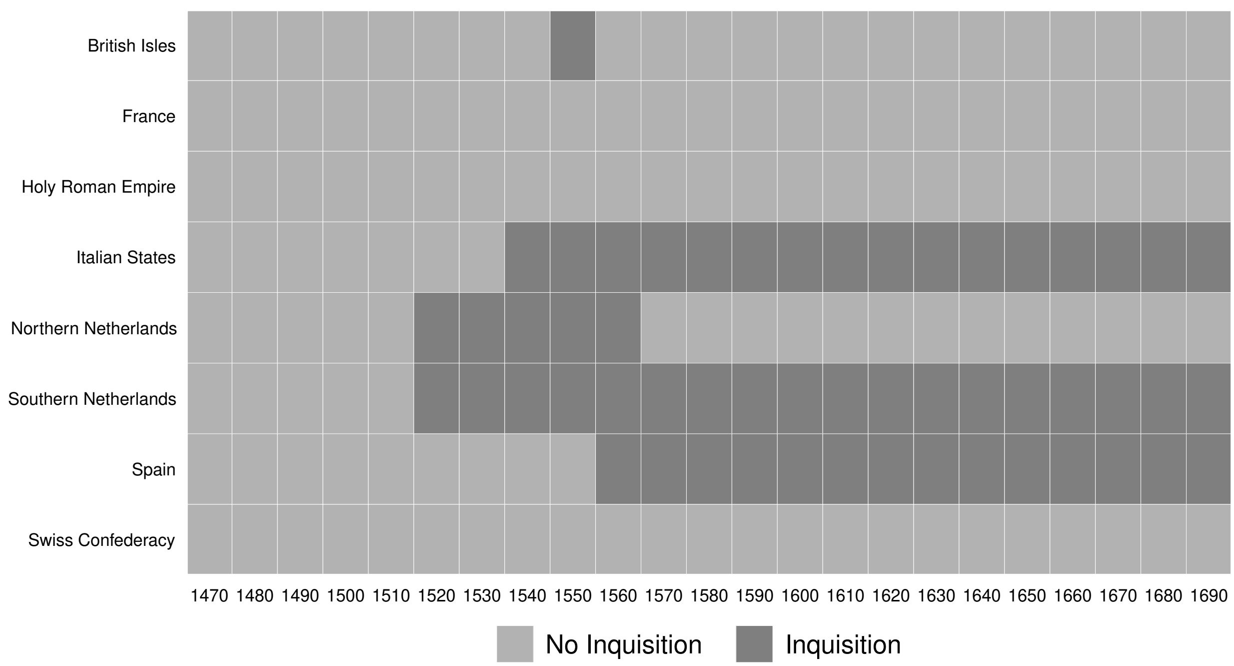
Figure 6	Time series plot of the proportion of living notable Spanish adults who had a STEM occupation. For this figure, we study the full DBE database. For each year from 1500 to 1700, we compute the proportion of living adults (i.e., over 15 years old) who have a STEM occupation (e.g., mathematician, chemist, astronomer, physicist, engineer, scientist, anatomist, inventor, botanist, zoologist, physician).
Table 2	Robustness checks; same databases as those in Figures 3, 5 and 6.
Figure 7	Agglomeration economies over time. We use the new panel of 411 Spanish authors, and the subset of authors who published a book before 1700 of the panel of prolific British authors provided by Cox and Figueroa (2023).

9.2 Difference-in-differences results

9.2.1 Inquisitorial persecution over time

The figure below shows the exposure to high levels of inquisitorial activity in our sample of countries. The category "No Inquisition" refers to either the absence of an Inquisition or to low activity levels. The category "Inquisition" refers to all periods after the first onset of high-intensity inquisitorial activity until the Inquisition's disbandment.

