ISSN 2042-2695

CENTRE for ECONOMIC PERFORMANCE

CEP Discussion Paper No 1600

January 2019

New Media and Competition: Printing and Europe's Transformation after Gutenberg

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Abstract
We study the role of book content in economic, religious, and institutional development after the introduction of printing, and the role of competition in determining the amount and content of local printing. We focus on (1) business education content and (2) religious ideas during the Protestant Reformation. We construct data on printing output and competition in European cities 1454-1600.We document positive relationships between business education content and city growth, and Protestant content and institutional change. We find competition predicts content. We confirm the relationships between competition, content, and outcomes using printer deaths as a source of exogenous variation.

Key words: competition, firms, media, technology, institutions, religion, politics
JEL Codes: L1; L2; N0; N3; N8; O3; O4

This paper was produced as part of the Centre's Growth Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

We thank Russ Gasdia, Kevin McGee, David Rinnert, Ava Houshmand, David Schlutz, and Luis Molestina-Vivar for research assistance. We thank colleagues at American University, Barcelona GSE, Berkeley, Chicago Booth, Columbia, LSE, Michigan, Munich, NBER Summer Institute, Northwestern, NYC Media Seminar, Sussex, Stanford, UCL, and UC San Diego for comments. We thank anonymous referees, Sascha Becker, Davide Cantoni, Ralf Meisenzahl, Joel Mokyr, Suresh Naidu, Jesse Shapiro, Nico Voigtländer, Joachim Voth, and Noam Yuchtman for valuable feedback. Dittmar acknowledges support through the Deutsche Bank Membership at the Institute for Advanced Study, the National Science Foundation, the Centre for Economic Performance, and the European Research Council: this project has received funding from the European Union's Horizon 2020 research and innovation programme under grant number No. 638957. This paper incorporates research that previously circulated as Dittmar (2015), \New Media, Ideas, and Growth: Europe After Gutenberg" and Dittmar and Seabold (2016), \Media, Markets, and Radical Ideas: Evidence from the Protestant Reformation."

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Published by
Centre for Economic Performance
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

1 Introduction

Starting in the late 1400s, Gutenberg's printing press technology transformed the diffusion of ideas in Europe. This paper studies how the diffusion of ideas in print shaped economic, institutional, and religious development – and the role of competition in printing in determining the amount and content of locally produced books in the 1500s. We focus on two major diffusion processes: the diffusion of knowledge about radical innovations in business practices, which changed economic activity; and the spread of the Protestant Reformation, which led to fundamental changes in beliefs and institutions.

Research on the origins of economic development in Europe highlights the importance of the opening of markets for ideas after 1500 (Mokyr 2016). Influential historical research argues that Gutenberg's printing technology transformed European society as a whole (Eisenstein 1980). Previous economics research has studied the extensive margin of technology diffusion, comparing the development of cities that did and did not have printing in the late 1400s (Dittmar 2011; Rubin 2014). However, printing changed the transmission of ideas by introducing both a new technology and new forms of competition. Regulation was light: printing fell outside guild regulation and was one of the first industries in European history in which firms organized production (Brady 2009; Barbier 2006; Hirsch 1967).[1] Market structure and competition varied across cities and time.

We provide evidence that the *interaction* between technology and economic competition was fundamental for the diffusion of ideas that drove profound changes in European society in the post-Gutenberg era. We construct novel evidence from books to measure the diffusion of ideas; study how competition in printing shaped diffusion across cities and time; and document the causal effects of ideas on economic and institutional outcomes, using printer deaths as a source of exogenous variation. We focus on ideas that changed how Europeans (i) did business and (ii) thought about religion and institutions.

Radical innovations in business practices appeared in Northern Italian cities by the 1300s, but diffusion was limited before printing (Miskimin 1975). The key innovations involved applied mathematics, accounting techniques, and cashless payments systems. With printing, a business education literature emerged that lowered the costs of knowledge for merchants (Jeannin 1996; Van der Wee 1967). The first printed mathematics texts were merchants' manuals that provided instruction on business applications for math; record-keeping, including double-entry accounting; and cashless payment technologies, including the bill of exchange. These ideas diffused in books and changed the

[1] We provide further details on regulation below, including how regulation emerged in response to the Protestant Reformation, after the political and religious implications became apparent to ruling elites.

way Europeans did business. European business shifted from an equilibrium of Roman numerals to the Arabic numbers we use today – in the 1500s (Meskens 2013).

Printing also played a central role in religious and institutional change. Before the 1500s, the Catholic Church enjoyed an ideological monopoly and unparalleled social power. Starting in 1517, the Protestant Reformation was the first mass movement to make use of the new information technology and the first successful challenge to the Catholic monopoly. The Protestant Reformation introduced new forms of religious and institutional competition into European society. The Reformation emerged in and spread across the cities of German-speaking Europe and led to institutional changes at the city level that expanded public goods provision and established public education.

The diffusion of innovations in business practices and the introduction of competition in religion were arguably among the most important pivots in the development of Europe. Printing played a key role in both processes. No prior research has systematically studied the diffusion of these ideas in the media in quantitative terms, how competition in the printing industry shaped transmission, or the causal impact of these ideas on outcomes.[2]

This paper constructs new data on radical ideas in books and on industrial organisation, and studies how the diffusion of ideas shaped economic outcomes and how competition determined the amount and content of locally produced books.[3] We construct novel data on (1) the diffusion of the merchant manual literature across European cities and (2) the diffusion of religious content during the Protestant Reformation across cities in German-speaking Europe. We document the positive relationship between the spread of merchant manuals, city growth, and individual achievement, and between the diffusion of Protestant ideas and institutional change at the local level. We investigate how competition in concentrated local markets influenced behavior in printing. We show that local competition among printers predicts book prices, the diffusion of ideas in print, and economic outcomes. We study the implications of variation in competition due to entry and exit and use the timing of the deaths of printers as a source of exogenous variation.

First, we construct new data on output, prices, and industrial organization in printing. We gather evidence on all known books printed in Europe between 1454 and 1600: over 295,000 publications printed in 200+ cities. We measure content at the book-edition level, which can be considered a variety produced in a given city-year.[4] We hand-code

[2]For example, Dittmar (2011) studies the relationship between the *presence* of printing before 1500 and city growth, but does not examine competition or the relationship between ideas and growth. Rubin (2014) shows that the *presence* of pre-1500 printing predicts city-level Protestantism, but does not investigate competition or systematically measure Protestant ideas in print, and acknowledges that his research does not distinguish between demand- and supply-side impacts of printing on diffusion.

[3]We use the designation "books" as a short-hand. Our data include religious pamphlets.

[4]The use of the edition as the measure of output is in part dictated by the available data. Records

individual merchant manual editions and classify religious publications as Protestant or Catholic based on the statistical distribution of authors' language, using methods for high-dimensional data (Taddy 2013b; Gentzkow and Shapiro 2010).[5] We assemble complementary microdata on individual book prices and characteristics. We construct data on industrial organization by identifying firms from inscriptions on historical books and biographical records. Finally, we assemble evidence on the timing of the deaths of printers, which we use as a source of exogenous variation.

Second, we document the correlation between the diffusion of ideas in print and outcomes. We find that the local diffusion of business education content was strongly related to long-run city population growth between 1500 and 1600 across Europe. We find no robust relationship between other kinds of printing and city growth. We focus our analysis of printing in the Reformation on German-speaking cities and study local variation in printing and institutional change after Martin Luther circulated his famous theses in 1517.[6] We find that local exposure to Protestant media in the first years of the Reformation predicts city-level institutional change, which we measure by the adoption of municipal Reformation laws in the 1500s in German cities. Our analysis provides the first systematic, quantitive measure of the diffusion of the Protestant ideas in the media.

Third, we provide evidence on competition and the role of printer deaths. We show that most cities had small numbers of firms. We then present historical evidence on competition and collusion among local printers. The narrative evidence indicates that price competition was important, collusion was frequent, and printer deaths were shocks that increased competition. Deaths disturbed collusive arrangements that were supported by reputational history and lowered barriers to entry. The historical evidence generates predictions that we test in novel microdata on book prices. We test and verify that when the number of printers in a city increased, the price of books in that city declined. For example, we find that the appearance of an additional printer was associated with a 25 percent decline in book prices within a city-decade.[7] We also test and verify that book prices similarly fell within cities when printer deaths are observed. We further document a strong positive relationship between transport distance and prices for traded books. Our results confirm the salience of within-city competition and indicate the incentives for printers to compete on non-price margins, including product differentiation and quantity.

on the size of print runs are available for only several hundred editions.

[5]Religious publications account for 35 percent of the total. Existing data do not record the ideology of books or authors, and a large share of religious output is by authors whose beliefs are not recorded.

[6]The emergence and diffusion of the Reformation in and across German cities reflected both printing and institutional factors. Printing in Germany was spread across a large number of cities and political authority was relatively decentralized across multiple jurisdictions (Pettegree 2015; Section 2 below).

[7]Mokyr (2005; p. 1121) observes that printing led to dramatic reductions in the price ("access costs") of information. We show that competition among printers drove significant variation in this price.

Fourth, we study the role of competition in determining the number and content of local books. We show that number of books printed responded to variation in market structure in a city; that merchant manual output responded to competition in the merchant manual press; and that Protestant ideas in the media spread most in cities where printing was more competitive when Protestant ideas hit the market in 1517. We find that both variation in the number of firms active in a city and transitions between years with just one firm and years with multiple firms mattered for total and merchant manual printing, even within in narrow city-specific time periods. Our identification strategy uses the fact that entries and exits were large, discrete changes in potential competition relative to more slowly evolving characteristics of local media markets.[8] We confirm our baseline findings with an instrumental variable (IV) strategy, using the timing of printer deaths as a source of exogenous variation in the number of firms competing in a city. Our identification strategy examining religious printing studies how cross-sectional variation in competition *before* the Reformation explains religious output after Protestant ideas hit the market in late 1517. We find that *ex ante* competition positively predicts the diffusion of religious media during the Reformation and the effects are strongest for Protestant content. We confirm these findings using printer deaths just before the Reformation as a source of exogenous variation in the pre-Luther competitive environment.

Fifth, we document the impact of ideas in books on economic and institutional outcomes. We find that the diffusion of merchant manuals explains cross sectional variation in long-run city growth between 1500 and 1600, using the deaths of merchant manual printers as a source of exogenous variation. Deaths of other types of printers have minimal impact on merchant manual output and no growth effects. We also show that shocks to merchant manual printing shifted individual-level achievement at the city-cohort level. We construct panel data from the *Deutsche Biographie*, the definitive "who's who" biographical dictionary of economic and cultural figures in German history (Hockerts 2008). We show that deaths of merchant manual printers drove variation in achievement in bourgeois occupations in cohorts exposed to shocks in late adolescence and early adulthood, i.e. in critical years for advanced human capital formation. We similarly find that variations in the diffusion of Protestant content during the Reformation drove differences in the probability of institutional change, using printer deaths in the immediate pre-Reformation era as a source of exogenous variation.

Our paper relates to several literatures. Research on the origins of European economic development highlights transformations in the market for ideas after 1500 (Mokyr 2016; David 2008). This research raises two central questions: What ideas drove economic and

[8] A related identification strategy is presented by Gentzkow et al. (2011), who study the role of newspaper entries and exits in shifting political activity in early 20th century US media markets.

institutional change? And how can we document the diffusion of ideas? Our research contributes quantitative evidence from printing to study the diffusion of economic and religious ideas that transformed European society. We provide identification strategies that examine how variation in competition in printing shifted the diffusion of ideas and outcomes. More broadly, the evidence from printing after Gutenberg provides a canonical setting in which to examine how the use of a break-through technology maps into output. We use this setting to study how the competitive environment in which technology is deployed may matter for its use, and in particular shape the implications of new media technology. In this respect, our investigation contributes to the economics of concentrated markets and cartels (Levenstein and Suslow 2006; Bresnahan and Reiss 1991).

Our research also contributes to the literature on management practices and upper tail human capital. Previous research has studied the impact of management practices on firm-level outcomes in the post-WWII era (Bloom et al. 2013; Giorcelli 2015). Classic arguments in the social sciences going back to Sombart (1953) suggest that knowledge-based business practices had a profound impact on the historical development of European capitalism. We use data from printing to measure the diffusion of these ideas, uncover sources of quasi-experimental variation in supply, and provide the first evidence documenting the impact of business practice ideas on local growth, to the best of our knowledge. Our findings also relate to the literature on upper human capital, which has documented the role of scientific elites in economic development during the industrial revolution (Mokyr 2011; Squicciarini and Voigtländer 2015). Unlike previous research, our paper provides evidence on sources of quasi-experimental variation in high achievement human capital elites and studies the growth effects of knowledge that transformed business and commercial activity before the industrial revolution.

Our paper also contributes to the literature on media, politics, and institutions. Prior research on the economics of the media has focused on settings where political competition is already established and supported by legal institutions (Gentzkow et al. 2011; 2014; DellaVigna and Kaplan 2007) and on the effects of propaganda by incumbent elites in non-democratic settings (Adena et al. 2015; Yanagizawa-Drott 2014). Prior research in political economy emphasizes the role of politically inclusive institutions as fundamental supports for economic inclusion (Acemoglu and Robinson 2012). In contrast, we provide evidence on the implications of economic competition in the media in a setting where political freedom and voice were otherwise severely restricted. During the Protestant Reformation, economic competition in printing promoted the diffusion of revolutionary ideas, opened new spaces for political and religious participation, and led to institutional change – in a setting with an entrenched elite administering an ideological monopoly.

2 Historical Background

2.1 The Printing Industry

This section provides a condensed review of the historical organization of printing in Europe. The key facts are that: printing was for profit; regulation was light; fixed costs were substantial; competition was oligopolistic; anti-competitive behavior was common; within-city competition was salient; printers had valuable knowledge and relationships; and printer deaths were shocks to local competition that lowered barriers to entry.

1. Printing was a for-profit enterprise from the outset. The first movable type printing press enterprise was established in Mainz, Germany around 1447 by Johannes Gutenberg and his business partners. Despite early attempts to maintain secrecy, the technology diffused to cities across Europe as it was adopted by firms (Dittmar 2011).

2. Printing diffused in an overwhelmingly unregulated, free market setting. Printing fell outside guild regulations (Barbier 2006; Nicholas 2003; Brady 1998). Füssel (2005; p. 59) observes that into the 16th century, the business was, "free to develop without regulation by governments, princely houses or the Church, nor is there any evidence that any restrictions were imposed by guilds." Entry was free and censorship was endogenous even during the Reformation (Hirsch 1967; Davis 1960; Creasman 2012). In some cities, restrictions were imposed on religious printing in response to the spread of Protestantism. For this reason, we study the implications of variation in competition *before* the Reformation for the diffusion of Protestant ideas after they hit the market in 1517.

3. Printing was characterized by fixed costs. The big firm-level fixed cost was the cost of moveable type. The process used to cast type was the key technological break-through in printing and remained semi-secret until 1540; the cost of a complete set of equipment in the mid-1500s was equivalent to 4 to 10 years of skilled wages (Dittmar 2011). In addition, paper was expensive, returns on print runs were realized only over time, and printing required a minimum efficient scale. As a result, printers typically required substantial wealth or financial backing. At the book level, the fixed costs included investments in cultivating and signing contracts with authors and in setting the type to print.[9]

4. The characteristic form of competition was oligopolistic and incumbents repeatedly entered into anti-competitive agreements. Close to 40% of cities with printing had one

[9]For example, in 1483 the Ripoli press in Rome paid 3 Florins for each 20 pages of type setting on Plato's *Dialogs*, used to print 1,000 individual book copies (de la Mare 1985; p. 411). Evidence on firm-level capital is limited, however in the early 1500s the agreements establishing the largest Venetian printing syndicates stipulated capital contributions equivalent to over 1,000 years of unskilled wages and over 100 years of income for a highly paid university professor (Nuovo 2013).

firm; almost 20% of cities had 2; just under 20% had 3 or 4; and just over 20% had 5 or more firms. This distribution was stable across the 1500s as printing spread to new cities. Both formal and informal anti-competitive agreements among firms were common (Pettegree 2011). Section 5 provides details on market structure, syndicates, and cartels.

5. High inter-city trade costs shaped competition. Print media was heavy and costly to transport overland, but also fragile and susceptible to water damage when transported by boat.[10] Books were traded across cities. But due to transport costs, local producers were partially sheltered from import competition, local production was important for access to ideas, and within-city competition was salient (Febvre and Martin 1958; Nuovo 2013; Reske 2007). It was typical to take texts to be printed in cities with potential demand, rather than export over short distances (Edwards 1994).[11] We assemble unique data on book prices in over 40 cities, using the purchasing records of Christopher Columbus' son, who established the most ambitious library collection of the 1500s. These records have "no equal in this time" (Dondi 2010; p. 222) and provide, "an almost unique opportunity to reconstruct the working of the European book market" (Pettegree 2011; p. 87). We use the data to investigate the importance of local competition and local shocks for prices, and the price-distance gradient in the inter-city book trade (Section 5).

6. Printing firms were family businesses to which master printers brought valuable and rare combinations of skills, knowledge, and contacts. Printers were capitalist entrepreneurs, "investors, organizers, and managers of their firms" (Brady 1998). Printers had to be multi-lingual, skilled mechanics, and flexible intellectuals (Eisenstein 1980).

7. The deaths of printers lowered barriers to entry and increased competition. Printer deaths impaired incumbents and unravelled collusive arrangements that were supported by reputational history and social ties. Entry increased in city-years printers where died, even when their firms survived (Reske 2007). Parker (1996; p. 521) observes, "It is difficult to overestimate the disruption caused by the death of a master printer."

2.2 The Role of Business Books in Economic Development

A debate exists within historical research over the impact of the innovations in business practices observed in the 1500s. A significant body of evidence suggests that knowledge-based innovations in math, accounting, and contracting supported the expansion of trade and development (Sombart 1953; Van der Wee 1967). But the adoption of best practice

[10] In a letter written in 1550, the Venetian printing magnate Benedetto Giunti observes: "we are entering a bad period to send books around both by sea and by land, because we are going into winter and they run the risk of getting wet" (quoted in Richardson 1999; p. 37-38). See also Appendix F.

[11] This was the case for pamphlets published during the Reformation (Pettegree 2000; Edwards 1994).

innovations was not universal and occurred with lags, raising questions about whether these innovations had large effects within firms or more broadly (Yamey 1964).[12] The historical debate involves questions that arise wherever best management practices are not adopted by firms for which there are substantial net payoffs (e.g. Bloom et al. 2013).

Narrative evidence suggests that three dimensions of knowledge were particularly consequential: mathematical knowledge for business applications; knowledge about accounting and record-keeping techniques; and knowledge about the use of cashless payments (Davis 1960; Meuvret 1953; Mills 1994; Hoock 2008). Mathematical knowledge provided fundamental human capital for merchants (Jeannin 1996). Knowledge about accounting and record-keeping contributed to efficiency directly and by lowering transaction costs, as accounting ledgers began to be accepted as evidence in commercial courts (Van der Wee 1967). Innovations in cashless payments directly lowered transaction costs and supported innovation in contracting and capital markets.[13]

Printing provided a channel for large scale diffusion. The first printed mathematics texts in Europe were *commercial arithmetics* that transmitted techniques used in business over the 1500s (Swetz 1987; Van der Wee 1993; Meskens 2013). The first guide to double-entry book-keeping was published in the 1490s and this technology spread in the 1500s. Mathematical notation became standardized and European business shifted from an equilibrium of Roman numerals to Arabic numerals – in the 1500s.[14] We observe this transition in publications in our data and in merchant practices. For example, the merchant's manual *Tot Profyte* (Antwerp, 1561) provides accounting examples in Roman and Arabic numerals. The records of Antwerp cloth merchant Frans de Pape switch from Roman to Arabic numerals in the 1560s.[15] More broadly, merchants' manuals provided instruction on business techniques (e.g. letter writing, contract design, norms of conduct).

Printing changed how business practice ideas spread.[16] Person-to-person learning continued and hand-written manuscripts did not vanish (Meskens 1996). But printing amplified and substituted for the diffusion of knowledge that occurred face-to-face and via migration (Cipolla 1981). For example, the first Flemish treatise on book-keeping

[12] A classic debate centered on the claim that double-entry book-keeping by itself revolutionized business activity (Sombart 1953; Yamey 1975; 1964; 1949). This paper emphasis a *suite* of innovations.

[13] The bill of exchange enabled merchants to settle obligations across time and space without exchanging or transporting cash. The bill of exchange also enabled merchants to circumvent prohibitions on usury by structuring loans as foreign exchange contracts (Miskimin 1975) and supported additional innovations in endorsement, discounting, contracting, and market-based transfers of debt obligations.

[14] Arabic numerals were introduced to Europeans in the 1200s, but remained marginal in European economic and cultural life until the print media revolution in the 1500s (Meskens 2013; De Roover 1937).

[15] Similarly, in the records of the Antwerp Schoolmaster's Guild, Arabic numerals first appear in 1545, initiating a gradual transition from Arabic to Roman numbers completed by 1580. See Meskens (1996).

[16] The innovations developed in Northern Italy and were transmitted *within* business organizations in manuscript form (Van Egmond 1980) and via apprenticeships and schooling (Goldthwaite 1972).

was published in Antwerp in 1519 by Jan Ympyn Christoffels on his return from a decade in Venice, where he had been sent by his merchant father to learn business practices and accounting. While printing lowered access costs, merchants' manuals were distinguished by relatively high prices, authors' fees, and mark-ups over costs.[17]

2.3 The Role of Printing in the Protestant Reformation

A debate exists over the role of printing in the Reformation. Martin Luther circulated his theses criticizing church corruption in October 1517. Within months Luther's theses were printed in multiple German cities, provoking a public controversy. When the Catholic Church attacked Luther and other protesting clergy, the reformers responded by disseminating their ideas in print (Cameron 1991). The broad censensus in historical research is that printing played a central role in the diffusion of Protestant ideas (Edwards 1994; Brady 2009; Eisenstein 1980). But prior research does not systematically document the spread of Protestant printing in quantitative terms and invites us to ask whether religious content was determined on the supply- or demand-side (Whaley 2011).

Protestant ideas spread first in the media and then orally in cities. The process followed a "strikingly common pattern" in cities across Germany (Brady 2009; p. 161). Print media impacted clergy and educated lay "opinion leaders," who transmitted ideas orally to the urban public and developed popular movements (Edwards 1994).[18] Early Protestants argued for a "religious community understood as a burghers' [i.e. urban citizens'] association" and used printing to transmit their ideas: "[w]ithout the specifically urban culture of print and humanism... the Reformation is unthinkable" (Hamm 1994; pp. 194-195). In Augsburg, "A wave of religious pamphlets and, from 1520, the introduction of evangelical preaching, spread the new teaching" (Broadhead 1996; p. 581). In Northern German cities, reading groups of the 1520s preceded activism and legal change in the 1530s (Schilling 1983). In Zürich, Reformation activism began when a printer and his workers engaged in civil disobedience by breaking the Lent fast with pastor Ulrich Zwingli as their witness. City authorities arrested the printers. Zwingli gave a sermon in their defense which was disseminated in pamphlet form, opening public debate.

To interpret the role of printing, it is important to observe that the Reformation spread first in cities (Cameron 1991; Ozment 1975). Protestants used printing to address urban

[17] For example, the accounts of the Antwerp printer Christopher Plantin from 1564/5 include information on an accounting manual by Pierre Savonne. The only more expensive book sold by Plantin was a richly illustrated anatomy text; the only book with a higher mark up over costs was a Hebrew bible; and the cost share of author's fees for Savonne were six times higher than for any other book (Voet 1969).

[18] A number of significant lay reformers were city clerks. For example, Lazarus Spengler and Jörg Vogeli were clerks of Nürnberg and Konstanz, respectively, and published reformist works in the 1520s.

audiences, and Protestant movements emerged in cities in the years after 1517 (Scribner 1979). As Dickens observes, "The first and most decisive landslide took place in a host of towns and cities," and "nothing could be more erroneous than to conceive of Lutheranism as a mere princely religion imposed by monarchs" (Dickens 1966; p. 74). Cities were the "avant-garde of the Reformation" in the critical first phase (Rüth 1991; p. 202). Princes adopted Protestantism with a lag, in response to the spread of Protestantism in cities. Indeed, one major "effect of the urban reformation was the powerful radiation of reform into princely reformations" and the "spread of urban behavior, sensibility, thought, and action" beyond the cities (Hamm 1994; pp. 204-5). The first prince to adopt Protestantism was Philipp of Hesse in 1524. Of 18 leading German princes who adopted Protestantism, only three did so by the late 1520s (Cantoni et al. 2018).

Historical research strongly indicates that local factors influenced the diffusion of the Reformation in cities, including behavior in printing. During the Reformation, "religious and moral competition... often took place in compact geographical areas, even within individual cities...competition led to a greater variety in proffered salvation" (Roeck 1999; p. 279). Significantly, the printing of Protestant books was depressed in cities with monopolies or anti-competitive combinations of printers: "Where a market was controlled, the free flow of innovative theological speculation was greatly inhibited" (Pettegree 2000; p. 114). Competition raised incentives for product differentiation, including in religious printing (Reske 2007; Creasman 2012). In Basel, pre-Reformation printing focused on scholarly Latin books for university customers and the sudden appearance of Protestant content, "created a clear opportunity for Adam Petri, who was able to corner the *local market* in evangelical works" (Pettegree 2015; p. 208 – emphasis added). In competitive markets, most printers would "cheerfully print for both sides" (Pettegree 2015; p. 217). For example, all five major firms in Strasbourg produced Protestant content, even the firm run by committed Catholic printer Johann Grüninger (Chrisman 1982). In cities with competitive markets, we observe printers publishing Luther's work and Papal denunciations of Luther in the same year.[19] Narrative evidence indicates that this mattered: Chrisman (1982; p. 29) observes that a printer's "decision to print or not to print a particular book or tract could have an immediate effect on political and religious events and, in a time of rapid change, on institutions. The most striking example of their influence can be seen in the religious publication of the pivotal years of the Reformation."

This historical evidence motivates our analysis of the role of printing in the diffusion of the Reformation at the city-level. We focus on the era in which printing played a central

[19]Erfurt printer Johan Knappe published Martin Luther and the Papal Bull condemning Luther. Similarly, Strasbourg printer Johann Schott had a 'hit' with Luther's *Babylonian Captivity* in 1520 and a few weeks later published the Papal Bull condemning Luther.

role, which began in 1518 and lasted until 1555. Over this period, Protestant ideas first spread in the media. Starting in the 1520s, Protestant reformers worked with city councils to pass laws that reformed religious services, established public education, expanded public goods, and generated institutional variation within territories (Hamm 1994). In 1555, the Peace of Augsburg formalized a legal settlement governing religion in the Holy Roman Empire – fixing institutions and establishing a geographic distribution of religion that would be maintained for several centuries (Brady 1998).[20] In several of our analyses, we focus further on printing in the first years of the Reformation, before any cities had adopted institutional change and before any princes had adopted Protestantism.

The supply of printed books was not the only factor influencing diffusion. Demand for Protestantism could vary (Ozment 1975; Whaley 2011). Institutions and culture also provided important preconditions. Moeller (1972) argued that cities with "free-imperial" status, which were not legally subject to a local lord, played a key role in the diffusion of the Reformation. Subsequent research has shown that the power of lords to control printing and the spread of Protestantism was very limited in the initial diffusion period, and that Protestantism spread dramatically in "territorial cities," which were *de jure* subject to local lords (Hamm 1994; Rüth 1991; Schilling 1983). This reflected the local autonomy of cities and the fact that, "Despite the variations, all urban communes were characterized by a similar ethos and throughout the Reich [i.e. Holy Roman Empire] they developed elements of what has been called 'Christian republicanism' during the medieval period... The autonomy of the community, its freedom from any external control, and its right to self-determination were fundamental... in decisions concerning policy, not only in administrative matters but also in questions of war and peace, taxation, changes in the [city] constitution, and religion" (Whaley 2011; p. 140). For example, public protest drove the Wittenberg city council to pass the first law formalizing the Reformation against the express disapproval of the Elector of Saxony, who was the local prince (Scribner 1979; Lindberg 1977).[21] Such events reflected the extreme decentralization of the Holy Roman Empire. Indeed the diffusion of Protestantism in German cities was arguably promoted by the interaction between competition in printing and political decentralization (Pettegree 2015). Pointing to the importance of local factors, we find that the implications of printer competition for city-level diffusion were not different in more decentralized regions.

[20] The Peace of Augsburg set the rule *cuius regio, euis religio* (whose rule, his religion) with exceptions for cities where Protestants and Catholics were to share churches and magistracies. We restrict some of our analysis to the spread of Protestantism in the media over the very first years of the Reformation.

[21] "Under immense pressure, and in the face of the express disapproval of the Elector, the town council found itself obliged to accept a whole raft of reforms, culminating in a new church ordinance on 24 January 1522. This embodied all the popular demands" (Whaley 2011; p. 199). This took place while Martin Luther was under house arrest for several months 200km away at the Wartburg castle.

3 Data and Estimation Strategy

3.1 Data

Publications — We measure publications by the book or pamphlet edition, which can be thought of as a variety produced in a given city-year. We study over 299,000 editions printed in Europe between 1454 and 1600. The data are from the Universal Short Title Catalogue (USTC 2012), which is designed to catalogue all known books and pamphlets printed in Europe before 1600.[22] The USTC does not identify business education publications or classify religious publications by denomination or ideology.

Business Education Publications — We manually code data on business education publications from *Ars mercatoria: eine analytische Bibliographie: Handbücher und Traktate für den Gebrauch des Kaufmanns* (Hoock et al. 1991; Hoock and Jeannin 1993; Hoock et al. 2001), a three volume compendium designed to record all merchant manuals and business education texts printed in Europe through 1600. The Hoock and Jeannin data catalogue 1,151 merchants' manuals printed across Europe 1474-1600. We match individual publications in the Hoock and Jeannin data to the USTC using title, author, date, printer, and other information as described in the Appendix.[23]

Classification of Religious Publications as Protestant or Catholic — We classify religious publications as Protestant or Catholic based on the statistical distribution of authors' language, using multinomial inverse regression (MNIR) (Taddy 2013b; Gentzkow and Shapiro 2010). We first estimate how the distribution of language changes with religious affiliations of known 459 authors (225 Catholics and 234 Protestants). We then classify religion at the author level based on the 'distance' between authors' language and that of known Protestants and Catholics. We classify at the author-level to improve classification both in-sample and out of sample in held-out subsets of the data.[24] We restrict our classification of religious publications to printing in cities in German-speaking

[22] Three key observations support our investigation using these data. First, "rates of survival are spectacularly good for pamphlet literature of Luther's day, because though essentially ephemeral, the *Flugschriften* [i.e. pamphlets] were gathered up and assiduously collected at the time of publication" (Pettegree 2007; p. 144). Second, it is unlikely that selective survival could account for our results examining total and merchant printing in the panel. To explain these findings, the selective survival would have to have shifted year-on-year with industrial organization. Third, our analysis of price data supports our interpretation of the evidence on the number of publications, and uses independently collected data which are not characterized by survival bias.

[23] We correct a limited number of errors and omissions in the Hoock and Jeannin data. See Appendix A.

[24] We defer a study of within-author variation to future research. Any sacrifice here is minimized by the fact that extremely few Protestant authors had any substantial publication record as Catholics. The within-author variation available to study is almost entirely within religion. To identify authors' religion we rely on Klaiber (1978), Mullett (2010), Carey and Lienhard (2000), and Wikipedia's list of Protestant Reformers. See www.wikipedia.org/wiki/List_of_Protestant_Reformers (downloaded 12/15/2012).

Europe, where the media played a key role in the diffusion of the Reformation, and to publications the USTC identifies as religious (35% of the total). We classify authors' output as Protestant if predicted Protestant is greater than or equal to 0.5 and Catholic otherwise.[25] Our classification enables us to measure content in the majority of output which is by unknown authors, and in cities in which no publications by known religious authors appeared (see Appendix A.4). Our classification uses within-Latin and within-German shifts in the language used by Protestants and Catholics.[26]

Our classification procedure studies variation in language in long historical book titles that provide extensive information on content.[27] To understand the information in titles, we provide two examples of English-language books printed in 16th century Germany.[28] An example Protestant title is a book written by Martin Luther and printed in Wesel:

> The last wil and last Confeßion of martyn Luthers faith concerning the principal articles of religion which are in controversy, which he wil defend & maiteine until his death, agaynst the pope and the gates of hell.

An example Catholic title is a book written by John Old and printed in Emden:

> A Confeßion of the most auncient and true christen catholike olde belefe accordyng to the ordre of the .XII. Articles of our comon crede, set furthe in Englishe to the glory of almightye God, and to the confirmacion of Christes people in Christes catholike olde faith.

Table 1 presents the top German-language three-word phrases differentiating Protestant and Catholic publications. The top Catholic phrases notably come from "postils," a genre of standardized biblical passages accompanied by brief outlines and explanations that was central in popular German-language religious publication (Frymire 2010).[29] We classify religion examining one-, two-, and three-word phrases. Appendix B provides more detailed evidence on which phrases carry the most weight in identifying religion within German printing and within Latin printing, and additional examples of titles.

[25] Our classification provides a *proxy* measure of religious content. Our baseline analysis examines the relationship between printer competition and classified counts of Protestant and Catholic publications. To address potential questions about this proxy, we also investigate the relationship between printer competition and a continuous measure of religion in books, and find similar results (Appendix E.10).

[26] The Catholic-Protestant distinction is a powerful first model for religious ideas in the Reformation. In part this is because later divisions between Lutheran and Calvinist Protestants were only incipient in the first half of the 1500s. We discuss extensions and time-varying features of religious language below.

[27] Taddy (2013c) applies a similar research design to measure political sentiment in twitter "tweets." The *median* title in our data is longer than the *maximum* length for a "tweet."

[28] These are titles that were printed in English in the 1500s, which we present exactly as they originally appeared. We provide examples of historic German titles, with our own translations into English, below. In the data, 96 percent of publications are in German and Latin in approximately equal shares.

[29] For example, Johann Wild, the Catholic Cathedral preacher of Mainz, authored a postil: "Postill oder predigbuch Evangelischer warheyt und rechter Catholischer lehr uber die Evangelien so vom Advent an biß auff Ostern gelesen werden und auff jeden Sontag..." Translation: "Preacher's book of evangelical truth and law, Catholic teachings on the Gospels, to be read at Easter and every Sunday..."

Our classifier shows high performance on in- and out-of-sample classification. In-sample, we correctly predict the religion of an author 86% of the time.[30] We obtain simlar success rates out of sample when we estimate (train) over 80% of the data and predict (test) over the held-out 20%. These cross-validation exercises also show that the estimator is not overfitting. Figure 1 shows the performance of the classifier on held-out test data from a single draw and highlights how well we predict prominent authors Martin Luther and Johannes Eck. We provide detailed evidence on our classification and how it compares to strategies in the literature in Appendix B.

Table 1: Phrases Differentiating Protestant and Catholic Publications in German

Protestant		Catholic	
sermon von dem	sermon on the	sacrament des altars	sacrament of the altar
sermon von der	sermon for the	die sontags evangelia	the evangelical sunday
in der kirchen	in the church	biß auff ostern	from easter
ain sermon von	a sermon on	auf die fest	from the feast
die jungen christen	the young christians	an biß auff	and so from
des liebs und	of love and	unser lieben frawen	our dear women

This table reports presents top three-word phrases (trigrams) that differentiate Protestant and Catholic authors. In the original, some words are capitalized which are rendered in lower case here. See text and footnotes for discussion of titles in which this language is observed.

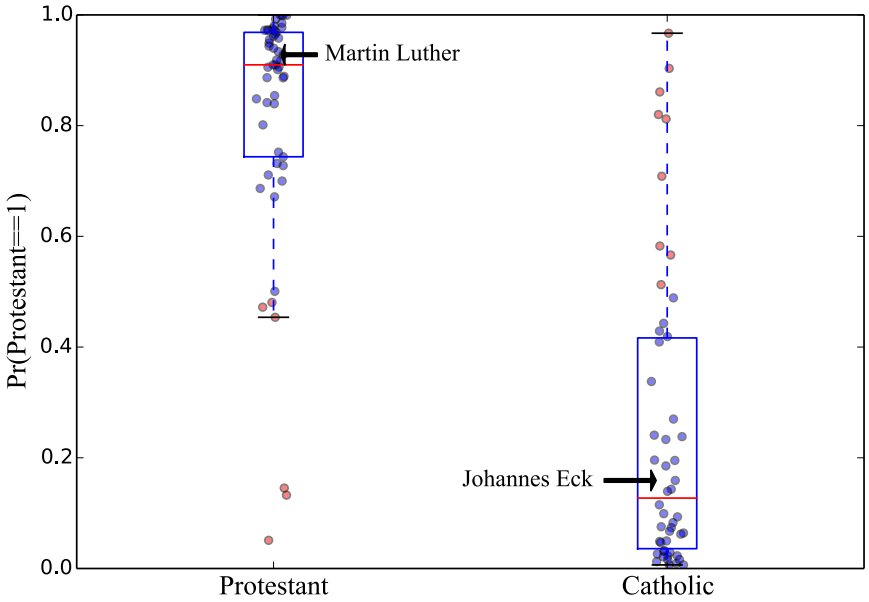
Prices — We code data on prices for books and pamphlets purchased by Hernando Colón from the library catalogues and records (Martínez et al. 1993; de Huelva 2012). We use the catalogues and archival research to code physical and content characteristics for each item, including book format, length, the presence of illustrations, the use of multicolor ink, binding, and 37 content fixed effects. We convert all prices into Venetian ducats and deflate prices by prevailing wages. Appendix A provides details on these data.

Printing Firms — We construct data on the firms active across cities and time as follows. (1) We construct a *publications measure* by identifying firms active at the city-year level from inscriptions on historical publications that identify printers. We harmonize names and construct consistent firm identifiers. (2) We construct a *biographical measure* by hand-coding data on the city-years of operation for printers in the subset of 205 German-speaking cities using Reske (2007; 2015), *Die Buchdrucker des 16 und 17 Jahrhunderts im deutschen Sprachgebiet*, the authoritative biographical and business dictionary of historical printers in German-speaking Europe.[31] See Appendix A for details.

[30] This success rate compares favorably to results in similar prediction problems in the literature. For example, Gentzkow and Shapiro (2010) predict the party of US Congress members based on the text of their speeches, and obtain a correlation of 0.61 between true and predicted affiliation.

[31] Reske (2007; 2015) builds on the biographical catalog produced by Josef Benzing (1982), librarian at the Prussian State Library 1934-1945 and at University of Mainz 1946-1966. See Appendix A.

Figure 1: Out-of-Sample Classification of Religious Authors



This graph presents the out-of-sample classification performance for a single draw from the data. The model is trained on 80% of the data and predicted on the held-out 20%. We present predictions for held-out Protestants (at left) and for held-out Catholics (at right).

Printer Deaths — We construct data on the timing of printer deaths as follows. (1) We construct a *publications measure* in which we infer the year of death from printed inscriptions in books. These inscriptions record whether a publication is produced by the widow or heirs of a printer. We infer that the printer death occurred in the first year such an inscription appears. By construction, the publication measure of deaths is observed for firms that survive deaths. (2) We construct a *biographical measure* from data on the years of death for German printers which we hand-code from Reske (2007; 2015). These data enable us to distinguish between deaths of active printers and deaths of printers who were retired or no longer active. We use these data to address questions concerning the selective observation of deaths in publications. For German firms before the Reformation the data are as follows. First are 8 firms that experience a death which leads to their exit. Second are 3 firms that experience a death but do not immediately exit because a widow or heir becomes owner-manager.[32] Third are 73 firms who survive without deaths. Fourth are the firms that exit between 1508 and 1517 without a death recorded in this period by Reske. For these 31 printers, we gather historical data on the timing of their later deaths, inter-city migrations, and business activities to document that they did not die in our key pre-Reformation period and that selective data preservation in Reske (2007; 2015) is not driving our results. See Appendix A for details.

[32]These 11 printer deaths are observed in 9 cities. Results are robust to studying the number of deaths or the binary (1/0) presence of a death as a source of variation in local competition. Results are robust to including as a "death" an additional case where historical records are ambiguous. We acknowledge here that the identifying variation in some parts of the analysis comes from a small number of cases.

Economic Outcomes — We use data from Bairoch et al. (1988) on the populations of 269 European urban agglomerations observed in 1500 and 1600. We construct data on the "who's who" of historical German cities from the *Deutsche Biographie* (Bayerischen Akademie der Wissenschaften 2015), the most comprehensive record of important individuals in German history to the best of our knowledge (Hockerts 2008). We classify the occupations of individuals in the *Deutsche Biographie* as either (i) bourgeois or (ii) Church or noble. Appendix A provides details on the data and occupational classification.

Institutional Outcomes — We measure institutional change with the passage of a Reformation law before the 1555 Peace of Augsburg. For cities in contemporary Germany, we code laws recorded in, *Die evangelischen Kirchenordnungen des 16 Jahrhunderts* (Sehling et al. 1909-2013; 21 volumes), which collects the texts of all known Reformation laws passed in the 1500s in German cities. For a small number of German-speaking cities in Switzerland, Alsace, and Poland we rely on additional sources described in Appendix A. We study institutional outcomes in 191 German-speaking cities that either (i) were printing cities or (ii) had population observed in 1500 in Bairoch et al. (1988).

3.2 Estimation Strategy

We study how competition in printing shaped the diffusion of ideas, and how ideas drove economic and institutional change. These relationships can be summarized schematically:

$$\text{Competition} \Rightarrow \text{Ideas in Publications} \Rightarrow \text{Outcomes}$$

We examine the relationships between competition and ideas, and between ideas and outcomes, with several different research designs. We study variation in panel data and in the cross-section, depending on the nature of the available data.

In Section 4, we motivate our analysis by documenting cross sectional correlations between the diffusion of ideas and city-level outcomes. Merchant manual printing was correlated with city growth across Europe between 1500 and 1600; Protestant printing was correlated with institutional change during the Reformation in German cities.

In Section 5, we characterize the nature of competition. We present evidence on market structure, the prevalence and fragility of anti-competitive arrangements, and the role of printer deaths as shocks that *increased* entrance and competition.

In Section 6, we study how variation in market structure that shaped competition explains production. We study variation in total and merchant manual output at the city-year level. We estimate models that examine how variation in competition predicts

variation in output within city-decade. The intuition is that the timing of entries and exits within city-decades provides quasi-experimental variation in market structure relative to more slow-moving demand-side features of local media markets.[33] We study two proxy measures of competition. The first is whether at least two firms are active: we compare production in city-years with multiple firms and in city-years with monopoly. The second is the number of firms active: we compare production as the number of firms varies. We examine the implications of variation in the number of firms directly and using printer deaths as an IV for the number of firms. In contrast, we study religious printing during the Reformation in a cross-sectional design. We study how competition before Protestant ideas hit the market in 1517 predicts religious printing in the "post" period that runs from 1518 to the 1555 Peace of Augsburg. We estimate separate models for Protestant and Catholic publication outcomes. We compare production with multiple firms and with monopoly and study the implications of variation in the number of firms in the cross section, using printer deaths just before the Reformation as a source of exogenous variation in the number of firms active in a given city.

Finally, in Section 7 we study the causal impact of ideas on city growth and institutional change, using the deaths of printers as a source of exogenous variation in number and content of publications in cross-sectional designs. For merchant printing, we use deaths of merchant printers over the course of the 1500s. For our study of merchant printing, we provide corroborating evidence from panel data on individual achievement at the city-cohort level. We show that shocks to merchant printing that hit city-cohorts in late adolescence positively impacted individual achievement in 'bourgeois' occupations (i.e. in financial services, public sector administration, education, science, medicine, and the arts) and negatively shifted individual achievement in religious careers. To study the role of the media in institutional change during the Reformation, we examine variation in religious publishing induced by printer deaths just before the Reformation.

4 The Role of Book Content in Economic and Institutional Change

In this section, we present evidence on the relationship between the content of books and pamphlets and economic and institutional outcomes. We document positive relationships between the diffusion of business education content and city growth, and between the diffusion of Protestant content and institutional change at the local level during the

[33] It is also unlikely that any selective survival of books varies with competition at these frequencies.

Reformation. These results are suggestive correlations, not causal statements.

4.1 Business Education Content and City Growth

We study the relationship between the local production of merchants' manuals and city growth between 1500 and 1600 and document a large and highly significant positive correlation. In contrast, the correlation between total book publication and growth is relatively small, and conditional on business education there is effectively no relationship between the diffusion of books and growth. We examine city growth as a measure of economic dynamism in pre-industrial Europe motivated by the literature on historical growth (Acemoglu et al. 2005; DeLong and Shleifer). We disaggregate book production to document the relationship between urban dynamism and specific bodies of knowledge and ideas in print and restrict attention to 269 European cities with printing and with population recorded by Bairoch et al. (1988).

To study the relationship between the diffusion of content and growth, we estimate regressions of the form:

$$\ln(pop_{1600}/pop_{1500})_i = \alpha_0 + \alpha_1 publications_i + \gamma X_i + \epsilon_i \quad (1)$$

The outcome is log population growth and *publications* measures the number of publications produced between 1500 and 1600. We first look at merchants' manuals, then publications in general, and then a 'horse race' between merchants' manuals and publications in general. We measure publications in levels and in logarithms. The X_i control for initial city population, port location, the presence of universities, navigable rivers, latitude, longitude, the interaction of latitude and longitude, and country fixed effects.