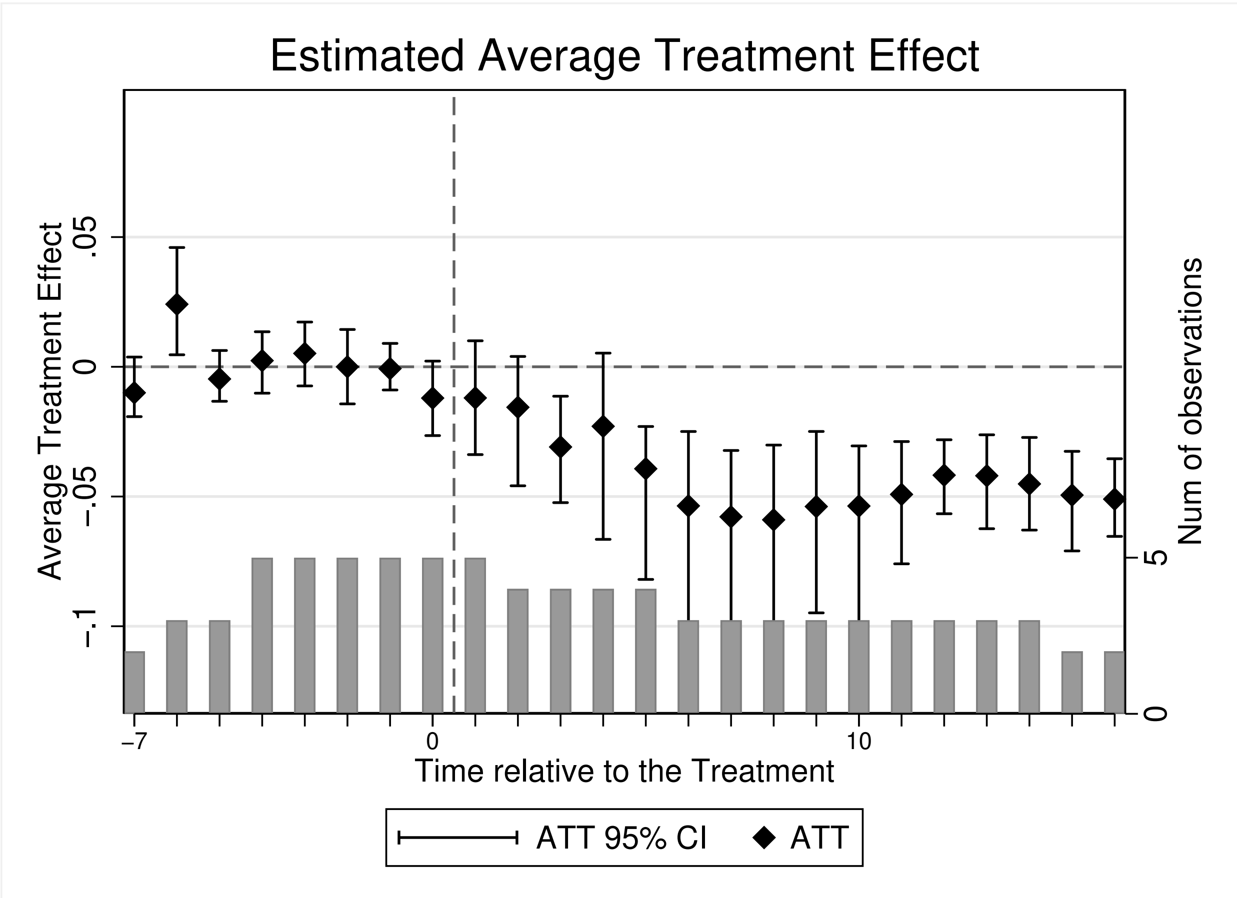
Figure A1: Inquisitorial persecution over time within cases



9.2.2 Dynamic treatment effect

This figure shows the treatment effect of inquisitorial persecution on STEM output for different times relative to the onset of the treatment (t=0). Treatment effects were calculated with the Liu et al.'s (2024) FEct estimator. Vertical bars indicate 95 percent confidence intervals (constructed with 1,000 bootstrap permutations).