Table 2 shows that merchant manual production had a large, robust, and highly significant relationship with city growth, whereas books in general did not. These results highlight the importance of disaggregating the ideas in print and raise the question of whether the estimated parameters reflect unobservables that were the underlying determinants of city growth. The positive relationship between merchants' manuals and growth could capture the impact of knowledge in books or variations in underlying business environments and demand. We consider this question below, using printer deaths as a source of exogenous variation in supply.

Table 2: Merchant Manual Printing and City Growth

	(1)	(2)	(3)	(4)	(5)	(6)
	Outcome: Log Population Growth 1500-1600					
Merchant Manuals	0.454**		0.429*			
	(0.193)		(0.243)			
Publications		0.002**	0.000			
		(0.001)	(0.001)			
Ln Merchant Manuals				0.173***		0.127**
				(0.051)		(0.047)
Ln Publications					0.065***	0.023*
					(0.019)	(0.013)
Observations	269	269	269	269	269	269
R^2	0.26	0.25	0.26	0.32	0.28	0.33

This table reports estimates from regressions studying city population growth. The outcome is log population growth at the city level: $\ln(pop_{1600}/pop_{1500})$. "Publications" is the count of publications (varieties) observed 1500-1600 in units of 100. "Merchant Manuals" is the count of merchant manuals observed 1500-1600 in units of 100. All regressions control for log population in 1500, country fixed effects, city latitude and longitude, and indicators for: navigable rivers, ocean or sea ports, printing pre-1500, and the presence of universities established pre-1500. Standard errors in parentheses are clustered by country. Significance denoted: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2 Protestant Content and Institutional Change

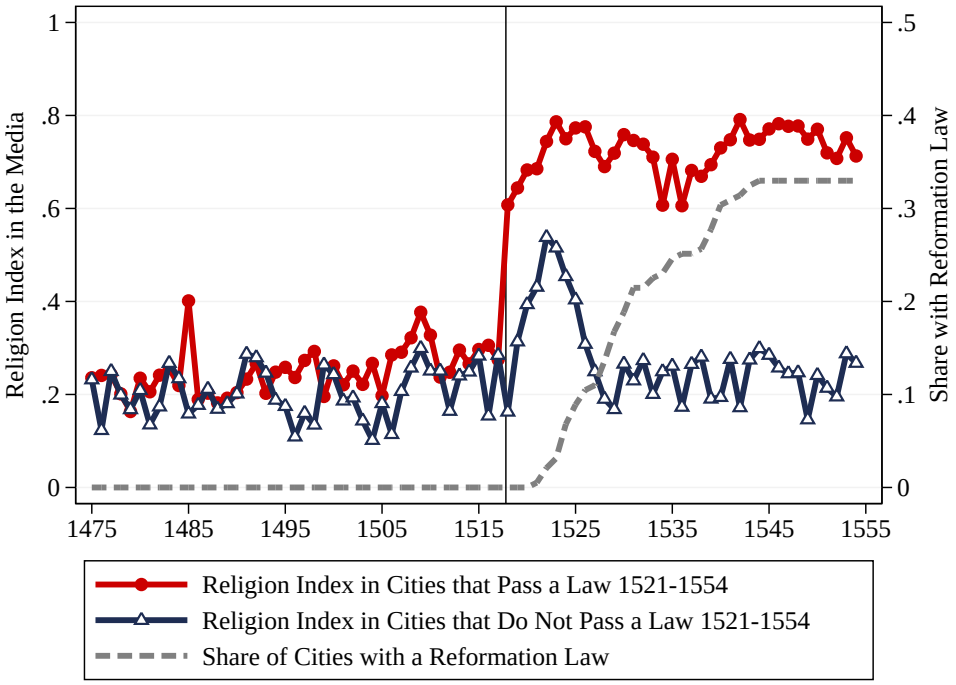
Narrative evidence indicates that the diffusion of ideas in print led to institutional change at the city level during the Protestant Reformation.[34] We examine whether local exposure to Protestant media positively predicts institutional change. We study city level institutional change because the legal institutions of the Reformation were first developed at the city level (Hamm 1994; Cameron 1991); cities provide rich variation in both printing and institutional change; and these institutions explain subsequent human capital and growth outcomes across cities (see Dittmar and Meisenzahl (2018) and Appendix E).

In Figure 2, we plot the relative intensity of Protestant ideas in cities that did and did not adopt city-level Reformation laws and the share of cities adopting Reformation institutions over time. We measure religion in the media as the mean of religious content (Protestant = 1, Catholic = 0). Prior to the Reformation, cities that did and did not adopt institutional change were producing similar religious media and there are no pre-trends. During the first years of the Reformation, Protestant content increased in all cities, but cities that pass laws produced more. From the 1520s, a gap opens and stabilizes. While large shifts in media content are observed in 1518, shortly after Martin Luther circulated his *hand-written* theses in late October 1517, institutional change

[34]For example, Ozment (1975; p. 49) observes that the Protestant books and pamphlets that we study, "express viewpoints that were later embodied... in church ordinances."

started in the 1520s. The share of cities with a Reformation law plateaus in the 1540s, when institutional change was arrested by the Schmalkaldic War 1546-7. Within the set of adopting cities, the Protestant share of religious content increases in years prior to institutional change and is stable afterwards, as we show in Appendix E.

Figure 2: Religious Ideas in the Media and City-Level Institutional Change



This graph presents the annual mean of the religion index for religious publications in cities that did and did not pass Reformation laws (Protestant = 1, Catholic = 0 on left axis). The graph also presents the share of cities having adopted institutional change measured by the passage of a city Reformation law (on right axis). The vertical line at October 1517 marks the first circulation of Martin Luther's theses.

We test whether local variation in Protestant media output in the early years of the Reformation predicts institutional change. Luther's ideas hit the media in 1518. Institutions began to change in 1521. The outcome we study is the passage of a Reformation law between 1521 and 1554, one year before the Peace of Augsburg. We use linear probability models to examine how local output of Protestant media between 1518 and 1521 shifted the probability of institutional change. Our baseline estimating equation is:

$$law_{i,1521-1554} = \alpha + \beta \ln(protestant\ publications)_{i,1518-1521} + \theta X_i + \epsilon_i \qquad (2)$$

where law_i is an indicator for cities with Reformation laws, $\ln(protestant\ publications)_i$ is the logarithm of Protestant publications plus one. The X_i control for pre-Reformation city characteristics: the presence of formal market rights, universities, free-imperial status, city status as subject to ecclesiastical or prince-bishop rule, location on rivers, universities, and initial population. To control for the influence of local lords and regional

factors that may have influenced supply and demand, we study variation within states and within geographic grid cells of 3-degrees (210 km) and 1-degree (70 km) latitude.[35]

Table 3 presents our results and documents a strong positive relationship between Protestant media and institutional change. Our estimates imply that a one standard deviation increase in Protestant content between 1518 and 1521 is associated with a 6% to 9% increase in the probability a city adopted the legal institutions of the Reformation (one standard deviation in 'ln Protestant' is 1.10). Our estimates are relatively stable across specifications, and hold within tight geographic regions. Institutional change was thus related to variation in media content even across neighboring cities exposed to similar regional influences, including the preferences of territorial rulers. The first prince to adopt Protestantism, Philipp of Hesse, did so later, in 1524.

Table 3: Protestant Media and Institutional Change at the City-Level

	(1)	(2)	(3)	(4)
	Outcome: Reformation Law Passed 1521-1554			
Ln Protestant Publications 1518-1521	0.09***	0.06***	0.06	0.08**
	(0.03)	(0.02)	(0.04)	(0.04)
Cluster Definition	State	State	210km	70km
Cluster Fixed Effect		Yes	Yes	Yes
Observations	191	191	191	191
Controls	Yes	Yes	Yes	Yes

This table presents linear probability model estimates of the relationship between institutional change and Protestant publications. The outcome is a binary indicator for the passage of a law between 1521 and 1554. "Ln Protestant Publications 1518-1521" is the logarithm of the count of Protestant publications plus one. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for university towns, feudal cities (not free-imperial), Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Standard errors are clustered on state or on geographic grid cells as indicated. The states are the historic principalities of the Holy Roman Empire. Following the Euratlas classification, free cities are assigned to the "Small States of the Holy Roman Empire" state category. The "210km" cluster designates grid cells of 3 degrees latitude (2 degrees × 3 degrees, reflecting the earth's curvature). The "70km" grid cell designates 70km grid cells of 1 degree latitude. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

While local variation in religious media predicted institutional change in tight geographic neighborhoods, both printing and institutional change may have reflected variation in local demand. Below we use an IV strategy to isolate plausibly exogenous variation in printing, focussing on the timing of printer deaths in the immediate pre-Reformation years as shocks to competition and thus output.

[35]There are 21 grid cells of 210 km (mean 9.1 cities) and 56 cells of 70 km (mean 3.4 cities).

5 Market Structure, Competition, and Printer Deaths

5.1 Historical Evidence

Historical evidence on competition and the role of printer deaths motivates our analysis.

Media markets in Renaissance Europe were characterized by a small number of producers. Table 4 shows that most cities had few printing firms. Across the 1500s, approximately 40% of cities with printing had one firm and approximately 20% had two firms, three to four, and five or more. This distribution was relatively stable over time.

Table 4: The Number of Firms Active Across European Cities

		Share of Cities with			
Year	Cities	1 Firm	2 Firms	3 or 4 Firms	5+ Firms
1500	82	.46	.22	.13	.18
1525	112	.41	.18	.22	.19
1550	142	.43	.20	.16	.21
1575	178	.37	.19	.20	.24

This table presents evidence on the number of firms active across European cities. Firms are identified from the inscriptions on historical books as described in Section 3.

Narrative evidence indicates that price competition was salient. Hirsch (1967; p. 27) observes that "undercutting was used without interference" because printing developed in a lightly regulated, "free enterprise fashion." "Ruthless, price-cutting tactics" were developed by printers like Nicolaus Jenson in Venice who emerged as major producers (Lowry 1992; p. 381). Indeed, there was frequently "ruinous competition" among printers (Bühler 1960; pp. 54). Historical research indicates competition within cities was salient, and that local industrial organization influenced competitive conduct in printing, because inter-city transport costs were high (Pettegree 2011; Nuovo 2013; Richardson 1999).

Printers developed arrangements to limit competition. The two largest printers in Venice, Johannes de Colonia and Nicolaus Jenson, known for "ruthless" price competition, formed a syndicate in 1480 with several smaller printers. In the 1500s, the Giunti family established a syndicate to fix book prices and limit output. The syndicate comprised, "the most powerful names in Venetian publishing... the contract stipulated the timing and procedures for the realization of [a multi-year publishing] program. It also prohibited competition... and [determined] what the press runs... and sale prices were to be" (Nuovo 2013; pp. 56-59).[36] A contract among Milanese printers stipulates that

[36]The contract was designed to simplify and facilitate monitoring: prices were fixed on a per page basis. The capital contributions in the business agreement were equivalent to over 1,000 years of wages

books, "are not to be put on the market at a price lower than the company's selling price" and that the parties are "bound to secrecy about the business operations" (Brown 1891; p. 27). In 1552, Parisian printers signed an agreement to jointly produce editions of Thomas Aquinas, split the output equally, and maintain a price floor (Parent 1974; p. 141). Renewable agreements limiting competition and establishing syndicates were typically set for a fixed duration of under 10 years, as was the syndicate established in Lyon by Jacques Giunta (Dureau-Lapeyssonie 1969), syndicates in Italy (Lowry 1992), and Germany (Reske 2007). Informal collusion was also common. In Paris several printers coordinated their activities under the leadership of Jean Janot, who was "effectively the head of a single enterprise that comprised three printing houses" (Runnalls 2000; p. 824). More generally, "If a single printer or group of printers was known to command a particular market, interlopers could be deterred from entering" (Pettegree 2011; p. 70). Interlocking business relationships were common (Reske 2007; Renouard 1964). Further details on anti-competitive arrangements are provided in Appendix C.

Reputational history and social ties supported anti-competitive arrangements. In Paris, for example, "the industry developed a complex set of alliances between leading families, which effectively froze out newcomers" (Pettegree 2015; p. 271), with the printer Jean Janot at the center of "a network of commercial and familial relations" designed to limit entry (Runnalls 2000; p. 800).[37] In Lyon, Luxembourgo Gabiano was the "pivot" in a close knit company with a local monopoly over specific types of books (Dureau-Lapeyssonie 1969). In Augsburg, Johan Otmar coordinated production with Erhard Ogelin and Johann Schönsperger (Reske 2007). The narrative evidence indicates that reputational history and social ties shaped behavior through the information they conveyed about competitors and their influence on beliefs, consistent with the economic theory of oligopoly and cartels (Levenstein and Suslow 2006; Tirole 1988).

Printer deaths were shocks that disturbed collusive arrangements, lowered barriers to entry, and typically increased competition. Printer deaths removed printers with reputational histories that supported collusion and directly dissolved syndicates (Reske 2007). The multi-firm syndicate set up by Venice's two leading printers in 1480 lasted only one year due to the deaths of the two leading partners (Nicolaus Jenson and Johannes de Colonia both died). Similarly, the Giunti syndicate declined in the 1570s after the death of its leader (Nuovo 2013). Printer deaths also lowered barriers to entry, both by perturbing collusive arrangements and by weakening directly affected firms, limiting their individual ability to take actions to limit entry (Maclean 2009).[38] When printers died,

for an unskilled worker. Lowry (1992; p. 381) observes that the Giunti, "laid the foundations of a financial oligarchy," as the original six year printing syndicate agreement was repeatedly prolonged.

[37]These printers shared and divided their business and operated as what Runnalls terms a "clan."

[38]In general, deaths triggered costly legal action among printers with business relationships: "If the

entry increased even when their firms survived (Reske 2007). For example, Augsburg printer Erhard Oeglin had cooperative business arrangements with Johan Otmar and Johann Schönsperger, but died in 1520 (Reske 2007). Oeglin's widow printed through 1522. But Melchior Ramminger entered the Augsburg market in 1520; Matthaus Elchinger entered in 1522; and Phillip Ulhart entered in 1523 and acquired Oeglin's type. Entrants could come from within a city, but the intercity mobility of printers is well-documented (Febvre and Martin 1958). In our data, 8% of printers made permanent moves.[39]

The historical evidence implies predictions on prices, quantities, and entrance. We present and test predictions on prices first. We then study how output responded to variation in competition and the role of printer deaths (Section 6). We also show that when printers died entrance increased, including due to cross-city relocations by printers, which indicate the importance of location and transport costs (see Appendix C).[40]

5.2 Predictions and Evidence on Prices

The narrative evidence on competition implies predictions on prices. We predict that local competition influenced book prices: prices should fall when competition increases in a city. We predict that printer deaths are associated with price declines within a city, given the evidence indicating these deaths promoted competition. We also expect that prices should rise with trade distance. Significantly, the evidence on these predictions will help us interpret the relationship between competition and publication outcomes.

We use microdata on prices to test and verify these predictions. We first focus on changes in industrial organization and prices within cities over narrow time periods. Our data allow us, for example, to compare prices for books purchased in Nürnberg across years in the 1520s, before and after one additional printer entered the market. Our data record purchases made 1512 to 1536 and within city-decade variation in competition and prices for over 1,000 purchases in Brussels, Frankfurt, León, Milan, Modena, Nürnberg, Rome, and Venice. We focus on how changes in the number of local printers translated into changes in book prices, controlling for the overall level of prices in a city-decade, which may have reflected city-specific demand and exposure to regional book markets. We also study how prices varied with printer deaths, and with the distance between the city in which a book was purchased and the city where it was printed. Further details

associations or companies of publishers had to be terminated because of death or disharmony, the resultant legal actions seem often to have been highly complex and expensive" (Maclean 2009; p. 246).

[39]For this calculation, "permanent" moves are defined as moves where the year of the last book printed in city A is equal to or earlier than the year of the first book printed in city B.

[40]We further show that the deaths of specialized merchants' manual printers precipitated entry by new merchant manual printers, while deaths of other printers did not (see Appendix C).

on book purchases and summary statistics are provided in Appendix A.

We first estimate a regression model of the form:

$$p_{ijt} = \beta competition_{jt} + \theta_{j,decade} + \lambda distance_i + \gamma X_i + \epsilon_{ijt} \quad (3)$$

Here p_{ijt} is the logarithm of the price of book i purchased in city j at year t, and $competition_{jt}$ records the number of printers active in this city-year. The $\theta_{j,decade}$ are city-decade fixed effects and $distance_i$ is the logarithm of distance in kilometers between the city where the book was purchased and the city where it was printed plus one. The X_i are book characteristics including: indicators for whether a book was printed in another city, book format (folio, quarto, octavo, or other), illustrations, multicolor ink, and 37 content categories, as well as the number of pages and book age. We extend the analysis to examine the variation in price associated with the transition from monopoly to having multiple printers active, and the relationship between prices and printer deaths.

Table 5 presents our estimates. We find that when the number of printers increases, prices fall significantly. An additional printer is associated with a 25 percent decline in book prices within a city-decade, controlling for book characteristics (column 1). We find that the transition between monopoly and competition, defined as more than one printer, is associated with a price decline of over 35 percent (column 2). However, in the price data we only observe the transition from monopoly to competition in Leuven and do not observe multiple purchase years in Leuven in the same decade. For this reason, in column 2 we report estimates with city fixed effects and interpret our results with more caution.[41] Printer deaths, which delivered shocks to local competition, are similarly correlated with low prices (column 3). The variation we study here arises from printer deaths in Augsburg, Bologna, Cologne, Nürnberg, and Venice. In these cities we do not observe within city-decade variation in deaths and prices, so we estimate a model with city fixed effects and emphasize that our results are suggestive correlations.[42] Significantly, these results may understate the impact of competition on real prices if increases in competition also led to an expansion in the variety and quality of publications printed and on the market in a given city. We investigate these competitive effects below.

We also find that transport distance is positively associated with price as predicted. The estimates in columns 1-3 imply that doubling transport distance was associated with a price increase of approximately 30 percent. Transport distance similarly predicts prices within city-years, indicating that the price-distance correlation is not driven by factors

[41] Purchases are observed in Leuven in 1521 and 1522, with one printer active, and 1531, with multiple.

[42] As price data are available irregularly, we investigate printer deaths more fully in the data on publications, where we have data on output, competition, and deaths for all city-years.

that vary across years (column 4). Because one might wonder whether both transport distance and price may have been high for books prized for an underlying collectibility, we also restrict analysis to new books where this is less likely. We find a positive, significant, and even larger relationship between distance and price for new books (column 5). To interpret these estimates as recovering the causal impact of transport on price, an identifying assumption is that there are not omitted factors associated with transport distance and price. We provide further discussion in Appendix F.

Table 5: Printer Competition and Book Prices

	(1)	(2)	(3)	(4)	(5)
	Outcome: Ln Price				
	Complete Data				New Books
Printers: Number of Firms	-0.25***				
	(0.07)				
Indicator: 2+ Printers		-0.37**			
		(0.16)			
Printer Death			-0.43*		
			(0.24)		
Ln Transport Distance	0.36***	0.37***	0.37***	0.36***	0.60**
	(0.08)	(0.08)	(0.08)	(0.08)	(0.23)
City-Decade Fixed Effects	Yes	No	No	No	No
City & Decade Fixed Effects	No	Yes	Yes	No	No
City-Year Fixed Effects	No	No	No	Yes	Yes
Book Characteristics	Yes	Yes	Yes	Yes	Yes
Observations	2035	2035	2035	2035	363
With Variation	1168	78	514	2017	360

This table presents regression estimates examining individual book prices in the Cólon data. "Printers: Number of Firms" is the count of printers active in a city-year (measured from book inscriptions). "Indicator: 2+ Printers" is an indicator for at least two printers. "Printer Death" is an indicator for a printer death in the prior ten years. "Ln Transport Distance" is the logarithm of the distance in kilometers between the purchase city and the printing city plus one. Column 5 restricts analysis to new books, defined as books purchased within one year of publication. "Book characteristics" included in all regressions comprise: log number of pages; age of book measured in years since publication; indicators for format (folio, quarto, octavo), multicolor ink, illustrations, and for books not subject to intercity trade (i.e. purchased where printed); and fixed effects for 37 types of book content. Standard errors clustered by city-decade in column 1; by city in columns 2 and 3; and by city-year in columns 4 and 5. Statistical significance at the 90, 95, and 99 percent confidence interval denoted "*", "**", "***". "With Variation" reports the number of data points with variation in: "Number of Firms" within city-decades (column 1); "2+ Printers" and "Printer Death" within cities (columns 2 and 3, respectively); and transport distance across purchases within city-years (columns 4 and 5).

The evidence in the price data has implications for our analysis. First, the fact that prices fell when city-level competition increased strongly indicates that local competition influenced behavior. Local competition would not matter for prices if trade was costless.[43]

[43]The relationship between local competition and prices holds even when we examine cities that were close to other cities with printing, e.g. within 50 kilometers, as we show in Appendix F.

Second, the observed price movements provide support for the measure of competition we construct from book inscriptions. We use the inscriptions to identify the number of printers active in different city-years, and interpret this as a proxy for competition. Our results show that this measure of competition explains variation in separately collected price data, as predicted. Third, the magnitude of the price responses implies that there were incentives for printers to devise anti-competitive arrangements and to compete on non-price dimensions, consistent with historical evidence. Fourth, the fact that prices fell in response to increased competition helps us interpret how the number of publications printed responded to changes in competition below (Section 6). If entrance was simply a response to positive demand shocks, we might expect prices to remain stable or rise when new producers enter a market. Instead, we observe prices fall following entrance, indicating that entrance increased competition. The negative correlation between printer deaths and prices is also consistent with historical evidence indicating that deaths led to increased competition.[44] Fifth, the behavioral shifts we observe cannot be plausibly explained by other, non-competition supply-side factors. For example, printing technology was evolving gradually over this period (Febvre and Martin 1958).

6 Printer Competition and the Book Production

This section studies the effect of printer competition on book production. We study the relationships between overall competition and total city printing output, competition in the merchant press and merchant manual output, and competition just before the Reformation and the post-1517 production of religious media in German cities. Our measure of output is the number of different publications produced in a given city.

In our analysis of total output and merchant manual output, we study how variation in industrial organization explains differences in output within cities and within city-specific time periods. Our research design uses the fact that entries and exits were discrete events relative to more slow-moving characteristics of media markets to study how shifts in local industrial organization drove variation in the number and content of publications. We first study how output rises in years with at least two producers, relative to years with monopoly in the same city-decade, to provide evidence on how transitions to potentially more competitive industrial organization impacted production. Because collusion was frequent, we emphasize that discrete transitions to "multiple firms" provide just one measure of competition. Moreover, transitions between monopoly and non-monopoly focus attention on variation in industrial structure across cities with a small number of

[44]The negative correlation between deaths and prices makes it unlikely that deaths were selectively observed in locations with positive demand shocks, as discussed below.

firms. To consider the entire distribution, we examine the output implications of variation in the number of firms. We study all the variation in the data and use printer deaths as a source of exogenous variation, conditional on lagged industrial structure and output.[45]

To analyze the diffusion of religious media during Protestant Reformation, we study how cross-sectional variation in market structure just *before* 1517 relates to the diffusion of Protestant and Catholic media after Protestant ideas hit the market in 1517. We examine the implications of the pre-1517 competitive environment because market structure became endogenous to the Reformation after 1517.[46] This enables us to study how initial competition predicts the diffusion of radical ideas originating from the small and previously unimportant town of Wittenberg, where Luther was based (Pettegree 2015). Competition prior to 1517 potentially reflected city characteristics that directly drove demand for religious innovation. We use the timing of printer deaths in the pre-Reformation period to isolate plausibly exogenous variation in industrial organization, and find similar effects of competition on religious output. We restrict our analysis of religious printing to German-speaking cities where the Reformation emerged and where printing played a central role in the diffusion of Protestant ideas.[47]

6.1 Competition and Total Book Production

To study the implications of competition for total output we estimate regressions:

$$publications_{it} = \theta_i + \delta_t + \beta_1(any\ printers)_{it} + \beta_2(multiple\ printers)_{it} + \epsilon_{it} \quad (4)$$

$$publications_{it} = \theta_i + \delta_t + \beta printers_{it} + \epsilon_{it} \quad (5)$$

The outcome variable *publications* is the number of publications printed in a city-year. In equation (4), we model production with indicators for any printers ("*any printers*") and more than one firm ("*multiple printers*"). We present specifications that control for city and year fixed effects or with city-decade fixed effects, to study the implications of changes in industrial organization within narrow city-time-periods. Thus β_2 recovers the incremental variation explained by moving from monopoly to non-monopoly within

[45] While our main outcome, the number of different publications, provides a measure of total output and product differentiation, we also provide evidence that the quality of local printing responded positively to competition. Significantly, we find that competition promoted (1) an increase in the production of works by established stars and (2) an even larger increase in the production of works by authors who would *become* star authors at the pan-European level in the future. We report this analysis, along with a discussion of competition on the input dimension, in Appendix C.

[46] We defer analysis of endogenous entry due to the Reformation to future research.

[47] Our baseline results on religious printing use our biographical measure of firms. We obtain similar, though quantitatively slightly weaker results, using the publications measure of firms as discussed below.

a city or within a city-decade such as "Munich in the 1520s". In equation (5), *printers* measures the number of printing firms active. We estimate equation (5) with OLS and 2SLS, using the number of printer deaths in the past 10 years as the IV, conditional on lagged firms. We restrict analysis to city-decades with some observed printing and study the unbalanced panel that broadly expands as printing was established in new cities.[48] We emphasize that the number of firms and the distinction between monopoly and non-monopoly are proxy measures of the competitive environment.

Table 6 presents our estimates and shows that were consistent positive effects associated with our measures of competition. Column 1 shows that output increased significantly in years with multiple firms over the baseline with any printing. Column 2 shows that strong positive effects are observed within city-decades: output increased by approximately 2.1 publications in years with multiple firms active, relative to a mean of 13.1. Columns 3 and 4 show that an extra firm was associated with 3.8 or 2.7 more publications when with study within-city and within city-decade variation, respectively.

We find strong and slightly larger output effects when we study the implications of variation in the number of firms induced by printer deaths. We find that an extra firm was associated with 2.9 additional books when our instrument is the number of deaths (Column 5) and 3.4 additional books when the IV is the binary (1/0) presence of deaths in the last ten years (Column 6). The identifying assumption for the IV is that the *timing* of printer deaths was random, conditional on observables including the number of firms and production just before the IV period, and that deaths shifted output through their effects on induced entry.[49] In Columns 7 and 8 we instrument for "2+ Printers", taking "Any Printers" as exogenous. The first stage is weak and the IV estimates are large and imprecise when we use the count of deaths as the IV (Column 7). The first stage is strong and the IV estimate indicates a large positive effect on output when we use the presence of a death as the IV. We present these results for completeness, but interpret them modestly, emphasizing that the "compliers" are only those cities induced to move from having one firm to having multiple by a death.

6.2 Competition in the Merchant Press and Merchant Manuals

To study the role of competition in the diffusion of business education content we estimate regressions studying the relationship between the number of merchant manuals printed

[48] There are a few years with zero publications occurring just before printing was established, or in a few cases after it left, or because the firm(s) in the city produced no output in that year.

[49] We find no significant effect of firm age on production, or of firm age induced by deaths in particular. We provide further discussion of this below. The results are also robust to controlling for lagged output.

Table 6: Competition in Printing and Total City Output

Panel A: OLS and IV Estimates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Outcome: Number of Publications							
	OLS Estimates				IV Estimates			
Indicator: Any Printers	1.67***	2.12***					-61.81	-8.49*
	(0.37)	(0.12)					(51.61)	(5.05)
Indicator: 2+ Printers	3.89***	2.13***					233.96	40.70**
	(0.76)	(0.19)					(186.55)	(18.09)
Printers: Number of Firms			3.83***	2.68***	2.94*	3.38***		
			(0.30)	(0.44)	(1.66)	(1.07)		
F Statistic on IV					8.39	21.10	2.17	19.47
Panel B: IV First Stage								
					Number of Printers		Indicator: 2+ Printers	
Printer Deaths: Count 10 lags					1.02***		0.01	
					(0.35)		(0.01)	
Printer Deaths: Any 10 lags						1.21***		0.27***
						(0.26)		(0.02)
Observations	21439	21439	21439	21439	21430	21430	21430	21430
City-Years w/Printer Deaths					485	485	485	485
City Fixed Effects	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	No	Yes	No	Yes	Yes	Yes	Yes
City-Decade Fixed Effects	No	Yes	No	Yes	No	No	No	No
Lagged Printers	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Mean of Outcome	13.06	13.06	13.06	13.06	13.06	13.06	13.06	13.06

This table presents regression estimates of the relationship between the structure of merchant printing and city-level output. The outcome in Panel A is the number of publications produced at the city-year level. "Indicator: Any Printers" and "Indicator: 2+ Printers" are 1/0 indicators for at least one and at least two printing firms, respectively. "Number of Printers" measures the number of printing firms active in a city-year. Columns 1 to 4 are estimated with OLS. Columns 5 to 8 are IV estimates. Panel B presents the first stage estimates for the IV estimates. "Printer Deaths: Count 10 lags" measures the number of printer deaths in the current and previous ten years. Columns 7 and 8 report estimates instrumenting for "Indicator: 2+ Printers" and treat "Indicator: Any Printers" as exogenous. "Printer Deaths: Any 10 lags" is a binary variable for any deaths in current or past ten years. "Lagged Printers" denotes the inclusion of lagged values as of the period before the IV realization. The analysis is restricted to city-decades with some printing activity (minimum of one publication and one firm). Standard errors in parentheses are clustered by city in specifications with city fixed effects and by city-decade in specifications with city-decade fixed effects. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Several observations with no "within variation" are dropped from the IV estimates.

in a city-year and measures of market structure in merchant printing. We estimate regressions for equations (4) and (5), focusing attention to how variation in the number of firms active in merchant printing explains merchant manual publishing.[50]

Table 7 reports our findings and shows that competition in the merchant press explains merchant printing. Column 1 shows that output rose by 0.13 publications in years with multiple merchant manual printers, relative to years with just one merchant printer. Column 2 shows that this effect remains highly significant but falls to 0.10 when we study variation within city-decades. Columns 3 and 4 document the output effects of variation in the number of firms and show similar effects: an additional firm is associated with an increase of 0.11 merchant manuals, over a mean of 0.07. Columns 5 and 6 show that our estimates are very similar when we examine variation in the number firms induced by the deaths of merchant manual printers. Columns 7 and 8 show that we estimate large, but imprecise effects when we instrument for having "2+ Merchant Printers." We interpret these results modestly, as the variation arises from the limited set of cities where a death induced a shift from one to more than one merchant printer.

Our results show changes in industrial organization in merchant printing drove sharp, highly significant output responses in this specialized content. The identifying assumption for our OLS designs is that changes in industrial organization are random within narrrow city-specific intervals. The identifying assumption for our IV design is that the timing of the deaths of merchant manual printers is random, conditional on observables including lagged merchant manual output, and that these deaths shifted production through their impact on industrial organization as opposed to through other channels. Appendix C shows that merchant manual firms entered in city-years where merchant printers died, including in cases where the incumbent firms survived.

6.3 Competition and Religious Media During the Reformation

We study how religious printing during the Reformation era reflected variation in competition in printing in the immediate pre-Reformation period. We examine Protestant and Catholic publication outcomes over the period between Luther's initial intervention (1517) and the Peace of Augsburg (1555) in a cross-section of German cities.[51] The outcomes we study are the number of publications produced and indicators which record whether the number of publications crossed different thresholds, which provide evidence on outcome effects across the distribution (Angrist 2001). We examine both cities with

[50] Most firms never printed merchant manuals. No firms were wholly specialized in merchant printing.

[51] We provide additional evidence on religious publications in the very first years of the Reformation (i.e. 1518-1521) in Section 7.2 and in Appendix E.6.

Table 7: Competition in Merchant Printing and Merchant Manual Output

Panel A: OLS and IV Estimates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Outcome: Number of Merchant Publications							
	OLS Estimates				IV Estimates			
Indicator: Any Merchant Printers	0.04***	0.07***					-0.40	-0.06
	(0.01)	(0.02)					(0.36)	(0.8)
Indicator: 2+ Merchant Printers	0.13***	0.10***					2.01	0.57*
	(0.04)	(0.03)					(1.45)	(0.30)
Number of Merchant Printers			0.11***	0.11***	0.19***	0.16***		
			(0.01)	(0.03)	(0.04)	(0.06)		
F Statistic on IV					8.83	10.37	3.72	13.11
Panel B: IV First Stage								
					Outcome: Merchant Printers			
					Number		Indicator: 2+	
Merchant Printer Deaths: 10 Lags					0.57***		0.05*	
					(0.19)		(0.03)	
Merchant Printer Deaths Any: 10 Lags						0.59***		0.15***
						(0.18)		(0.04)
Observations	21439	21439	21439	21439	21430	21430	21430	21430
City-Years with Printer Deaths					118	118	118	118
Year Fixed Effects	Yes	No	Yes	No	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	No	Yes	No	Yes	Yes	Yes	Yes
City-Decade Fixed Effects	No	Yes	No	Yes	No	No	No	No
Lagged Printers	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Mean of Outcome	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

This table presents regression estimates of the relationship between the structure of merchant printing and merchant manual output. The outcome in Panel A is the number of merchant manuals published at the city-year level. "Indicator: Any Merchant Printers" and "Indicator: 2+ Merchant Printers" are indicators for at least one and at least two merchant printing firms, respectively. Merchant printers are defined as printers that ever produce merchant manuals. "Number of Merchant Printers" measures the number of merchant printing firms active in a city-year. Columns 1 to 4 are estimated with OLS. Columns 5 to 8 are IV estimates. Columns 7 and 8 reports estimates instrumenting for "Indicator: 2+ Merchant Printers" and treat "Indicator: Any Merchant Printers" as exogenous. In Columns 5 and 7 the IV is the number of merchant printer deaths in current and previous ten years. In Columns 6 and 8 the IV is an indicator for any merchant printer deaths in current and past ten years. IV estimates control for firms (one year before the IV period). Panel B presents the first stage estimates for the 2SLS analysis. Standard errors in parentheses are clustered by city in specifications with city fixed effects and by city-decade where city-decade fixed effects are introduced. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Data are restricted to city-decades with any printing. Several observations with no "within variation" are dropped from the IV estimates.

and without printing before the Reformation to study the extensive and intensive margins of printing. To differentiate between the effect of having printing and the effect of having a market structure with multiple firms, we present results that compare religious publishing during the Reformation in cities without printing before the Reformation, with prior printing, and with multiple firms active *ex ante*. We then study the implications of variations in the number (count) of firms active, both directly and using printer deaths in the decade before the Reformation as an IV.[52]

Table 8 presents our findings examining how religious printing during the Reformation reflected the *ex ante* presence of printing and market structure. Panel A studies Protestant publication and Panel B studies Catholic printing. Columns 1 and 2 present OLS regressions where the outcome is the count of publications. We observe large, imprecise effects of having two firms for Protestant output, on the order of 200 additional publications, but not for Catholic output. In Columns 3 to 8 we study variation across the distribution and find that cities with multiple firms were more likely to cross output thresholds for Protestant publications. As we examine higher Protestant publication thresholds, the salience of having multiple firms grows in magnitude and statistical significance, whereas the salience of "any printing" declines and loses statistical signficance. The positive relationship between more competitive industrial organization and Protestant publication holds when we study variation within narrow geographic neighborhoods defined by 210×210 kilometer grid cells (Columns 4, 6, and 8), indicating that our findings are not driven by factors shared by cities at the regional level, such as regionally varying preferences that shaped demand or regional variations in supply that could reflect the preferences of territorial lords.[53] For Catholic printing we find no appreciable effects of printing at low output thresholds and that a market structure with multiple firms only raised the probability of crossing the highest output thresholds. These findings suggest that economic competition had asymmetric effects on the diffusion of (i) revolutionary ideas and (ii) ideas supporting the incumbent religious monopoly.[54] We control for the *ex ante* number of Latin and vernacular publications, the share of pre-1517 output that was religious, and institutional features of cities: whether they were ecclesiastical cities, subject to feudal lords, ruled by prince-bishops, or had formal market rights.[55]

[52]We use evidence on printers' deaths from biographic records that cover *all* deaths, in both surviving and exiting firms. Appendix A provides information on individual printers.

[53]We use grid cells rather than territories because there are a large number of singleton territories with one city, limiting the within-territory variation available to study.

[54]We emphasize the difference between the effects for Protestant and Catholic printing. We acknowledge, however, that the Catholic effect is an imprecise zero and that we cannot consistently reject the possibility that the effect was the same for Protestant and Catholic.

[55]We show that p-values testing for a difference between the Protestant and Catholic effects fall between 0.2 and 0.1. We emphasize that the number of Protestant books is itself an important intermediate outcome. Narrative evidence indicates that competition promoted a shift in the idea space, previously

Table 8: Competition Before 1517 and Religious Publications During the Reformation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Protestant Publications 1518-1554								
	Count Protestant		Binary: Protestant Count Crosses Threshold					
	Count	Count	10+	10+	25+	25+	50+	50+
Indicator: Any Printers Before	17.27	-1.33	0.22*	0.24**	0.30**	0.33***	0.16*	0.16*
	(36.25)	(59.18)	(0.12)	(0.11)	(0.11)	(0.11)	(0.08)	(0.09)
Indicator: 2+ Printers Before	239.49	264.57	0.20	0.26**	0.23*	0.25**	0.32**	0.34**
	(198.77)	(213.04)	(0.14)	(0.12)	(0.13)	(0.11)	(0.13)	(0.12)
Panel B: Catholic Publications 1518-1554								
	Count Catholic		Binary: Catholic Count Crosses Threshold					
	Count	Count	10+	10+	25+	25+	50+	50+
Indicator: Any Printers Before	-12.50	-8.42	0.08	0.11	0.05	0.09	-0.10*	-0.09
	(9.96)	(13.19)	(0.11)	(0.11)	(0.11)	(0.12)	(0.05)	(0.06)
Indicator: 2+ Printers Before	4.04	2.90	0.03	0.06	0.02	0.02	0.30***	0.31***
	(30.39)	(16.75)	(0.13)	(0.11)	(0.10)	(0.09)	(0.09)	(0.08)
Observations	191	191	191	191	191	191	191	191
Geographic Grid Cell Fixed Effect		Yes		Yes		Yes		Yes
Protestant − Catholic difference: 2+ Printers								
p-value: count outcome	0.18	0.14						
p-value: normalized count outcome	0.16	0.11						

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Indicator: Any Printers Before" is an indicator for cities with any firms active 1508-1517. "Indicator: 2+ Printers Before" is an indicator for cities with multiple firms active 1508-1517. Panel A presents studies Protestant printing. Panel B studies Catholic printing. In columns (1) and (2) the outcome is the number of books classified as Protestant or Catholic. Outcomes are modelled using OLS. In columns (3) to (8) the outcome is an indicator for the number of publications crossing designated thresholds and regressions are OLS. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Specifications with geographic fixed effects include fixed effects for 210×210 kilometer grid cells. Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "Protestant − Catholic difference: 2+ Printers" designates tests of the hypothesis that the estimated effects of variation in "Indicator: 2+ Printers" are the same for Protestant and Catholic publication outcomes. The *p*-value "count outcome" reports *p*-values testing the equality of the reported estimates for "Indicator: 2+ Printers Before" when the outcome is (i) Protestant publications and (ii) Catholic publications. The *p*-value labelled "normalized count outcome" reports the same test results examining otherwise identical regression estimates in which the outcome is the normalized count Protestant or Catholic publications. Normalized counts are demeaned and divided by the standard error for a given type of religious publication.

Table 9: OLS and IV Analysis of Competition and Religious Publications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Protestant Publications 1518-1554								
	OLS				IV			
	Outcome: Count or Binary				Outcome: Count or Binary			
	Count	10+	25+	50+	Count	10+	25+	50+
Number of Printers Pre-Reformation	34.93*	0.06**	0.08**	0.08**	133.74**	0.13*	0.14**	0.18***
	(19.08)	(0.02)	(0.03)	(0.03)	(60.42)	(0.07)	(0.07)	(0.06)
Observations	191	191	191	191	191	191	191	191
Panel B: Catholic Publications 1518-1554								
	OLS				IV			
	Outcome: Count or Binary				Outcome: Count or Binary			
	Count	10+	25+	50+	Count	10+	25+	50+
Number of Printers Pre-Reformation	16.58	-0.00	0.01	0.04	56.42**	0.22**	0.24***	0.05
	(11.43)	(0.04)	(0.03)	(0.03)	(27.86)	(0.10)	(0.07)	(0.04)
Observations	191	191	191	191	191	191	191	191
Protestant − Catholic difference								
p-value: count outcome	0.37				0.42			
p-value: normalized count outcome	0.72				0.86			
Panel C: First Stage for IV								
					Outcome: Firms Pre-Reformation			
Printer Deaths 1508-1517					0.99***	0.99***	0.99***	0.99***
					(0.14)	(0.14)	(0.14)	(0.14)
F Statistic on IV					52.50	52.50	52.50	52.50
Observations					191	191	191	191
Printer Deaths 1508-1517					9	9	9	9

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Number of Printers Pre-Reformation" is the count of firms active 1508-1517. Panel A presents studies Protestant printing. Panel B studies Catholic printing. In columns (1) and (5) the outcome is the number of books classified as Protestant or Catholc. In all other columns, the outcome is an indicator for the number of publications crossing designated thresholds. Panel C presents first-stage estimates for the IV. The outcome is the number of firms pre-Reformation. The IV is the number of printer deaths 1508-1517. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. IV estimates additionally control for the lagged number of firms active (firms active 1498-1507). Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "Protestant − Catholic difference" designates tests of the hypothesis that the estimated effects of variation in "Number of Printers Pre-Reformation" are the same for Protestant and Catholic publication outcomes. The *p*-value labelled "count outcome" reports *p*-values testing the equality of the reported estimates when the outcome is (i) Protestant publications and (ii) Catholic publications. The *p*-value labelled "normalized count outcome" reports the same test results examining otherwise identical regression estimates in which the outcome is the normalized count Protestant or Catholic publications. Normalized counts are demeaned and divided by the standard error for a given type of religious publication.

A natural question is whether variation in competition caused differences in the diffusion of religious ideas or whether the sudden appearance of Protestant ideas activated unobserved differences in preferences, institutions, or human capital. While both processes were active, we use the deaths of printers active in the period 1508-1517 as an IV that provides plausibly exogenous variation in pre-Reformation competition – *conditional* on the lagged number of printers active and observables. Printer deaths before the Reformation were shocks to competition that are free from forms of endogeneity that could characterize entrance and city responses to deaths during the Reformation.[56] We measure printer deaths with the number of deaths occurring not more than one year after a printer's last business activity. This allows us to discriminate between the deaths of active printers and of retirees, which we use as a placebo in estimates in Appendix E.

Table 9 studies the relationship between religious output during the Reformation and the number of firms active using OLS and 2SLS. Columns 1 to 4 present OLS results and show variation in the number of firms is a positive and statistically significant predictor of Protestant but not Catholic printing. Columns 5 to 8 present IV estimates that document positive and statistically significant relationships between the number of firms in a city before the Reformation and Protestant content that are consistently larger than the OLS estimates. The IV estimates indicate that an extra firm raises the probability of Protestant publications crossing output thresholds by 13-18%, where the OLS estimates range between 6% and 8%. The IV estimates for Catholic publications are also positive and with one exception statistically significant (Panel B, Columns 5 to 7), whereas the OLS estimates for Catholic publications are close to zero and statistically insignificant. Consistent with narrative evidence indicating that printer deaths increased competition, the interpretation of the first stage results in Panel C is that a printer death in the period before the Reformation increased the number of firms active in this period by almost 1 firm, conditional on the number of firms active in the previous period.

There are several possible explanations for the fact that the IV estimates are larger than the OLS estimates. First, the IV may address proxy measurement error implicit in the OLS estimates. Second, it may be that variation industrial organization due to shocks was more consequential than variation arising from other sources, including endogenous factors. Historical evidence that printer deaths destabilized anti-competitive arrangements points in this direction. Supporting the view that printer deaths had their impact via competitive channels, we find that deaths did *not* drive variation in publications through their impact on the age composition of firms (Appendix E). However, it

dominated by an unobserved "stock" of received Catholic ideas (Cameron 1991; Pettegree 2011).

[56]This distinguishes the methodological scope and aims of our study from research that studies incentives to ideological positioning for entrants (Gentzkow et al. 2014).

remains the case that the IV recovers a local average treatment effect.[57]

Another important question concerns the potential interaction between pre-existing institutions and printer competition in shaping the diffusion of Protestantism. Our evidence indicates that economic competition promoted the diffusion of ideas that otherwise faced profound barriers and resistance. Is it the case that this competition effect was *stronger* where pre-existing institutional barriers were otherwise higher? In the appendix, we present corroborating evidence showing that this was indeed the case: the competition effect was stronger in territorial cities than in free cities (Appendix E.11). A related question concerns institutions that shaped *regional* political decentralization: did the competition effects vary by region with decentralization? We find very limited evidence of any such interaction, suggesting the importance of city-level factors (Appendix E.11).