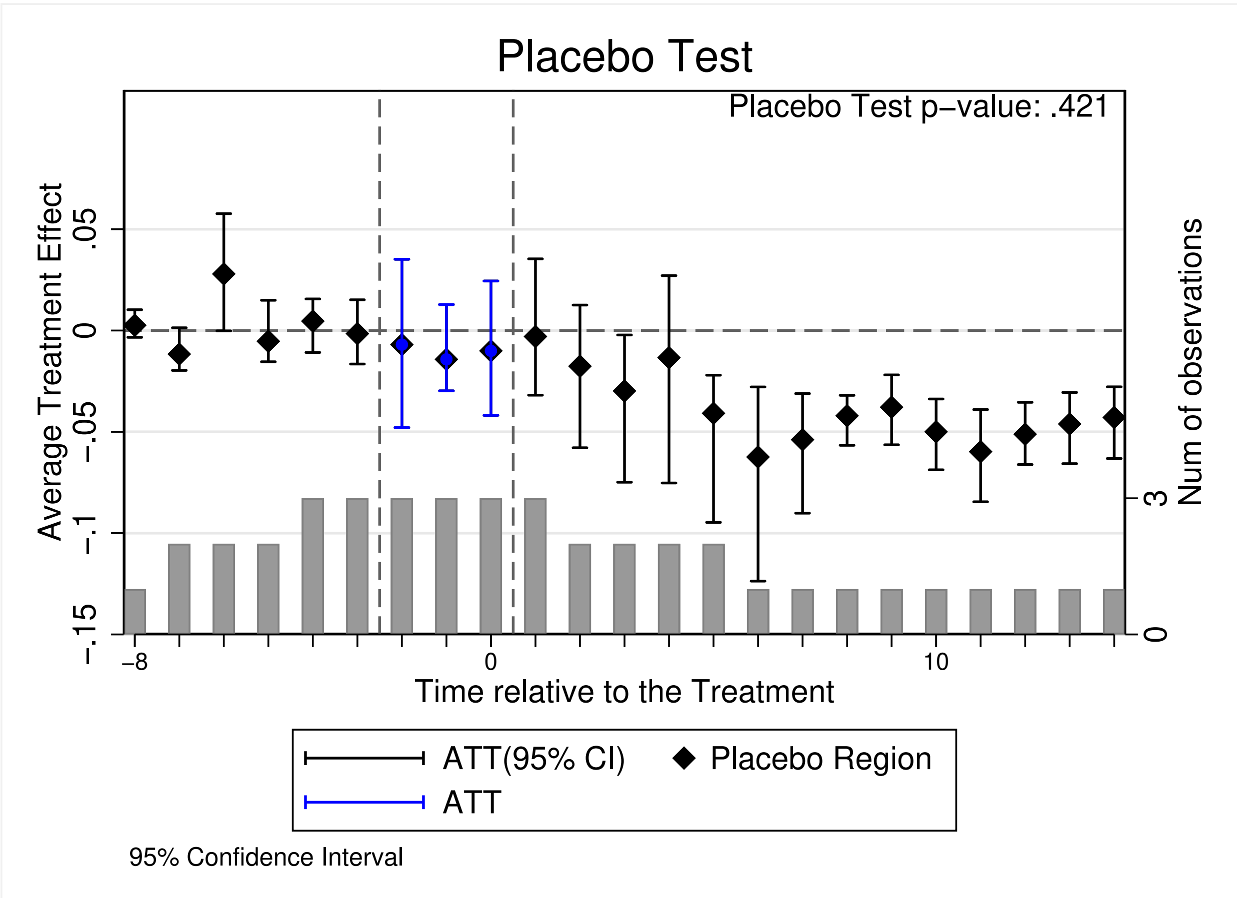
Figure A2: Dynamic treatment effect of inquisitorial persecution



9.2.3 Placebo test

This figure shows the result of a placebo test proposed by Liu et al. (2024), in which it is assumed that the treatment onset in treated units takes place three periods before the true onset. These placebo onset periods appear in blue in the plot. We estimate null placebo effects.

Figure A3: Placebo test: ATT in periods *before* the Inquisition



9.2.4 Effect on the total number of STEM books

The results we presented thus far focus on the proportion of STEM publications in each region. This proportion might decrease both because the number of STEM publications declines, or because of an increase in non-STEM outputs. In this table, we estimate the effect of inquisitorial persecution on the total number of STEM publications. We find a negative and statistically significant effect.

Table A2: Inquisitorial persecution and total STEM publications, 1470-1700

	Total STEM publications	
	(1)	(2)
	Two-way fixed effects model	Liu et al's (2024) FEct estimator
Inquisition	-386.540**	$\widehat{ATT}$ = -441**
	(123.715)	95% CI = [-881,-112]
		Treated region-decades = 54
Wild cluster bootstrap p-value	0.031	
Mean outcome	381.8	
Observations	184	
R-squared	0.399	

Notes: Robust standard errors clustered by region in parentheses. *p<0.1, **p<0.05, ***p<0.01.

9.2.5 Alternative measures of inquisitorial persecution

Our measure of "inquisition" for the difference-in-difference results considers all periods after the onset of high-intensity inquisitorial activity until the Inquisition's disbandment. In this appendix, we examine the robustness of our results to alternative ways of coding inquisitorial persecution. First, we ignore the Marian Inquisition and consider Britain as never treated (column 2). Second, we consider both Britain and Southern Netherlands as never treated (column 3). Third, we consider only Spain (after 1560) and the Italian states (after 1540) as subject to inquisitorial persecution. The different ways of coding inquisitorial persecution do not affect our results.