7 The Effect of Ideas on Economic Development and Institutional Change

In this section, we study the relationship between ideas in print and economic outcomes using printer deaths as a source of plausibly exogenous variation in supply. We first study the relationship between the diffusion of business education publications and long-run city growth in a cross-sectional design. We present corroborating panel data evidence on shocks to merchant printing and individual achievement at the city-by-cohort-by-sector level. We then study the relationship between the spread of Protestant ideas in the media and city-level institutional change across cities in German-speaking Europe.

7.1 Merchant Printing, City Growth, Individual Achievement

This section first presents IV estimates of the relationship between business education content and long-run city population growth in the cross-section. To further test whether shocks to merchant printing drove or responded to economic development, we also examine the relationship between the timing of shocks to business education printing and individual achievement in panel data at the city-decade level.

City Growth – We study the relationship between business education content and city growth using the deaths of active printers who were producers of merchant manuals as a

[57] In the data, there are no cities where deaths were associated with a reduction in the number of firms over the immediate pre-Reformation period. There are two cities where deaths were associated with no increase, however it is not clear that these should be thought of as "defiers" and one of these cities (Zurich) become an important center of Reformation activity.

source of exogenous variation in supply. We examine two measures of business education content: (1) the number of manuals published 1500-1600 and (2) the log of the number of manuals printer plus one ($\ln[manuals + 1]$). In all specifications, the controls X include city population in 1500, pre-1500 printing, port location, the presence of historic universities, navigable rivers, latitude, longitude, and country fixed effects. We control for whether a given city produced any business education content. To focus on variation in exposure to shocks and output across *ex ante* highly comparable cities, we place cities in matching groups (cells) based the similarity of their printing industries along three key dimensions over the period 1454-1499, before any deaths are observed for business education printers. All cities in a matching group (1) belong to the same initial output quantile, (2) were above (below) average producers of scientific books, and (3) were above (below) average educational books, as classified in the USTC.[58]

We consider a first stage model examining variations in business education content:

$$manuals_i = \alpha_0 + \alpha_1 deaths_i + \alpha_x X_i + \epsilon_i \tag{6}$$

The first stage results isolate plausibly exogenous variation in supply we use to estimate the relationship between growth and the merchant manual publications in a model:

$$\ln(POP_{1600}/POP_{1500}) = \beta_0 + \beta_1 manuals_i + \beta_x X_i + \nu_i \tag{7}$$

We focus on the IV estimates in this section and report first stage estimates in Appendix D. The first identifying assumption is that the deaths of merchant printers were random across cities conditional on observables, including the composition of printing output as of 1500. The second identifying assumption is that the deaths of merchant printers impacted long-run growth only through their effects on the supply of business education publications. We discuss these assumptions below and in Appendix D.

Table 10 presents IV estimates of the relationship between growth and merchant manual publications. Panel A examines the complete set of cities and uses the measure of printer deaths from publications data. Columns 1-4 show that when printer deaths are used as an IV for supply we estimate that an additional merchants' manual was associated with an increase in population growth of 0.2%-0.8%. Columns 5-8 present estimates examining variations in growth induced by variations in the log of business education publications. The estimated elasticities of growth with respect to this media output fall between 0.05 and 0.12. To interpret these magnitudes, consider that the mean city experienced 30% population growth 1500-1600. These estimates reflect an IV with

[58]For details on matching groups and within-group variation in printer deaths see Appendix D.

variation that is not eliminated through law of large numbers effects. For example, Dresden, Königsberg, Metz, and Zürich had *no* merchant printer deaths despite producing considerable output and Hamburg only had a death in the 1590s.

To interpret our results, several observations are important. First, our results using merchant printer deaths as a source of variation in merchant publications are robust to controlling for the presence of other printer deaths (Table 10, Columns 2-4 and 6-8). This shows that our effects are not explained by a generalized economic boom that drew more printers and mechanically led to more printer deaths of all types being observed.[59] Second, our findings are not driven by the potentially selective observation of deaths in "good cities" when we measure deaths using book inscriptions.[60] We obtain similar results when we restrict attention to German cities where we can measure printer deaths using either book inscriptions or biographical records (Reske 2007). Panel B shows results for German cities using the measure of deaths from book inscriptions as the IV and Panel C shows results using the measure of deaths from biographical data. The results are similar in magnitude to the baseline results for all of Europe. In fact, estimates using evidence on deaths from biographical records as the IV are slightly larger in magnitude and somewhat more precisely estimated than the results using evidence from book inscriptions. Third, we find no evidence of growth effects due to variation in non-merchant printing induced by the deaths of non-merchant printers (see Appendix D, Table D3). Fourth, it is possible that local economic growth in the 1500s could have differentially induced entry by merchant manual printers and thus mechanically led to *relatively* more such deaths being observed in dynamic cities. To test whether local development preceeded or followed shocks in printing in higher frequency data, we study individual-level achievement outcomes at the city-cohort level.

Individual Achievement – To provide more precise evidence on the timing of the relationship between shocks to the merchant press and economic outcomes, we study how individual achievement at the city-cohort-sector level responded to the deaths of manual printers and to variation in merchant publishing induced by these deaths.

We measure individual achievement by the number of people from a given city-cohort observed in the *Deutsche Biographie*. We define cohorts as individuals born in the same city-decade. We distinguish between achievement in (i) bourgeois occupations and (ii) in the church (religious occupations). We examine the 70 German-speaking cities from Table 10 and cohorts born between the 1450s and the 1580s (i.e. turning 30 before the

[59] Results are even stronger controlling for the number of other printer deaths, as shown in Appendix D.

[60] To be clear, deaths in inscriptions are observed in firms that survive. The natural question is whether firms survive to have inscriptions recording deaths in a positively selected subset of cities.

Table 10: IV Estimates of the Growth Impact of Merchant Manuals

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Baseline All Cities – IV from Book Inscriptions								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.004**	0.003***	0.002***	0.002**				
	(0.001)	(0.001)	(0.001)	(0.001)				
Ln Merchant Manuals					0.117***	0.095***	0.079**	0.070*
					(0.031)	(0.031)	(0.037)	(0.040)
Observations	269	269	269	269	269	269	269	269
Ffirst	258.60	223.30	206.75	166.42	7.04	6.50	10.76	10.32
Panel B: German-Speaking Cities – IV from Book Inscriptions								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.007***	0.004**	0.003	0.004				
	(0.001)	(0.001)	(0.001)	(0.004)				
Ln Merchant Manuals					0.101***	0.064**	0.052*	0.077
					(0.020)	(0.021)	(0.024)	(0.071)
Observations	70	70	70	70	70	70	70	70
Ffirst	139.78	367.89	455.85	180.89	15953.70	993.18	1376.75	32.54
Panel C: German-Speaking Cities – IV from Biographical Data								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.008***	0.006**	0.005	0.005				
	(0.003)	(0.003)	(0.003)	(0.003)				
Ln Merchant Manuals					0.124***	0.096**	0.090*	0.103*
					(0.033)	(0.040)	(0.050)	(0.057)
Observations	70	70	70	70	70	70	70	70
Ffirst	97.00	95.66	86.77	79.28	189.77	135.82	145.59	110.84
Death Other Printers		Yes	Yes	Yes		Yes	Yes	Yes
Ever Manuals			Yes	Yes			Yes	Yes
Match Group Fixed Effects				Yes				Yes

This table presents instrumental variable estimates of the relationship city growth and merchant manual supply. The dependent variable is: $ln(POP_{1600}/POP_{1500})$. "Merchant Manuals" is the count of merchant manuals. "Ln Merchant Manuals" is the log of manuals ($\ln[manuals+1]$). "Deaths Other Printers" is an indicator for other printer deaths. "Ever Manuals" is an indicator for cities that ever produced business education content. Match group fixed effects are as discussed in the text. All regressions control for population in 1500, pre-1500 printing, port location, the presence of historic universities, navigable rivers, latitude, longitude, and country fixed effects. Panel A presents estimates examining all European cities and uses merchant printer deaths recorded in books as the IV (the publications measure). Panel B presents estimates examining German-speaking cities and uses merchant printer deaths recorded in books as the IV (the publications measure). Panel C presents estimates examining German-speaking cities and uses merchant printer deaths recorded in biographical data as the IV (the biographical measure). Standard errors clustered at the country level. Statistical signficance denoted * $p<0.1$, ** $p<0.05$, *** $p<0.01$. First stage estimates are reported in Appendix Table D2.

outbreak of the Thirty Years War in Germany).[61]

We first estimate reduced-form regressions:

$$people_{it} = \alpha_i + \delta_t + \sum_{\tau=-3}^{3} (\beta_\tau death_{i,\tau}) + \epsilon_{it}$$

The outcome $people_{it}$ measures individual achievement by the number of people born in a city-decade and observed in the *Deutsche Biographie*. The parameters β_τ capture how achievement responded to the timing of shocks to the business education press, measured by the first death of a merchant printer ($death_{i,\tau}$) at the city-decade level.[62] The timing of shocks is indexed relative to individuals' decade of birth: $\tau = 0$ corresponds decade of birth, $\tau = 1$ the decade in which individuals turned 10, and $\tau = 2$ the decade in which individuals turned 20, etc. The α_i and δ_t are city and decade fixed effects, respectively.

Table 11 shows that shocks to merchant printing are significant positive predictors of achievement in bourgeois occupations for cohorts hit in late adolescence and early adulthood.[63] City-decades with shocks produced an additional 0.4 to 0.5 high achievement individuals in 'bourgeois' occupations, relative to a mean of 0.39. Shocks to merchant printing are significant negative predictors of achievement in church careers for the same cohorts. These effects hold controlling for leads and lags of non-merchant printer deaths (column 2) and controlling for factors shared by cities in the same region-and-decade (column 3). The relationship between shocks to the merchant press and individual achievement is also not driven by outlier cities, as shown in in Appendix Table D5, where we estimate the relationship sequentially dropping individual cities from the analysis. Shocks in other periods are not significant conditional predictors of achievement.

We next estimate IV regressions and find that variation in merchant manuals printed predicts bourgeois achievement, using deaths of merchant printers as a source of exogenous variation. Table 12 shows that an additional merchant manual was associated with an additional 0.3 to 0.8 high achievement bourgeois individuals in a city-cohort, relative to a mean of 0.4. Our estimates are imprecise controlling only for city and decade fixed effects (column 1), but become more precise when we control for lagged deaths of mer-

[61] Motivated by evidence on uses of business-related knowledge in the public sector and spillovers across occupations, we classify non-religious and non-noble occupations as 'bourgeois'. Achievement by nobles does not respond to merchant press shocks and we drop the small number of nobles from our analysis.

[62] To illustrate the variation we examine, Erfurt experienced a death in the 1530s, Frankfurt am Main in the 1540s, Leipzig and Rostock in the 1550s, Cologne in the 1560s, Lübeck in the 1570s, and the commercial port of Hamburg only in the 1590s. Only a few cities have multiple deaths and most of the variation operates through the timing of the first and only death in a given city.

[63] On average the shocks occur at age 20. Because we 'bin' individuals by decade, some individuals in a cohort experience the same shock in their teens and others in their twenties. We emphasize that this result is descriptive and we cannot reject the hypothesis that estimates for different cohorts are equal.

Table 11: Merchant Printer Deaths and Achievement Across Cohorts

	(1)	(2)	(3)	(4)	(5)	(6)
	Outcome: Count of Individuals by City-Decade					
	Bourgeois Occupations			Church Occupations		
Merchant Death in Decade Individuals Turn 30	-0.063	0.007	0.123	-0.075	-0.061	-0.076
	(0.124)	(0.139)	(0.197)	(0.089)	(0.101)	(0.129)
Merchant Death in Decade Individuals Turn 20	0.459*	0.497*	0.393**	-0.199**	-0.212**	-0.221**
	(0.256)	(0.254)	(0.192)	(0.092)	(0.101)	(0.099)
Merchant Death in Decade Individuals Turn 10	-0.082	-0.067	-0.051	0.086	0.081	0.093
	(0.131)	(0.139)	(0.167)	(0.148)	(0.147)	(0.150)
Merchant Printer Death	0.031	0.015	0.184	0.058	0.049	0.046
	(0.177)	(0.195)	(0.238)	(0.164)	(0.159)	(0.190)
Merchant Death in Decade Individuals Age – 10	0.222	0.220	-0.112	0.215	0.212	0.234
	(0.320)	(0.324)	(0.230)	(0.278)	(0.282)	(0.346)
Merchant Death in Decade Individuals Age – 20	0.054	0.032	0.197	0.253	0.262	0.309
	(0.218)	(0.213)	(0.254)	(0.204)	(0.204)	(0.208)
Merchant Death in Decade Individuals Age – 30	0.858	0.870	0.882	0.023	-0.008	0.019
	(1.157)	(1.174)	(1.468)	(0.219)	(0.222)	(0.251)
Observations	980	980	980	980	980	980
Mean of Outcome	.39	.39	.39	.083	.083	.083
P-value: Joint Significance of Deaths Before Turn 20	.67	.65	.27	.36	.43	.39
City Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Decade Fixed Effects	Yes	Yes	No	Yes	Yes	No
Leads & Lags of Non-Merchant Printer Death	No	Yes	Yes	No	Yes	Yes
Decade × Region Fixed Effects	No	No	Yes	No	No	Yes
Cities	70	70	70	70	70	70

This table reports regression estimates of the relationship between the individual achievement outcomes and the deaths of printers who produced merchant manuals. Achievement outcomes are measured at the city-cohort-sector level by the number of people born in a given city-decade with occupations classified as 'bourgeois' or 'church' who are recorded in the *Deutsche Biographie*. Occupations are classified as bourgeois if they were neither in the church (religion) or nobility. The independent variables are indicators that capture the timing of the first city-decade with the death of a merchant manual printer. "Merchant Printer Death in Decade Individuals Turn 30" is an indicator for the first death of a printer of merchant manuals in the decade individuals in a given city turned 30 years old. "Merchant Printer Death in Decade Individuals Turn 20" is an indicator for first death of a merchant manual printer in the decade individuals turned 20. Other variables are defined similarly. We examine data on people born from the 1450s through the 1580s, hence turning 30 by or before the first the 1610s. All specifications include city and decade fixed effects. "Decade × Region Fixed Effects" are interactions between decade and region fixed effects, using 14 regions constructed from longitude-latitude grid cells (the mean region comprises 5 cities). Standard errors clustered by city. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 12: Merchant Manual Publication and Individual Achievement Across Cohorts

	(1)	(2)	(3)	(4)	(5)
Panel A: First Stage Estimates					
	Outcome: Merchant Manuals Published in City-Decade				
Merchant Death in Decade Individuals Turn 20	1.55***	1.49***	1.33**	0.92**	0.92**
	(0.57)	(0.55)	(0.50)	(0.38)	(0.38)
Observations	980	980	980	980	980
Panel B: IV Estimates					
	Outcome: High Achievement Individuals by City-Decade Cohort				
	Bourgeois Careers	Bourgeois Careers	Bourgeois Careers	Bourgeois Careers	Church Careers
Merchant Manuals in Decade Individuals Turn 20	0.30	0.33*	0.40*	0.72*	-0.32*
	(0.19)	(0.18)	(0.24)	(0.38)	(0.18)
Observations	980	980	980	980	980
F-statistic on IV	7.43	7.33	7.01	5.81	5.81
Controls Across Specifications					
City and Decade Fixed Effects	Yes	Yes	Yes	Yes	Yes
Lags of Merchant Printer Death	Yes	Yes	Yes	Yes	Yes
Lags of Non-Merchant Printer Death		Yes	Yes	Yes	Yes
Lags of Total Publications			Yes	Yes	Yes
Lags of Merchant Manual Publications				Yes	Yes

This table reports IV regression estimates of the relationship between the individual-level achievement outcomes and local merchant manual publishing. High achievement outcomes are measured by people born in a given city-decade cohort and recorded in the *Deutsche Biographie*. Panel A presents IV estimates. In columns 1-4, the outcome is the number of people who had bourgeois occupations. Individual occupations are classified as bourgeois if they were not in the nobility and were not religious (i.e. were outside the Church, were not not rabbis, etc.). In column 5, the outcome is people who had church (religious) careers. The independent variable is the number of merchant manuals published in the decade a city-cohort turned 20. Panel B presents first stage estimates where the outcome is the number of merchant manuals published in the city-decade when a cohort turns 20 years old. "Merchant Death in Decade Cohort Turns 20" is an indicator for the first death of a merchant manual printer in the decade individuals turned 20. All specifications include city and decade fixed effects. All lagged controls include five decadal lags. "Lags of Merchant Printer Deaths" indicates five lags of merchant printer deaths. "Lags of Non-Merchant Printer Deaths" indicates five lags of non-merchant deaths in the decade a cohort turns 20. "Lags of Total Publications" indicates five lags of the number of total publications on all subjects. "Lags of Merchant Manual Publications" indicates five lags of merchant manual publications. The analysis examines data on people born from the 1450s through the 1580s. Standard errors clustered by city. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

chant printers (column 2) and of non-merchant printers (column 3). The estimates rise in magnitude when we control for lagged publications (column 4) and lagged merchant manual publications (column 5). We find a negative relationship between achievement in the church and variation in merchant manuals induced by printer deaths (column 6), consistent with the reduced form results.[64]

7.2 Protestant Ideas and City-Level Institutional Change

We study the relationship between media content and city-level institutional change using printer deaths as a source of exogenous variation in content. We examine the implications of printer deaths that occurred on the years immediately preceeding the Reformation, conditional number of firms active in a city in the early 1500s, the composition of pre-Reformation print media, the institutional status of cities, the presence of universities, and locational characteristics.

We focus on Protestant publishing over the critical first years of the Reformation from 1518 until 1521, before institutional change began. We focus on these years because historical evidence suggests that printing in this era was critical in shifting views (Chrisman 1982; Brady 2009) and to examine the relationship between printing and subsequent institutional change *before* institutional change could itself determine publication patterns. By restricting our analysis to publishing through 1521, we focus attention on the period before new restrictions on religious printing were introduced.[65]

We estimate a first stage regression:

$$\ln(protestant_i) = \alpha + \beta death_i + \gamma X_i + u_i \tag{8}$$

Here $\ln(protestant_i)$ is the log of the number of Protestant books printed between 1517 and 1521, the year of the first city law, plus one. The IV ($death_i$) is an indicator for printer deaths in the ten years before the Reformation (1508-1517). The X_i control for: vernacular and Latin publications, and the share of religious publications, before the

[64]To be clear, printers had to decide to print a merchant manual. Taken together, our results indicate that when a merchant manual printer dies, we are subsequently likely to see more merchant manual printers and more merchant manuals printed in a city. Our results show that this selection into merchant manual production responded to the deaths of merchant manual printers.

[65]For example, Nürnberg's city council first asked printers not to publish Lutheran tracts in 1521 – before adopting the Reformation in the face of popular pressure. Similarly, Lutheran publishing flourished in Leipzig in the first years of the Reformation, before restrictions were initially imposed, and then lifted when Protestantism was adopted. Thus, while censorship in German cities was broadly endogenous (Creasman 2012) and punishments for publishing controversial materials were light compared to those in the Low Countries and France (Pettegree 2015), we focus here on the institutional implications of publications produced in an initial period when printing in Germany was particularly open.

Reformation; for status as a Hansa city, ecclesiastical rule, prince-bishoprics; distance to Wittenberg, universities, and locations on navigable water. In the second stage, we examine the institutional outcome: whether a city adopted a Reformation law between 1521 and the 1555 Peace of Augsburg.[66]

Table 13: Protestant Publications and Institutional Change IV Estimates

Panel A: First Stage	(1)	(2)	(3)	(4)
	Outcome: Ln Protestant Publications 1518-1521			
Printer Deaths 1508-1517	0.80***	0.81***	0.55**	0.57
	(0.19)	(0.21)	(0.26)	(0.35)
Firms 1498-1507	0.41***	0.42***	0.13	0.14*
	(0.06)	(0.07)	(0.09)	(0.08)
Observations	191	191	191	191
R^2	0.58	0.58	0.66	0.68
Panel B: IV Estimates				
	Outcome: Reformation Law Passed 1521-1554			
Ln Protestant 1518-1521	0.28***	0.22***	0.34**	0.17
	(0.10)	(0.08)	(0.17)	(0.11)
Firms 1498-1507	-0.05	-0.04	-0.01	0.00
	(0.04)	(0.05)	(0.04)	(0.04)
Observations	191	191	191	191
F Statistic on IV	17.07	14.13	4.46	2.59
Population in 1500		Yes	Yes	Yes
Controls			Yes	Yes
Geographic Grid Cell FE				Yes

This table presents IV regression estimates examining the institutional change outcome. In Panel A, the outcome is a binary indicator for the passage of a law between 1521 and 1554. The endogenous independent variable is the number of log of the number of Protestant publications produced 1518-1521 plus one. The IV is the number of printer deaths 1508-1517. Panel B presents the first stage Estimates. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Controls are: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Standard errors are clustered on territories (principalities) of the Holy Roman Empire or on geographic grid cells where fixed effects are introduced. Geographic grid cells are 2 degree × 3 degree (approximately 210km×210km). Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

Table 13 presents our estimates. We find that a printer death in the years preceding the Reformation was associated with an increase in Protestant content of approximately 0.81 log points, controlling for city population and approximately 0.55 log points control-

[66]We present sensitivity analysis examining other measures of Protestant printing in Appendix E, where we investigate how institutional change was related to whether Protestant printing crossed specific distributional thresholds, thus relaxing the functional form assumptions embodied in the analysis in Table 13.

ling for city characteristics and geographic grid cell fixed effects (see Panel A). Introducing grid cell fixed effects does not change our first stage point estimate but substantially increases the standard errors. We find in the second stage that variations in Protestant content induced by pre-Reformation printer deaths shifted the probability of institutional change. While our estimates are median unbiased, when we introduce controls the first stage F-statistic falls to 4.46 (column 3). Our first stage precision declines and the second stage ceases to be statistically significant when we introduce geographic grid cell fixed effects. This reflects the fact that local variation in exposure to shocks was limited, and that variation in both printing and in institutional change was driven by multiple factors.[67] While our findings are thus not without qualification, they point towards the role of shocks to competition in media markets as a source of variation in content that influenced institutional change, consistent with narrative evidence.[68]

8 Conclusion

European markets for ideas were transformed starting in the 1500s, following the introduction of Gutenberg's printing press. Prior scholarship has characterized the emergence of open markets for ideas and the dynamics of knowledge in Europe using narrative evidence. Our research contributes quantitative evidence on the role of the printing industry in the diffusion of radical ideas about business practices and religion. Printing spread ideas about business practices that changed how European capitalists conducted affairs and directly transformed the economy. Printing also spread religious ideas that challenged the ideological monopoly of the Catholic Church and led to institutional change.

It is sometimes presumed that new technology carries relatively direct implications for output. This paper presents evidence indicating that competition and market structure in printing profoundly shaped the diffusion of ideas and radical social changes commonly ascribed to the printing press technology alone. We find that competition among printers promoted the spread of business practice ideas that drove individual achievement and local growth. Competition in printing also mattered for the diffusion of revolutionary religious ideas. In an environment in which political freedom, representation, and voice were severely restricted, economic competition among printers promoted the diffusion of religious and political ideas that drove institutional change during the Protestant Reformation.

[67] For example, Dittmar and Meisenzahl (2018) examine shocks that shifted demand for institutionalization of Protestantism and were orthogonal to supply-side shocks due to printer deaths.

[68] In Appendix E we show that printer deaths did not shift Protestant printing via any effects on the age distribution of firms, consistent with the view that effects ran through competition.

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Appendices

A Data

A.1 Summary Statistics

City-Year Data on Publications, Printing Firms, and Printer Deaths – Table A1 presents summary statistics on printing at the city-year level. These data are restricted to years in city-decades with at least some printing.

Table A1: City-Year Panel Data on Total Publishing and Printer Deaths

	Mean	SD
Publications	13.06	43.04
Number of Printers	3.90	12.49
Indicator: Any Printers	0.72	0.45
Indicator: 2+ Printers	0.41	0.49
Printer Deaths: Past 10 Years	0.25	1.05
Merchant Manuals	0.07	0.42
Number of Merchant Printers	0.73	2.14
Indicator: Any Merchant Printers	0.28	0.45
Indicator: 2+ Merchant Printers	0.13	0.34
Merchant Printer Deaths: Past 10 Years	0.07	0.35
Observations	21439	

"Publications" is the total number of publications. "Number of Printers" is the number of active printers. The "Printer Deaths" variables are the number of printer deaths over the specified number of years. "Merchant Manuals" is the number of merchant manuals published. "Number of Merchant Printers" is the number of active merchant manual printers. Indicators and deaths for merchant manual printers defined similarly. This table presents summary statistics on total printing that correspond to the regression estimates presented in Tables 6 and 7 in the main text.

Cross-Sectional Data on Publications and Growth – Table A2 presents summary statistics on city growth, publishing, printer deaths, and other covariates. These summary statistics correspond to cross-sectional regression estimates examining city population growth (Table 10 in the main text).

Panel Data on Individual Achievement – Table A3 presents summary statistics on individual achievement at the city-cohort level. We observe these high achievement individuals across 70 German-speaking cities with printing. Table A3 presents summary statistics at the city-decade level.

Printing and Institutional Change During the Protestant Reformation – The baseline sample comprises 191 cities. We include German-language printing cities identified in Reske (2007). We also include cities in German-speaking regions of the Holy Roman Empire for which population in 1500 is recorded in Bairoch et al. (1988). Our baseline

Table A2: Cross-Sectional Data for City Population Growth Regressions

	Mean	SD
Ln Population Growth 1500 to 1600	0.28	0.50
Ln Population in 1500	2.38	0.91
Publications	922.36	3352.96
Merchant Manuals	4.99	18.71
Deaths of Merchant Printers	0.36	1.50
Deaths of Other Printers	1.17	4.36
Printing before 1500	0.47	0.50
University in 1500	0.22	0.41
Port	0.18	0.39
Navigable River	0.23	0.42
Observations	269	

This table presents summary statistics for the following variables. "Ln Population Growth 1500 to 1600" is $\ln(POP_1600/POP_1500)$. "Ln Population in 1500" is the log of initial populations. "Publications" is the count of total publications. "Merchant Manuals" is the count of merchant manuals. "Deaths of Merchant Printers" is the number of deaths of merchant manual printers. "Deaths of Other Printers" is the number of deaths of non-merchant manual printers. "Printing before 1500", "University in 1500", "Port", and "Navigable River" are binary indicator variables.

Table A3: City-Cohort Data on Individual Achievement

	Mean	SD
Bourgeois Occupations	0.39	1.57
Church or Nobility Occupations	0.08	0.36
Merchant Printer Death Shock	0.02	0.13
Observations	980	

This table presents summary statistics on on individual achievement measured by the number of individuals born in a city-decade with occupations in a given sector as observed in the *Deutsche Biographie*. Data are from 70 German-speaking cities with printing and with population observed in Bairoch et al. (1988) in 1500 and 1600. Data are for cohorts born between the 1450s and the 1580s. "Bourgeois Occupations" is the count of individuals with bourgeois occupations. "Church or Nobility Occupations" is the count of individuals with religious or noble occupations. "Merchant Printer Death Shock" is an indicator for first decade with death of a merchant manual printer.

data includes Konstanz, Landshut, and Oppenheim which had printers active 1508-1517 but no population recorded in 1500. Our baseline sample also includes cities such as Aachen and Bremen which both had 18,000 inhabitants in 1500 but no printing as of 1517. Other notable cities without printing in 1517 included Schwaz, Goslar, Stralsund, Osnabrück, Hildesheim, Elblag (Elbing), Szczecin (Stettin), Dortmund, and Berlin.

The analysis in the body of the paper examines the relationship between the institutional change outcome and several features of cities, including variations in the structure of their pre-Reformation media markets. Table A4 presents summary statistics on city

characteristics.

Table A4: Summary statistics on German cities in Reformation era

	All Cities		Cities Printing pre-1518			
			No Law pre-1555		Law pre-1555	
	Mean	SD	Mean	SD	Mean	SD
Firms 1508-1517	0.60	1.93	1.23	2.21	2.52	3.57
Firms 1498-1507	0.59	1.78	1.12	1.97	2.45	3.24
Printing pre-1517	0.31	0.46	1.00	0.00	1.00	0.00
Religious Share pre-1517	0.13	0.24	0.36	0.22	0.50	0.24
Latin Publications pre-1517	0.63	2.86	1.43	4.20	2.51	5.39
German Publications pre-1517	0.23	1.04	0.35	0.58	1.08	2.29
Indicator: Lord Rule	0.77	0.42	0.85	0.37	0.52	0.51
Indicator: Ecclesiastical	0.14	0.35	0.36	0.49	0.07	0.27
Indicator: Hansa	0.26	0.44	0.08	0.27	0.33	0.48
Indicator: University	0.08	0.27	0.35	0.49	0.18	0.39
Indicator: Prince-Bishopric	0.16	0.36	0.38	0.50	0.30	0.47
Indicator: River	0.30	0.46	0.42	0.50	0.45	0.51
Population 1500: Unrecorded	0.25	0.43	0.31	0.47	0.15	0.36
Population 1500: 1-5k	0.41	0.49	0.19	0.4	0.15	0.36
Population 1500: 6-10k	0.19	0.40	0.31	0.47	0.24	0.44
Population 1500: 11-25k	0.12	0.33	0.15	0.37	0.36	0.49
Population 1500: 26k+	0.02	0.14	0.04	0.20	0.09	0.29
Distance to Wittenberg	309.95	160.07	404.02	84.31	298.19	168.71
Protestant Publications	63.96	255.02	26.04	52.32	326.42	544.10
Reformation Law pre-1555	0.34	0.47	0.00	0.00	1.00	0.00
Printer Deaths	0.07	0.33	0.08	0.27	0.33	0.69
Observations	191		26		33	

This table presents summary statistics on city-level variables. Columns 1 and 2 present summary statistics for all cities. Columns 3-6 present summary statistics for cities with any printing pre-1518. Columns 3 and 4 present summary statistics for printing cities that did not adopt Reformation law before 1555. Columns 5 and 6 present statistics for printing cities that did adopt Reformation law before 1555. Variable definitions are as follows. "Firms 1508-1517" and "Firms 1498-1507" are the measure of printers active coded from Reske (2007; 2015). "Indicator: Printing per-1517" is an indicator for any printing before 1517. "Religious Media pre-1518" is the share of titles (varieties) on religious subjects as classified by the USTC. "Latin Publications pre-1517" and "German Publications pre-1517" are the number of Latin and German publications pre-1517 in units of hundreds. "Indicator: Lord Rule" is an indicator for *landstadt* cities subject to lords (i.e. cities that were not "free"). "Indicator: Ecclesiastical" is an indicator for cities subject to ecclesiastical lords. "Indicator: University" is an indicator for cities with universities before 1517. "Indicator: Prince-Bishopric" and "Indicator: River" are indicators for these characteristics. Population variables are indicators that record city population categories derived from Bairoch et al. (1988). "Population 1500: Unrecorded" is an indicator for cities with population unrecorded. "Population 1500: 1-5k" is an indicator for cities with populations 1,000-5,000. Other population variables are defined similarly. "Distance to Wittenberg" is in kilometers. "Protestant Publications" is the count of predicted Protestant varieties 1518-1554. "Reformation Law pre-1555" is an indicator for cities adopting Reformation law (*kirchenordnung*) before 1555. "Printer Deaths" is the number of printer deaths.

A.2 Publications

We obtain data on individual book and pamphlet editions from the USTC catalog (USTC 2012). We use the titles of books and pamphlets to classify religious publications produced in German-speaking Europe as Protestant or Catholic as described in Section 3 and Appendix B. We use information on printing location and date of printing directly from the USTC. For a small number of items we correct for misleading locations and dates.

A.3 Business Education Publications

The research constructs new data on the diffusion of the business education literature by identifying individual merchants' manuals and business education tracts. These publications are identified in the USTC catalog as follows (see also main text). First, data on individual business education publications are manually coded from the "Hoock and Jeannin data" (Hoock et al. 1991; Hoock and Jeannin 1993; Hoock et al. 2001). Second, these data are then matched to the USTC catalog. Third, additional merchant manual titles are identified in the USTC. Additional manuals are identified by matching on title, manually reviewing all publications by authors of any known merchant manual, and by reviewing all books and pamphlets with key words used in the titles of merchant manuals.

This data construction procedure is motivated by the fact that the Hoock and Jeannin data include a substantial number of observations on individual publications where the recorded year of publication is an approximate date provided in library or archive catalogues as of the 1990s. The presence of approximate dates introduces potential measurement error that is addressed by matching publications to the USTC. By matching individual level data on books to the USTC, we are able to identify which printers were merchant manual printers and to correct misleading publication dates.[69]

[69] To test for and document the presence of approximate dates we study date "heaping" in the available data. Specifically, we analyse the distribution of publication dates in (1) the Hoock and Jeannin data and (2) the database constructed in this research. We use regression analysis to test for evidence of heaping in the distribution of publication dates and find significant evidence of age heaping in the Hoock-Jeannin data, but none in the database assembled for this research. For example, the Hoock and Jeannin data assign some publications to "round" decadal years rather than the precise year of publication.

A.4 Religious Publications – The Classification Challenge and the Text Data Used to Classify Religion

We examine religious printing produced in German-speaking cities during the Reformation. In this section we present evidence on the overall size of religious printing in German-speaking cities and on the text data used in classification. Our classification procedure is described in Appendix B.

Table A5 presents summary statistics on output in media markets and shows that almost half of religious media was written by authors whose religion we do not observe.

Table A5: Print media output in German-speaking Europe 1454-1599

Time Period	Cities Printing	Total Publications	Religious Publications	Religious by Known	
				Protestants	Catholics
1454-1517	59	16966	6635	64	204
1518-1554	91	33218	17108	8883	1535
1555-1599	107	57940	23247	6560	1190

The time periods in this table are pre-Reformation (1454-1517), Reformation before the Peace of Augsburg (1518-1554), and after the peace (1555-1599). Cities printing records the number of cities printing in the USTC. "Total Publications" records the number of publications. "Religious Publications" records the number of publications classified as "Religion" by the USTC. The Protestant and Catholic columns under "Religious by Known" record the number of religious publications by known Protestants and Catholics whose religion we identify directly from historical evidence.

Table A6 summarizes the distribution of the lengths of titles in our data, as is and dropping "stop words" (words such as *and* and *the*).

Table A6: Summary statistics on the length of historical titles

	Number of Words in Titles					
	Mean	5%	25%	50%	75%	95%
Titles with stop words	23.2	3.0	11.0	21.0	33.0	51.0
Titles without stop words	14.2	2.0	7.0	13.0	20.0	32.0

This table presents the mean and select percentiles of the title length distribution.

In the main body of the paper we present two examples of the titles of English-language publications. In our complete data, 96% of publications are in German and Latin. The long and content-revealing nature of the titles which we study in the original can also be illustrated with examples. A first example is a pamphlet by the little known Heinrich Spelt, published in 1523, under the title:

> Ain ware declaration oder Erklaerung der profession Gelübten und leben so die gemalten falschen gaystlichenn wider alle Ewangelische freyhayt und Christliche lyeb thun und wie sy solche halten auch ursach varum sy den selben gleyssenden Hailigenschein nit vlassen

A rough translation of this title is:

> A True Explanation of the Profession, Vows and Life which the Coloured, False Priests Pursue Against Evangelical Freedom and Christian Love and how they behave is the reason why they do not leave the same Blinding Halo

A second example is a booklet by the little known Johann Schwann, also published in 1523, under the title:

> Ein Sendbriff. Darinne er anzeigt außder Bibel und schryfft, Warumb er Barfusser orden des er etwan ym Kloster zu Baßell gewest, verlassen

A rough translation of this title is:

> An epistle, in Which He Shows from the Bible and Scripture Why He Left the Barefoot [i.e. mendicant Franciscan] Order in Whose Cloister at Basel He Formerly Was

We provide additional and detailed discussion of how we treat and classify language, and which figures of speech are most associated with different religious views, in the classification appendix below.

A.5 Prices of Books and Pamphlets

We gather data on book prices, and evidence on the physical and content characteristics of priced books, from the purchasing records for a library established by Christopher Columbus' son Hernando Colón. Colón was employed as an official of the Hapsburg monarchy, travelled widely across Europe in connection with his official duties, and made large scale book purchases in over 40 cities over a period of several decades. Colón explicitly aimed to establish a universal library containing all types of printed books. Colón recorded prices paid and current exchange rates for individual book and pamphlet purchases.

These records provide unparalleled evidence on prices. As we note in the main text: these records have "no equal in this time" (Dondi 2010; p. 222) and provide, "an almost unique opportunity to reconstruct the working of the European book market" (Pettegree 2011; p. 87). Colón made purchases of, "all types of books, without linguistic or ideological restriction" (Wagner 1992; p. 486 – my translation).

We construct data on the prices of books and pamphlets from the catalogues recording the purchases made by Hernando Colón (Martínez et al. 1993; de Huelva 2012). A typical example of underlying inscription evidence that we hand-code is follows:

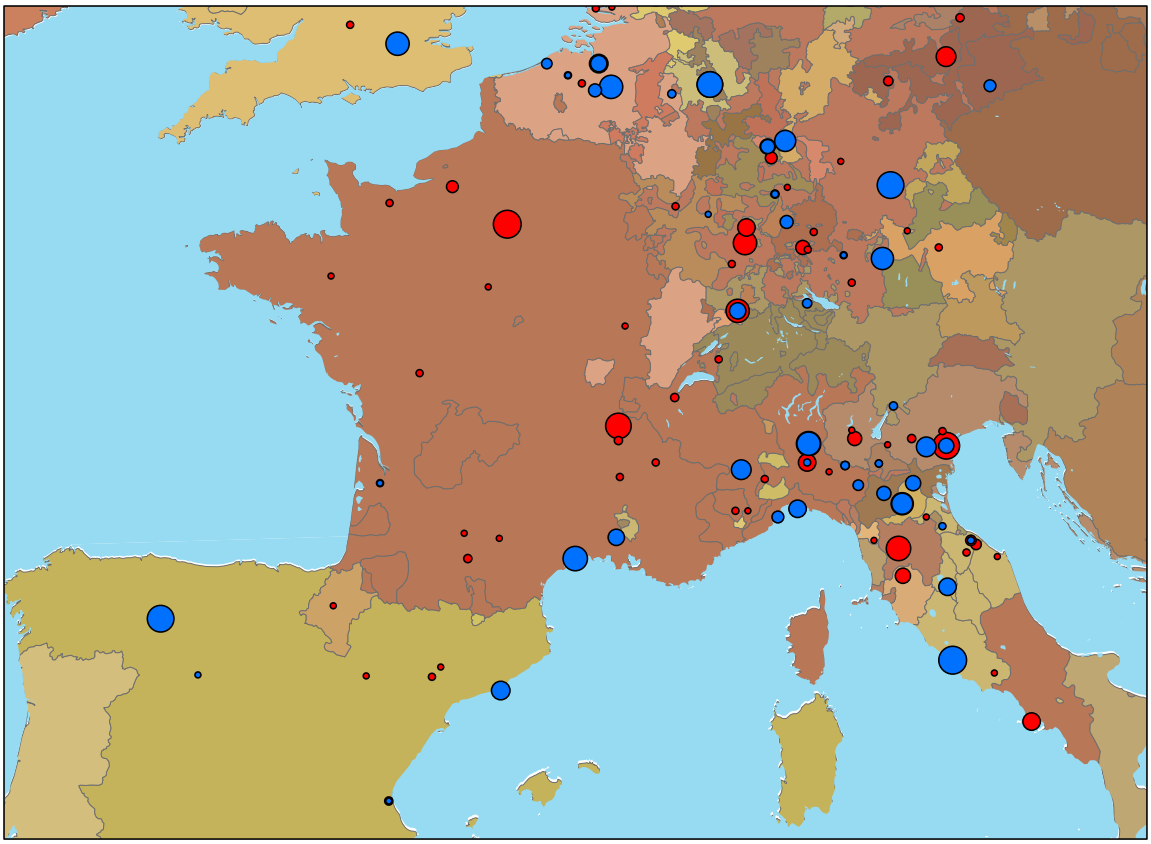
> "Este libro costó 8 negmit en Anvers a 29 de julio de 1531 y el ducado de oro vale 320 negmit."

This records the purchase of a book that cost 8 negmit in Anvers [Antwerp] on July 29, 1531 when the gold ducat was worth 320 negmit. These data are then manually coded in a database.[70] We also gather information on the distance between the city where Colón executed a given purchase and the city where the purchase item was produced, as well as physical and content characteristics of the publications, including number of pages, format (folio, quarto, octavo, or other), the presence of illuminations, the size of pages, and a classification of content.

Figure A1 maps the cities in which Hernando Colón bought books and the cities that produced books that were exported and purchased by Colón elsewhere. Table A7 lists the years with purchases in different cities. Table A8 presents summary statistics on the data.

[70] There are some observations where the exchange rate is not observed. In the case, where other purchases made in the same month record the exchange rate, it is assumed that this exchange rate prevailed across all purchases made in that month. In addition, there are a small number of observations where the exchange rate recorded is obviously wrong and the error is due to either transcription error or ambiguity/illegibility in the original notes. In these cases, the correct exchange rate is used. However, the quantitative results reported below are not materially impacted if these observations are dropped altogether.

Figure A1: Cities in Book Price Data



Cities in which Hernando Colón purchased books 1510-1539 (blue markers) and cities producing books that were exported and purchased by Colon elsewhere (red markers). City markers scaled to reflect the number of purchases (exports) at each location.

Table A7: Cities with Book Purchases

City with Purchases	No. Purchases	Years with Purchases
Aachen	2	1522, 1531
Antwerp	17	1531
Augsburg	46	1521, 1531
Avignon	15	1536
Barcelona	31	1536
Basel	17	1531
Bologna	43	1520, 1530
Bordeaux	1	1531
Bruges	8	1522
Brussels	10	1520, 1522, 1531
Cesena	2	1530
Cremona	3	1531
Ferrara	16	1531
Frankfurt	54	1522, 1524
Freiberg	7	1531
Genova	24	1529, 1530
Gent	3	1520, 1530
Köln	153	1522, 1531
Konstanz	7	1521, 1531
Léon	187	1525, 1535, 1536
Leuven	64	1522, 1531
London	74	1522
Mainz	12	1522, 1531
Milan	49	1530, 1531, 1532, 1535
Modena	15	1529, 1530, 1531
Montpellier	79	1535
Nürnberg	255	1512, 1520, 1521, 1522
Padua	33	1521, 1531
Parma	3	1530
Pavia	1	1531
Perugia	23	1530
Pesaro	2	1530
Piacenza	8	1530
Rome	703	1512, 1513, 1515, 1520, 1522, 1530, 1531
Savona	9	1531
Speyer	1	1531
Torino	35	1531
Trento	3	1521
Ulm	1	1531
Valencia	1	1531
Valladolid	1	1518
Venice	17	1521, 1530, 1531

This table summarizes the locations where Hernando Colón made purchases of books and pamphlets that we examine in the main text. Note that a small number of purchases in the original records are excluded due to ambiguity in information on specific aspects of a purchase or on the publication itself.

Table A8: Summary Statistics on Book Purchases

	Mean	St. Dev.
Ln Price	-0.67	1.45
Printers Active	6.16	5.19
Indicator: Folio	0.20	0.40
Indicator: Quarto	0.58	0.49
Indicator: Octavo	0.22	0.41
Number of Pages	55.90	75.04
Book Age in Years	12.19	12.18
Log Transport Distance	4.54	2.52
Illustrated	0.06	0.24
Religious (not Bibles)	0.36	0.48
Poetry	0.17	0.37
Academic	0.10	0.30
Ordinances & Edicts	0.06	0.24
Linguistics & Philology	0.06	0.24
Dialectics & Rhetoric	0.06	0.23
Medicine	0.05	0.22
Literature	0.04	0.20
Bibles	0.04	0.20
History & Chronicles	0.03	0.17
Jurisprudence & Law	0.02	0.14
Observations	2035	

This table provides summary statistics on books and pamphlets purchased by Hernando Colón. "Ln Price" records the log of price in days of wages, using wage data from Allen (2012). "Printers Active" is the number of printers active in the city-year in which the book or pamphlet was purchased, as measured from USTC book inscriptions. The indicators for Folios, Quartos, and Octavos record the format (and size) of edition pages. A small number of books are in other formats. "Number of pages" records the number of made purchases. "Book Age" measures the number of years between publication and purchase. "Log Transport Distance" measures the log of distance between the city where a publication was printed and the city where it was purchased, plus one. "Illustrated" is an indicator for illustrated and illuminated publications. The remaining variables starting with "Religious (not Bibles)" are indicators for different content classifications. This table presents all classifications with at least 2 percent of books. These account for 98 percent of the purchases. The complete data include a further 26 subject classifications.

A.6 Printing Firms

In this section we describe how we construct evidence on the number of firms active in local media markets. We construct two measures. First, we construct a measure of firms active based on evidence from publications – using the insciptions on historic books to identify firms. This measure is available for all city-years. Second, we construct a measure of firms active based on unique evidence on printer biographies available for printers in German-speaking Europe. This measure is restricted to historically German-speaking cities.