Table A3: Alternative ways of coding inquisitorial persecution

	(1)	(2)	(3)	(4)
Inquisition	-0.032***			
(Baseline)	(0.007)			
Inquisition II		-0.034***		
(Britain never treated)		(0.008)		
Inquisition III			-0.028***	
(Britain and Southern Netherlands never treated)			(0.008)	
Inquisition IV				-0.034**
(Only Spain [1560-] and Italy [1540-] treated)				(0.012)
Observations	184	184	184	184
R-squared	0.324	0.341	0.277	0.275
Number of code	8	8	8	8
Region FE	Yes	Yes	Yes	Yes
Decade FE	Yes	Yes	Yes	Yes

Notes: Robust standard errors clustered by region in parentheses. *p<0.1, **p<0.05, ***p<0.01.

9.3 Placebo cutoff tests

As we argue in the body of the paper, the interrupted time series results we present could be influenced by random fluctuations in the time series. To address this concern, we conduct a falsification check. For each placebo cutoff $t* \in [1530, 1680]$, we perform interrupted time series regressions as follows:

$$\text{University}_t = \beta_0 + \beta_1 \text{Years}_t + \beta_2 \text{After t*}_t + \beta_3 \text{Years After t*}_t + u_t$$

$$\text{STEM}_t = \beta_0 + \beta_1 \text{Years}_t + \beta_2 \text{After t*}_t + \beta_3 \text{Years After t*}_t + u_t$$

where u_t represents a Newey-West error term. These falsification checks enable us to compare the estimated immediate and long-term changes in 1559 with estimates derived from 150 placebo cutoffs.

The figures below illustrates the results for each cutoff $t*$. Each subplot displays the estimated immediate change after the cutoff (left) and the estimated change in slope after the cutoff (right) with 90% confidence intervals. Vertical lines represent the "true" cutoff in 1559, while horizontal lines indicate zero change.

Figure A4: Comparing 1559 with placebo cutoffs: secular education

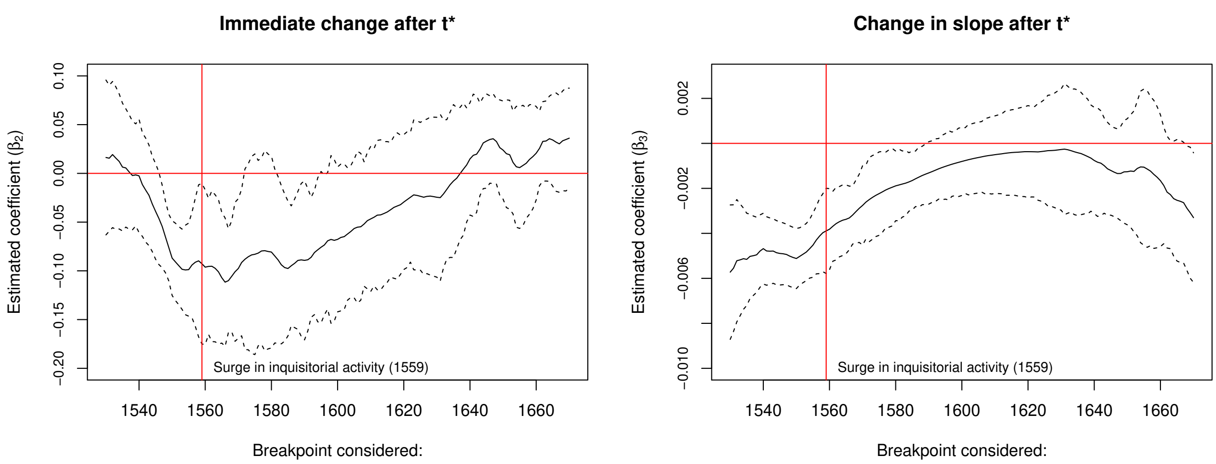


Figure A5: Comparing 1559 with placebo cutoffs: STEM occupations

9.4 Expected interactions

The figure below shows the expected number of elite interactions in Madrid (left) and London (right). We compute these values as:

$$\text{Expected interactions}_{ct} = \#\ \text{Authors}_{it} \times \text{Proportion interacting}_{it}$$

where $\#\ \text{Authors}_{it}$ is the number of authors residing in the top cluster of country i (Madrid or London), and $\text{Proportion interacting}_{it}$ is the proportion of authors in each country who interacted in year t.

Figure A6: Expected interactions in Madrid and London (agglomeration × propensity to interact)