Publications Measure

We construct a measure of firms from publication-level data using printed inscriptions on historical books and pamphlets. Information identifying firms is available on 98% of historic media but in highly non-standardized form. Printers are identified in multiple languages (e.g. Latinized and vernacular variants of the same name), with non-standard spelling, abbreviations, and in some instances aliases. The cleaning and standardization of printer names is the key challenge in the data construction. In a limited number of cases, the inscriptions mention financial backers (i.e. non-printer publishers). Our coding specifically counts printers and *not* non-printer financial backers. We discuss this below. We also discuss the fact that generically printers were, in fact, "printer-publishers".

Table A9 provides an example of the underlying publication-level data and how we construct standardized firm identifiers. Table A9 presents inscriptions for 8 individual publications printed in Augsburg and provides a microcosm of the coding we conduct for the full set of publications in our data. In these examples, widows and heirs are identified as follows. For publication 3, the inscription indicates that the book was "printed and sold by Anna Rügerin in the imperial city of Augsburg." We observe that Anna Rügerin is a woman based on first and last name (the suffix "in" in the last name indicates gender in historic German). Having identified Rügerin as female, we examine the German sources (Reske 2007; 2015), which record that she was the widow of Thomas Rüger, who also appears in our data. For publication 7, we observe that the inscription directly records that this book was produced by the heirs of Erhard Oeglin, as indicated by the Latin designation "haer."

Our overall research strategy is as follows. To determine standardized printing firm names, 20,000+ non-standardized printer text strings are programmatically parsed to eliminate non-name text and identify which books are printed by widows and heirs. Widows and heirs are identified by a tremendously wide range of descriptions and abbreviations across the full range of European languages (see below for a relatively simple

Table A9: Example of how firms are identified from book-level inscriptions

	Printer Inscription from a Publication (1)	Firm 1 (2)	Firm 2 (3)	Widow or Heirs (4)
1.	Johann Schönsperger	Johann Schönsperger		
2.	Johann Schönsperger & Thomas Rüger	Johann Schönsperger	Thomas Rüger	
3.	Gedruckt und volendt von Anna Rügerin in der keyserlichen stat Augspurg	Thomas Rüger		Yes (Firm 1)
4.	Heinrich Steiner von Augsburg	Heinrich Steiner		
5.	Heinrich von Augsburg Steiner	Heinrich Steiner		
6.	Heinrich von Augsburg Steiner & haer. Erhard Oeglin	Heinrich Steiner	Erhard Oeglin	Yes (Firm 2)
7.	excudebat Heinrich von Augsburg Steiner	Heinrich Steiner		
8.	apud Heinrich von Augsburg Steiner	Heinrich Steiner		

This table presents examples of the printer inscriptions on eight individual books in our data that were published in the city of Augsburg.

example).[71] This preliminary work delivers a set of clean but non-standardized names. An automated query is run to look up each of these clean but non-standardized names in the Consortium of European Research Libraries's (CERL) online Thesaurus of early modern printers.[72] For each name found, the Thesaurus provides a set of variants and aliases (sometimes none, sometimes a dozen) used on the title pages of books printed by individual printers' firms. The name variants and aliases provide a first name standardization. Minor spelling errors are corrected using a program that matches names by minimizing a Levenshtein-distance metric. All names are then automatically and manually checked against digitized versions of printed bibliographic dictionaries of historical printers (Benzing 1982; Reske 2007; 2015; Müller 1970; Gruys and de Wolf 1989; Casado 1996). To identify, father-son transitions (as opposed to transitions to widows or heirs)

[71]For example: "apud Jean de Foigny veuve" (a widow), "appresso haer. Francesco I Rampazetto" (heirs), "vid. Dietrich Baum" (a widow), or "en casa de la viuda de Querino Gerardo" (a widow). Some widows printed under their own names and are not directly identified as widows, for example: "Gedruckt und volendt von Anna Rügerin in der keyserlichen stat Augspurg..." In these cases, we search for and identify the former husbands of female managers. In the case of Anna Rügerin – the first known woman printer and operating in Augsburg, Germany in the 1480s – her husband was the printer Thomas Ruger.

[72]See: http://www.cerl.org/en/resources/cerl_thesaurus/main.

we similarly search for documentation of relationships in the CERL Thesaurus, the existing printed sources, and on-line. To link named women printers to their husbands, we search for each individual across all available sources.[73]

Most printers were printer-publishers (Hirsch 1967; Reske 2007; Brady 2009). However, in some cases book inscriptions indicate not simply printers but non-printer publishers and financial backers. For example, Richardson (1999; p. 29) observes,

> "The backing of a publisher might be signalled at the start or end of a book by the presence of his name preceded by a phrase such as *ad instantia di* (at the request of) or, in Latin, *impensis*, *sumptu* or *sumptibus*."

We code the data accordingly. We count as printers only printers; we do not count non-printer publishers and financial backers as printers.

To clarify how we identify printers, we provide examples to illustrate how our methodology treats the underlying source material for the limited share of books with inscriptions that record both (1) printers and (2) financial backers and non-printer publishers.

Example 1 – inscriptions indicating financial backing with the term "*sumptibus*".

> In our source data, there are 822 individual publications (0.3% of the total) in which the term *sumptibus* appears in the frontispiece inscription published between 1500 and 1600. This term indicates that a given book was produced "at the expense" of a given financial backer, who was typically not the printer.
>
> Where *sumptibus* appears, we do not classify the designated financial backers as "printers". We only designate as printers the actual printers listed in the inscriptions. To illustrate our coding, we provide several specific examples, listed here with USTC (2012) identification codes.
>
> For example, we observe a publication printed in Venezia in 1508 with the inscription: "*per Gregorio De Gregori sumptibus Giovanni Giacomo De Angelis*". We classify this publication as printed by "Gregorio De Gregori". We do not classify Giovanni Giacomo De Angelis as a second printer. (USTC 860773)
>
> In a second example, we observe a publication printed in Paris in 1518 with the inscription: "*per Didier Maheu sumptibus Gottfried Hittorp*". We classify this as printed by "Didier Maheu". We do not classify Gottfried Hittorp as a second printer. (USTC 181841)

Example 2 – inscriptions indicating a publisher with the term "*expensis*".

[73] Most female printers are designated as "the widow of" or "heirs of" (Parker 1996). A subset of female printers published under their own names. The research identifies named female printers in two independent ways: manually and using the www.genderchecker.com database. The research forms the firm-level panel by searching for the husband or other predecessor(s) of each female printer.

> In our source data there are are 816 individual publications (0.3% of the total) in which the term *expensis* appears in the inscription published between 1500 and 1600. This term designates financial backers rather than printers. We accordingly separate financial backers from printers.
>
> For example, we observe a publication printed in Milan in 1511 with the inscription: "*per Leonhard Pachel expensis Giovanni Giacomo & fratres Da Legnano*" (USTC 822696). We classify this as printed by Leonhard Pachel. Giovanni Giacomo and the Da Legnano brothers are not classified as printers.
>
> In a second example, we observe a publication printed in Salamanca in 1556 with the inscription: "*Andrea de Portonariis expensis Juan Moreno et Luis Méndez*" (USTC 346500). We classify this as printed by "Andrea de Portonariis". We do not classify Moreno or Méndez as printers."

In our complete data, there are additional designations that we examine. For example, in a small number of publications (0.01% of the total) the term *aere* appears in the frontispiece inscription, which may designate a non-printer participant. We observe, for example, a publication printed in Venezia in 1536 with the inscription "*aere & diligentia Giovanni Francesco Trincavelli: in aedibus Bartolomeo Zanetti.*" (USTC 810885) We classify this as printed by Bartolomeo Zanetti. We do not classify Giovanni Francesco Trincavelli as a second printer. Note that a large share of the "*aere*" publications in the data were printed by Zanetti and have this inscription. Trincavelli only appears in the data as a publisher-cum-backer, not as a printer, and only for these publications. However, a contrasting case is a publication printed in Venezia in 1526, with the inscription "*suo aere ac typis Lucantonio I Giunta*" (USTC 814426). We classify this publication as printed by Lucantonio Giunta I given the designation "*typis*".

Several further observations may clarify how the inscription data may be interpreted. When considering the inscriptions as a source of evidence, it is important to observe that printers were typically printer-publishers. The role of publisher was typically not separate from that of printer (Reske 2007; Hirsch 1967; p. 23). Thus (Brady 2009; p. 27) observes:

> "Unrestrained by guild regulations, in the print shops the same man usually combined most or all of the requisite crafts of type founder, printer, publisher, editor, and bookseller."

This is confirmed in the biographic data we construct from Reske (2007; 2015), which provide unparalleled evidence on individual printers. The Reske volumes complete a research project initiated by Joseph Benzing, who was Prussian State Librarian before World War II and subsequently head librarian at the University of Mainz, to document the activities of "printer-publishers":

> "The most comprehensive biographical dictionaries of XVI-th century *printer-publishers* are those of Joseph Benzing for the German-speaking area" (Hirsch 1967; p. 20 - emphasis added).

Thus, while we code our data to separate printers from non-printer publishers and focus our attention on printers, printers typically were printer-publishers. There is some remaining residual ambiguity in the inscriptions (Richardson 1999; Gilmont 1992). Our analysis therefore uses the inscriptions to construct *proxy* measures of industrial organization and competition, which we validate by examining both price and quantity data.

Biographical Measure

We construct a biographical measure of firms in German-speaking cities from the authoritative biographical dictionary of printers in German-speaking Europe: Reske (2007; 2015), *Die Buchdrucker des 16 und 17 Jahrhunderts im deutschen Sprachgebiet: auf der Grundlage des gleichnamigen Werkes von Josef Benzing*.[74] To identify firms from biographical data we manually code information from Reske (2007; 2015). Reske (2007; 2015) is a biographical dictionary that has the objective of providing an entry on every single printer active in German-speaking Europe over our time frame. Reske provides the dates printers were active in different cities and dates that they died. We manually code this information into a database to identify (i) the firms active in different cities in different periods, (ii) the dates printers died, and (iii) whether printers died while still active in business or when retired.

We show below that "missingness" does not drive our key IV results concerning printing during the Reformation. We track each individual printer who exited in the period just before the Reformation, and document that these exits were not caused by "missing" deaths.

Discussion

There are differences between the measure of firms from biographical data and from publications evidence. First, the biographical data are restricted to German-speaking cities. Second, within-German speaking Europe there are differences between the sources. The principal within-Germany difference is that the publications data include a fringe of small individuals named on the front pages of publications who are absent in Reske (2007; 2015). Our key results on the diffusion of religious printing during the Reformation

[74] Reske (2007; 2015) builds on the research in Josef Benzing's *Die Buchdrucker des 16 und 17 Jahrhunderts im deutschen Sprachgebiet* (Verlag Harrassowitz, 1963). Josef Benzing's research was conducted while he was employed by the Preußischen Staatsbibliothek in Berlin 1934-1945 and subsequently when Benzing was head librarian at the University of Mainz 1946-1966. Benzing was a member of the National Socialist party and during World War II coordinated both the cataloging and the theft of historic book collections in territories conquered by the Nazis.

are robust to using either the biographical (baseline) or publications measure of firms. However, several aspects of the evidence are notable. It is possible that printers named in inscriptions produced under aliases that we incorrectly class as independent printers and that occasional individuals brought out books under their name while actually working with or using the equipment of an established printer. Reske (2007) documents that the occasional publication would be produced under the name of a financial backer who was not and did not emerge as a principal player in local media markets, even in the workshop of and using the equipment of other established printers. It is possible that some of the printers we observe in publications data but not in Reske (2007; 2015) are of this type. In addition to these cases, there are a few printers recorded in Reske who do not appear in our data because no evidence of their output survives. When we compare our sources, we thus face generic economic questions about how we define production units and where the relevant variation lies for thinking about market structure, as well as challenges specific to data from the 1500s. Our two measures of firms provide a rich characterization of the actors in, and the operation of, historic media markets.

A.7 Printer Deaths

This section describes how we construct our measures of shocks due to the deaths of active printers. We construct two measures of printer deaths. First, we construct a measure of printer deaths from publications (output) data – using evidence from inscriptions on historic books. We refer to this as our "publications measure." Second, we construct a measure of printer deaths from biographical data on printers (Reske 2007; 2015). We refer to this as our "biographical measure."

As described in the main text, the advantage of the publications measure is that it is available for all cities across Europe. The disadvantage of the publications measure is that it is by construction available only for firms that survive a manager's death. This naturally raises questions about selection and whether cities, times, and firms where a printing enterprise survives the death of a printer are special. To address these questions, we construct our biographical measure of printer deaths which covers all deaths – including those that lead to firm exits. We use the biographical measure to document that our key results are robust to using either measure of shocks and that the selective observation of deaths in surviving firms does not account for our findings.

Publications Measure

The publications measure of printer deaths infers that a death occurs in the year in which a firm's output first has an inscription indicating that production was conducted

by a widow or heir. For example, Table A9 provides examples of several inscriptions on publications produced by the firm of Heinrich Steiner, one of which was published by his heirs. We infer that the death occurred in the first year in which such a publication is observed.

Biographical Measure

The biographical measure of printer deaths is constructed by hand-coding information on years of death from Reske (2007; 2015).

We rely most directly on the biographical measure of deaths from Reske (2007; 2015) as a measure of shocks to local printing just before the Reformation. For this reason, we provide a review of the construction of these data and the nature of the observed deaths in the immediate pre-Reformation era. The fundamental point is that our measure of shocks is based on tracking every printer active 1508-1517 in order to construct a comprehensive record of firms and cities where active printers died.

To understand how we track all printers and their firms, it is important to understand the nature of the historical data we construct. There are four types of firms in our baseline data on pre-Reformation printing in German-speaking Europe (Reske 2007; 2015).

1. There are firms active 1508-1517 that experience a death which leads to their exit in this period. Deaths are observed from Reske (2007; 2015).
2. There are firms active 1508-1517 that experience a death but do not exit. These firms survive because management passes to other family members (e.g. a widow or other heirs). Deaths are observed from Reske (2007; 2015).
3. There are firms active 1508-1517 that do not experience a death over this period and who do not exit. Survival without death is observed from Reske (2007; 2015).
4. There are firms that exit 1508-1517 without a death recorded in this particular period. We call these the "untreated who exit."

Our key questions about measurement and measurement error center on the last group: firms that exit just before the Reformation without recorded deaths in this period. The concern is two-fold. First, it could be that these exits were actually caused by unobserved deaths. Second, it could be that deaths are recorded more frequently in dynamic and sophisticated cities that were receptive to innovation in thought and belief. Were this the case, the variation in competition induced by observed deaths could be an artefact of the data preservation process, and the relationship between the induced

variations in competition and subsequent religious media could just reflect underlying differences in cities – as opposed to exogenous shocks to competition.

We document that our data are free of this sort of underlying selection by providing detailed information on the timing of death and circumstances of exit for each individual printer who makes an exit that is not associated with a death (the "untreated who exit"). Table A10 documents that unobserved deaths do not account for the exits by providing individual-level data on the exit circumstances and life histories of every printer who ceased production in some city over the period 1508-1517. Table A10 shows that we are able to definitively document that 25 of these 31 exits were not caused by deaths by examining evidence on: (i) relocation decisions, (ii) the closure or sales of business , (iii) the timing of other subsequent professional activities, and (iv) the timing of deaths observed after printers exited production, and (v) other historical evidence from university and city records. The remaining 6 printers where we are unable to pin down the timing of death definitively cannot account for our results. Of these 6 printers, all were located in cities that became Protestant. If we were to assume that these exits were caused by deaths – or that some arbitrary subset of these exits were caused by deaths – our baseline results do not change qualitatively and in fact because slightly stronger quantitatively. It is highly unlikely that these 6 exits were actually caused by deaths. In the case of 2 of these 6 ambiguous exits the evidence very strongly suggests that death had no role in the close of business. We class these as unlikely. The remaining 4 cases we conservatively class as uncertain. This classification is conservative in the sense that it remains highly unlikely that the death of an active printer would fail to be recorded in historical evidence given (i) the importance of both printers and printer deaths to the local organization of an industry that had such an important place in urban culture and the dissemination of ideas and (ii) the fact that printer deaths frequently initiated complicated legal proceedings associated with estate management and outstanding obligations.

Table A10: Printers Exiting 1508 to 1517

Name of Printer	City	Year Exit	Death	Evidence and Sources
Georg Stuchs	Nuernberg	1517	No	Stuchs died in 1520. See Reske (2007).
Hermann Guitschaiff	Cologne	1517	No	Guitschaiff's business operations ended when he was caught by Cologne city authorities printing a Reformist (Protestant) tract in 1517. This is recorded in city archives, "Im Liber malefactorum der Stadt Koeln." See Hoffmann (2003), "Entreregionisierung im Kölner Buchdruck in den ersten Jahrzehnten des 16. Jahrhunderts?" For discussion of Cologne, see Scribner (1972) cited in text and the main bibliography.
Johann von Solingen	Cologne	1517	No	Von Solingen lived until at least 1520. See Benzing (1982, Volume 2, p. 236).
Konrad Kachelofen	Leipzig	1517	No	Kachelofen died in 1528. See Reske (2007).
Konrad Kerner	Strassburg	1517	No	Kerner is observed in historical records on the city of Rottenberg from the 1520s. See Febvre and Martin (1979, p. 293). On possible evidence that Kerner briefly worked in Rothenburg ab Tauber in 1523, see Reske (2007, p. 879).
Jakob Stadelberger	Heidelberg	1516	Unlikely	Stadelberger's output was observed to be of strikingly poor quality ["auffallend schlechter Qualitaet"] for the four years before exit. See Reske (2007, p. 356)

Continued on next page

Table A10 – continued from previous page

Name of Printer	City	Year Exit	Death	Evidence and Sources
Klosterdruckerei der Karatause St. Barbara	Cologne	1516	No	This was the printing house of a religious establishment.
Matthias Hupfuff	Strassburg	1516	No	Hupfuff died in 1522. See Reske (2007).
Thomas Anshelm	Tubingen	1516	No	Anshelm moved from Tubingen to Hagenau in 1516. See Reske (2007).
Klosterdruckerei with Lukas Zeissenmair	Wessobrunn	1515	No	This was the printing house of a religious establishment outside our set of printing cities.
Konrad Hist	Speyer	1515	No	Hist died in 1531. See Reske (2007).
Privatepresse des Hermann Barkhausen	Rostock	1515	No	Barkhausen died in 1527. See Reske (2007).
Wilhelm Schaffner	Lahr	1515	No	Schaffner moved from Lahr to Strasbourg in 1515. Reske (2007).
Gregor Bartholomaus	Basel	1515	Uncertain	No historical information found
Wolfgang Huber	Nuernberg	1514	No	Huber's business was taken over by Jobst Gutknecht in 1514 (Reske 2007, p. 662)
Johann Weissenburger	Nuernberg	1513	No	Weissenberger moved from Nuernberg to Landshut in 1513. See Reske (2007).
Nikolaus Keibs	Durlach	1513	Uncertain	See Gisela Möncke: "Zum frühen Durlacher Buchdruck: Nikolaus Keibs," in *Gutenberg-Jahrbuch* (1994).
Privatpresse des Ulrich Pinder mit Drucker Friedrich Peypus	Nuernberg	1513	No	Peypus died in 1519. See Reske (2007).

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Table A10 – continued from previous page

Name of Printer	City	Year Exit	Death	Evidence and Sources
Sebaldus Striblita	Erfurt	1512	Uncertain	See Martin von Hase, "Sebaldus Striblita in Erfurt, der erst deutsche Kursivdrucker (1510)", *Gutenberg-Jahrbuch*, Bd. 11 (1936) S. 94-97
Freidrich Heumann	Mainz	1512	No	Heumann lived until 1535. See Falkenstein (1840, p. 150) *Geschichte der Buchdruckerkunrst in ihrer Entstehung und Ausbildung*
Kolsterdruckerei des Kartauserk-losters	Rostock	1512	No	This was the printing house of a religious establishment.
Reinhard Beck d. A	Baden-Baden	1511	No	Beck moved from Baden-Baden to Strasbourg in 1511. See Reske (2007).
Thomas Anshelm	Pforzheim	1511	No	Anshelm moved from Pforzheim to Tubingen in 1511. See Reske (2007).
Sixt Murner	Strassburg	1510	Unlikely	Murner is recorded as the printer of a single book written by his celebrated brother, the author Thomas Murner in 1510.
Hans Borchard with Thomas Borchard	Hamburg	1510	Uncertain	Hans [Johannes] Borchard produces solo 1505-1510 (Reske, p. 332). Deutsche Biographie indicates that nothing more is known after 1510: http://www.deutsche-biographie.de/sfz5287.html. Thomas Borchard only produces in 1491.
Nikolaus Kessler	Basel	1510	No	Kessler died in 1519. See Reske (2007).
Bartholomaus Kistler	Strassburg	1510	No	Kistler died in 1525. See Reske (2007).
Rudolf Spot	Cologne	1509	No	Spot lived until at least 1521. See *Deutsches Jahrbuch für Volkskunde*, Volume 6 (1960).

Continued on next page

Table A10 – continued from previous page

Name of Printer	City	Year Exit	Death	Evidence and Sources
Georg Richolff d. A fur Laurenz Bornemann	Muenster	1509	No	Richolff moved from Muenster to Luebeck in 1509. See Reske (2007).
Konrad Baumgarten	Frankfurt an der Oder	1509	No	Baumgarten closed his operations by selling plant and equipment to Johann Hanau in 1509. Johann Hanau operated his new business 1509-1540. See Deutsche Biographie: http://www.deutsche-biographie.de/sfz5223.html.
Balthasar Murrer with Nikolaus Lamparter	Frankfurt an der Oder	1509	No	Lamparter left Frankfurt for Basel in 1507. Murrer continued as sole proprietor until he sold the business to Johann Hanau in 1510. See Reske (2007, p. 268).
Ambrosius Lacher	Frankfurt an der Oder	1508	No	Lacher is observed engaged in academic training and working as academician from 1510s onwards for several decades. For example receives Lizentiat (degree) in Medicine in 1522 and works as Rektor at the University of Frankfurt. Dies in 1540. See Deutsche Biographie, online: Deutsche Biographie: http://www.deutsche-biographie.de/sfz47283.html

A.8 Economic Outcomes – City Growth and Individual Achievement

City population data are from Bairoch et al. (1988). These data record the populations of urban agglomerations in 1500 and 1600 for 239 cities with printing.

Individual achievement data are from the *Deutsche Biographie*. We measure individual achievement at the city-by-cohort-by-sector level. We assign individuals to their city of birth and to cohorts based on the decade in which they were born. We classify the sector of individual occupations as either "bourgeois" or "church or noble", which are mutually exclusive categories. We use "church" as a shorthand to refer to all religious occupations (including a small number of Jewish occupations, such as rabbis). We use this classification to assign individuals to two high-level occupational sectors. Individual occupations are designated in the *Deutsche Biographie* with hundreds of distinct occupational titles (descriptions) that we manually code. We examine 70 German-speaking cities with printing and population data (i.e. all German-speaking cities included in our analysis of city growth).

A.9 Institutional Change Outcome

We measure institutional change by the passage of a Reformation Law over the period between 1518 and 1554 in German-speaking cities. Our measure is a binary: 1 for cities that passed a Reformation Law over this period and 0 for those that did not. When we study the dates of Reformation Laws, we study the dates of the first Reformation Law passed at the city level.[75]

For cities in Germany, we code information on the locations and dates of city laws (*Kirchenordnungen*) from the multi-volume collection of Protestant church ordinances *Die Evangelischen Kirchenordnungen Des XVI. Jahrhunderts*, originally edited by Emil Sehling. The complete list of volumes we code is as follows. Emil Sehling editor, Volume I Sachsen und Thüringen nebst angrenzenden Gebieten (1902) (Leipzig: O.R. Reisland). Emil Sehling editor, Volume II Sachsen und Thüringen nebst angrenzenden Gebieten (1904) (Leipzig: O.R. Reisland). Emil Sehling editor, Volume III Brandenburg, Ober- und Niederlausitz, Schlesien (1909). Emil Sehling editor, Volume IV Preußen, Polen, Pommern (1911). Emil Sehling editor, Volume V Baltische Länder, Mecklenburg, Lübeck, Lauenburg, Hamburg (1913). Institut für evangelisches Kirchenrecht der EKD, Volume

[75] Some cities passed multiple such laws, either amending existing legislation or passing distinct provisions as separate laws.

VI/1 Niedersachsen (1955). Institut für evangelisches Kirchenrecht der EKD, Volume VI/2 Niedersachsen (1957). Institut für evangelisches Kirchenrecht der EKD, Volume VII/1, Niedersachsen (1963). Institut für evangelisches Kirchenrecht der EKD, Volume VII/2, Niedersachsen (1980). Institut für evangelisches Kirchenrecht der EKD, Volume VIII Hessen I: Landgrafschaft bis 1582 (1965). Institut für evangelisches Kirchenrecht der EKD, Volume XI, Franken, (1961). Institut für evangelisches Kirchenrecht der EKD, Volume XII, Schwaben (1963). Institut für evangelisches Kirchenrecht der EKD, Volume XIII Altbayern (1966). Institut für evangelisches Kirchenrecht der EKD, Volume XIV Kurpfalz (1969). Institut für evangelisches Kirchenrecht der EKD, Volume XV Baden-Württemberg I: Hohenlohe (1977). Heidelberger Akademie der Wissenschaften, Volume XVI Baden-Württemberg II: Württemberg, Baden u. a. (2004). Heidelberger Akademie der Wissenschaften, Volume XVII/1; XVII/2 Baden-Württemberg III/IV: Reichsstädte (2007/09). Heidelberger Akademie der Wissenschaften, Volume XVIII Rheinland-Pfalz I: Zweibrücken, Veldenz, Sponheim u. a. (2006). Heidelberger Akademie der Wissenschaften, Volume XIX Rheinland-Pfalz II: Wild- und Rheingrafschaft, Leiningen, Wied u. a. (2008). Heidelberger Akademie der Wissenschaften, Volume XX/1 Elsass I: Straßburg (2011). Heidelberger Akademie der Wissenschaften, Volume IX Hessen II: Landgrafschaft ab 1582, Waldeck, Solms, Frankfurt u. a. (2011). Heidelberger Akademie der Wissenschaften,Volume X Hessen III: Nassau, Hanau-Münzenberg, Ysenburg (2012). Heidelberger Akademie der Wissenschaften, Volume XX/2 Elsass II: Hanau-Lichtenberg, Colmar, Mülhausen, Weißenburg u.a. (2013).

Our analysis includes several German-speaking cities outside contemporary Germany that are for this reason not covered in the *Die Evangelischen Kirchenordnungen Des XVI. Jahrhunderts* collection. For these cities, we classify institutional change status from additional historical sources that record whether and when cities adopted institutional change (*Kirchenordnungen*). For Zürich: Campi, Emidio and Philipp Wälchli, *Zürcher Kirchenordnungen 1520-1675* (Zürich: Theologischer Verlag Zürich, 2011). For Basel: Campi, Emidio and Philipp Wälchli, Philippe, *Basler Kirchenordnungen 1528-1675* (Zürich: Theologischer Verlag Zürich, 2012). For Brno (Brünn): Thomas A. Brady, Heiko Augustinus Oberman, James D. Tracy, *Handbook of European History 1400 - 1600: Late Middle Ages, Renaissance and Reformation* (Leiden: Brill, 1994). Haguenau: Joseph Guerber, *Haguenau et la Réforme* (Lyon: Le Roux L.F., 1861). Kostrzyn (Kostschin): Jürgen Sanowsky, "Vorgeschichte und Anfänge der Reformation in der Ballei Brandenburg des Johanniterordens", in Johannes Mol et al. eds., *Military Orders and the Reformation: Choices, State Building, and the Weight of Tradition* (Amersfoort: Uitgeverij Verloren, 2006). Montbéliard (Mompelgard): Elise Dermineur, "Rural Communities and the Reformation: the process of confessionalization in Montbéliard, 1524-

1660" (working paper www.academia.edu). Mulhouse: Peter Blickle, *Communal Reformation: The Quest for Salvation in Sixteenth-Century Germany* (Leiden: Brill, 1992). Schaffhausen: Cameron (1991). St. Gallen: http://www.sg.ch/home/kultur/stiftsarchiv/geschichte.

A.10 Institutional Variables Used as Controls

In the analysis of the Reformation, we examine several measures of *ex ante* institutions. Our principal source on the constitutional status of cities is the 1521 tax register (*Reichsmatrikel*) of the Holy Roman Empire. The *Reichsmatrikel* lists the cities constitutionally designated as free and imperial cities (*Freie und Reichsstädte*). For on-line list see: http://de.wikisource.org/wiki/Reichsmatrikel_von_1521 (downloaded December 2012). We use Cantoni (2014) to identify ecclesiastic cities and Wikipedia to identiy a list of historic prince-bishops of the Holy Roman Empire (https://en.wikipedia.org/wiki/Prince-bishop, downloaded February 2014). We gather data on the historic territories cities were located in using GIS maps from Euratlas (2008), *Periodical Historical Atlas of Europe*. These data are: Copyright 2008, Christos Nüssli, Euratlas www.euratlas.com, utilisation licence of 2009. In the econometric analysis, we cluster standard errors at the Euratlas territory ("holder") level. It should be understood that the Euratlas territories capture geographic proximity, but are not a direct measure of local institutions. Complicated and heterogeneous institutional arrangements in some cases applied even to cities sharing the status as *landstadt* (i.e. not a free city) within a given territory. See Whaley (2011) for a review. Table A11 summarizes the distribution of cities across political units.

Table A11: The distribution of cities across principalities and territories

Principality or Territory in 1500 [1]	Cities [2]
Archbishopric of Salzburg	1
County of East Friesland	1
County of Ruppin	1
Crown of Bohemia in Personal Union with Kingdom of Hungary	10
Duchies of Juelich and Berg	4
Duchy of Brunswick-Calenberg	2
Duchy of Brunswick-Lueneburg	2
Duchy of Brunswick-Wolfenbuettel	6
Duchy of Cleves and County of Mark	7
Duchy of Lower Bavaria-Landshut	4
Duchy of Mecklenburg	3
Duchy of Pomerania	6
Duchy of Saxony	14
Duchy of Upper Bavaria-Munich	3
Duchy of Wuerttemberg	6
Electoral Palatinate	4
Electorate of Brandenburg	6
Electorate of Cologne	2
Electorate of Mainz	1
Electorate of Saxony	14
Electorate of Trier	2
Habsburg Monarchy	8
Kingdom of Denmark	5
Kingdom of Poland	2
Landgraviate of Hesse	2
Lordships of the House of Nassau	1
Margravate of Baden	2
Monastic State of the Teutonic Knights	2
Prince-Bishopric of Passau	1
Principality of Anhalt	3
Small States of the Holy Roman Empire	57
Swiss Confederacy	8
Upper Palatinate	1

This table presents the territorial classification of cities in the Euratlas data.

B Classification of Religious Publications

This appendix describes the strategy we use to identify partisan language and classify religious publications. We describe the estimator used to classify and discuss how we select the vocabulary used to study how language shifts with religion. We then compare the performance of the estimator in our preferred strategy with alternative approaches in the literature.

B.1 Estimator

Using the subset of titles for which we code whether the author is Protestant or Catholic, we apply an estimation strategy that first provides a low-dimensional representation of each text that preserves the religious sentiment and second classifies this low-dimensional representation according to the religion of the authors. We are then able to find low-dimensional representations of religious content those texts for which we do not know the author's religious affiliation and to predict religion. The estimation framework is the multinomial inverse regression (MNIR) model introduced by Taddy (2013b).[76]

Formally, let a document be denoted $\boldsymbol{X}_i = [x_{i1,\ldots,iW}]$ where x_{iw} represents the number of times phrase w appears in document i for each of the W words in the the *vocabulary* V. We are interested in identifying the features that allow us to classify the documents according to their religious content r with $r \in P, C$ for Protestant or Catholic. Since the distribution of a sum of multinomial draws from the same distribution is multinomial, we are able to pool the observations into (at least) two classes P and C such that $\boldsymbol{X}_r = \sum_i x_{iwr}$ for $r \in P, C$. Our model for documents is

$$\begin{aligned} &\boldsymbol{X}_r \sim MN(\boldsymbol{q}_r, m_r) \text{ where} \\ &q_{rw} = \frac{\exp\left[\alpha_w + r\varphi_w\right]}{\sum_{j=1}^{W} \exp\left[\alpha_j + r\varphi_j\right]} \text{ for } w = 1, \ldots, W, r \in P, C \end{aligned} \tag{9}$$

Each $\boldsymbol{X}_r$ is a $W-$dimensional multinomial variable with size $m_r = \sum_i m_{ir}$ with $m_{ir} = \sum_w x_{iwr}$ and probabilities $\boldsymbol{q}_r = [q_{r1}, \ldots, q_{rW}]$. The estimated *factor loadings* $\boldsymbol{\varphi}$ allow us to compute a *sufficient reduction* (SR) score z_i for document word frequencies

[76] The estimation strategy follows the literature in high-dimensional estimation and machine learning, assumes that the order of phrases or words within a document is relatively unimportant in classifying the content of the text, and views documents as a *bag of words* (Salton and McGill 1986). This assumption allows documents to be treated as as multinomial random variables in which the phrases or words are the categories and the support is called the *vocabulary*. We thus increase efficiency by making an assumption about the functional relationship between text and sentiment (Taddy 2013c).

$\boldsymbol{f}_i = \frac{\boldsymbol{x}_i}{m_i}$. The identifying assumption is that the sufficient reduction score z_i is a scalar containing all relevant sentiment information in document i independent of the full $\boldsymbol{X}_i$ and its length.

$$z_i = \boldsymbol{\varphi}' \boldsymbol{f}_i \Rightarrow r_i \perp\!\!\!\perp \boldsymbol{X}_i, m_i \mid z_i \tag{10}$$

This assumption allows us to ignore the full-dimensional $\boldsymbol{X}_i$ and model the classification problem as a univariate regression problem:

$$Pr(r_i = r \mid z_i) = \frac{1}{1 + \exp\left[\beta_0 + \beta_1 z_i\right]} \tag{11}$$

To estimate the religious content of texts, we take the projection of the factor loadings estimated in (9) onto the frequencies of these out-of-sample texts to obtain SR scores $\hat{z}_i$. We then use the coefficients from (11) to infer the religious content of the texts.

To address possible implications of fat-tailed and sparse distributions, independent Laplace priors with unknown variance are placed on the factor loadings φ_w. The unknown rate parameter λ_w accounts for our uncertainty as to how much variable-specific regularization is appropriate and is given a gamma hyperprior $\Gamma(\alpha, \beta)$ such that:

$$\Pr(\varphi_w, \lambda_w) = \frac{\lambda_w}{2} e^{-\lambda_w |\varphi_w|} \frac{\beta^\alpha}{\Gamma(\alpha)} \lambda_w^{\alpha-1} e^{-\beta \lambda_w}, \ \alpha, \beta, \lambda_w > 0. \tag{12}$$

Estimation of the likelihood implied by the multinomial distribution in (9) and the prior (12) takes place via the gamma-lasso algorithm to maximize the joint posterior over coefficients and their prior scale (Taddy 2013b;a).

B.2 Vocabulary Selection

To prepare the titles for use in the classifier described in Section B.1, it is desirable to identify first the words which will serve as the support for the multinomial distribution. This is the vocabulary.

We construct the vocabulary as follows. First all generic titles are removed.[77] We clean the remaining text by making the titles lower-case and removing punctuation, numbers and roman numerals, and words that occur fewer than three times. Futhermore, we experiment with both removing German and Latin stop words and preserving them

[77] Titles that do not contain words illuminating what the works are about such as *Theil*, an alternate spelling of the German *teil* meaning part of a whole, and *Samml*, an abbreviation of the German for *collection*, are removed.

Table B1: Distribution of Known Catholic Title Lengths

	Total Words including Stop Words	Words in Estimating Vocabulary
5th Percentile	7.0	3.0
25th Percentile	15.0	7.0
Median	23.0	12.0
75th Percentile	33.0	18.0
95th Percentile	49.0	30.0
Mean	25.1	13.7

in estimation.[78] We do not stem words. Stemming involves using an algorithm to reduce words to a common root. It is common practice in text analysis to stem words. However, we choose not to stem words for several reasons. First, orthographic variation may in some instances reflect ideological differences in authors' religions that we wish to preserve. Second, the lack of orthographic standardization significantly complicates stemming. Third, we demonstrate meaningful results without stemming. We discuss this again in Section B.6.

For the computation of counts used to construct measures of denominational language, we temporarily drop titles that may be reprints and would therefore skew the usage of certain words simply by the number of times a given title appeared in print.

The impact of removing stop words on the title length distributions can be seen in the second column of table (A6). As can be seen in tables (B1) and (B2) the sample-wide distribution is indicative of the sub-populations of Protestants and Catholics.

In selecting the most relevant features of the language for classifying phrases as Protestant or Catholic, we examine three strategies. First, we use the χ^2 measure used by Gentzkow and Shapiro (2010) to select features. Second, we use the log-odds ratio proposed by Monroe et al. (2008). Third, we require no prior selection of the features, relying only on the model-based feature selection via regularization inherent in the estimator. For each strategy, we implement two variants: one in which stop words are removed and one in which stop words are preserved.[79]

To compare the performance of these six strategies, we perform out-of-sample cross

[78] German stop words include words such as *da* and *dass*, *der* and *die*, and *und* and *unde*. These are words for *this*, *the*, and *and* in both modern and Old High German.

[79] The intuition here is that stop words may contain relevant information for classification. Consider the distinction between the phrase "the Church" and a phrase like "our church."

Table B2: Distribution of Known Protestant Title Lengths

	Total Words including Stop Words	Words in Estimating Vocabulary
5th Percentile	4.0	1.0
25th Percentile	10.0	4.0
Median	17.0	8.0
75th Percentile	26.0	12.0
95th Percentile	42.0	20.0
Mean	19.1	8.8

validation. To implement the out-of-sample cross-validation, we train the model on 80% of the data and test it on a held-out 20%.[80] As discussed below, we find that the log-odds ratio performed best when retaining stop words and use this as our baseline strategy, as discussed below.

B.3 The χ^2 Measure

The χ^2 measure used in Gentzkow and Shapiro (2010) can be written as:

$$\chi^2_{wn} = \frac{\left(f_{wnc}f_{\sim wnp} - f_{wnp}f_{\sim wnc}\right)^2}{\left(f_{wnc} + f_{wnp}\right)\left(f_{wnc} + f_{\sim wnc}\right)\left(f_{wnp} + f_{\sim wnp}\right)\left(f_{\sim wnc} + f_{\sim wnp}\right)} \tag{13}$$

where f_{wnc} and f_{wnp} denotes the total number of times phrase w of length n is used in a title by a Catholic or Protestant writer, respectively. Whereas, $f_{\sim wnc}$ and $f_{\sim wnp}$ denotes the total number of times a length n phrase that is not w is used by Catholics and Protestants, respectively.

There are two challenges associated with the χ^2 measure. The first challenge is that there is nothing to differentiate "Catholic" phrases from "Protestant" phrases. The χ^2 measure classes any phrase that has more counts in "Catholic" documents as "Catholic," and vice versa. Figures B1-B6 show the results of applying the Gentzkow-Shapiro χ^2measure to the texts. These figures illustrate how Catholic words seem to be much more distinguished by the χ^2 measure than the language used by Protestants. The terms do conform to our expectations about what distinguishes Catholic terms from Protestant terms. However, in Figures B1-B6, the χ^2 values for the Catholics have been negated. This potential shortcoming is further discussed in Monroe et al. (2008).

[80]Simulations training the estimator on 65% and 90% deliver virtually identical results.

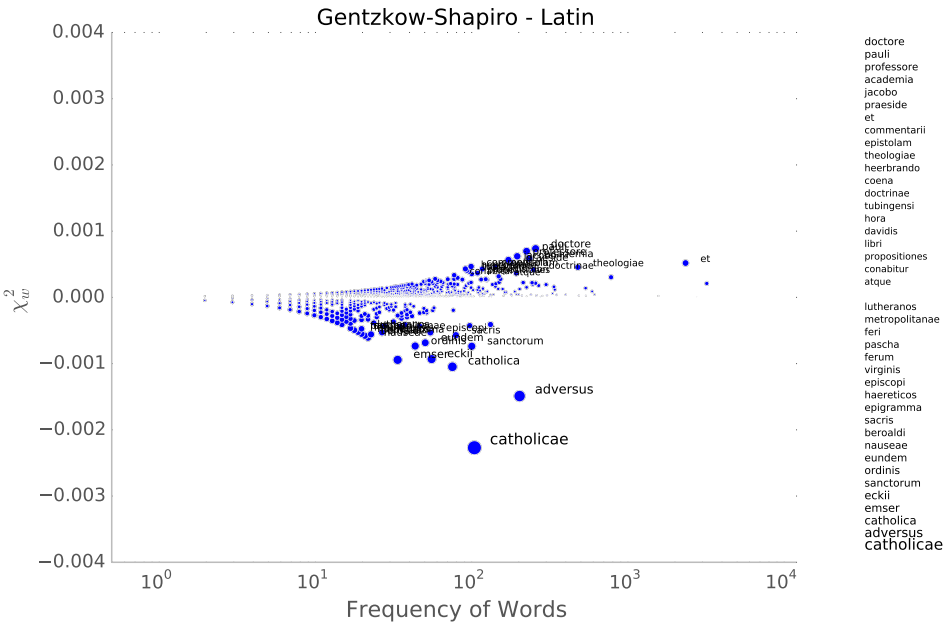


Figure B1: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin unigrams only.

Table B3: The number of phrases left after applying the feature selection method of Gentzkow and Shapiro. Stop words are not removed.

Language	unigrams		bigrams		trigrams	
	Protestant	Catholic	Protestant	Catholic	Protestant	Catholic
German	2000	1975	2000	2000	2000	2000
Latin	2000	1011	2000	2000	2000	2000

The second challenge with the χ^2 metric is that there is no natural significance cut-off for selecting partisan phrases. The scale of the values obtained from (13) do not appear to follow from any parameterized χ^2 distribution. Gentzkow and Shapiro (2010) select the top 2,000 each of unigrams, bigrams, and trigrams. We follow the same heuristic with one difference. After obtaining the measure for each phrase for both Protestants and Catholics, we sort each list of the n-length phrases for each group from largest to smallest and select out the smaller of 2,000 or the number of total phrases of length n from each groups to obtain our vocabulary. We do this for both Latin texts and German texts separately so that we do not bias the results due to choice of publication language. Tables B3 and B4 presents the results of this selection.

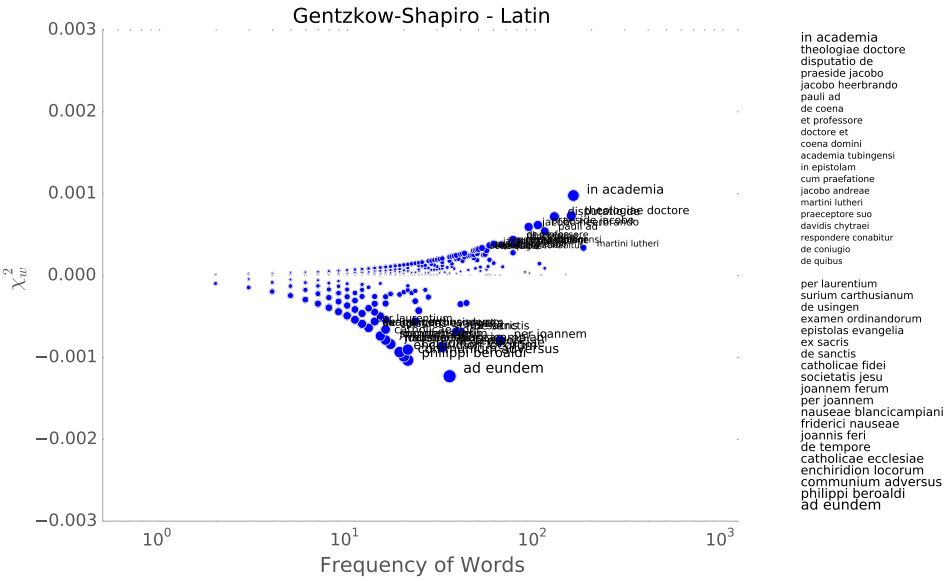


Figure B2: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin bigrams only.

Table B4: The number of phrases left after applying the feature selection method of Gentzkow and Shapiro. Stop words are removed

Language	unigrams		bigrams		trigrams	
	Protestant	Catholic	Protestant	Catholic	Protestant	Catholic
German	2000	1932	2000	2000	2000	2000
Latin	2000	982	2000	1997	2000	1719

B.4 Log-Odds Ratio with Informative Prior

Monroe et al. (2008) defines several variants of a log-odds ratios to use for feature selection in classification problems. We present here the results from using the so-called log-odds ratio with an informative Dirichlet prior.

The general idea is that when using the multinomial-based model described in (9), we can compute the parameter vector $\boldsymbol{q}$ for the multinomial in a Bayesian framework. Using the conjugate Dirichlet prior for $\boldsymbol{q}$, enables us to obtain the log-odds ratio for each phrase. By virtue of having a probabilistic model, we are able to compute the variance for each log-odds ratio and, in turn, a Z-score. This gives us a natural way to determine which phrases help us separate the models.

To implement the log-odds ratio, we start from the idea that the quantity of interest is the observed "odds" of word w being used by either Protestants or Catholics. We

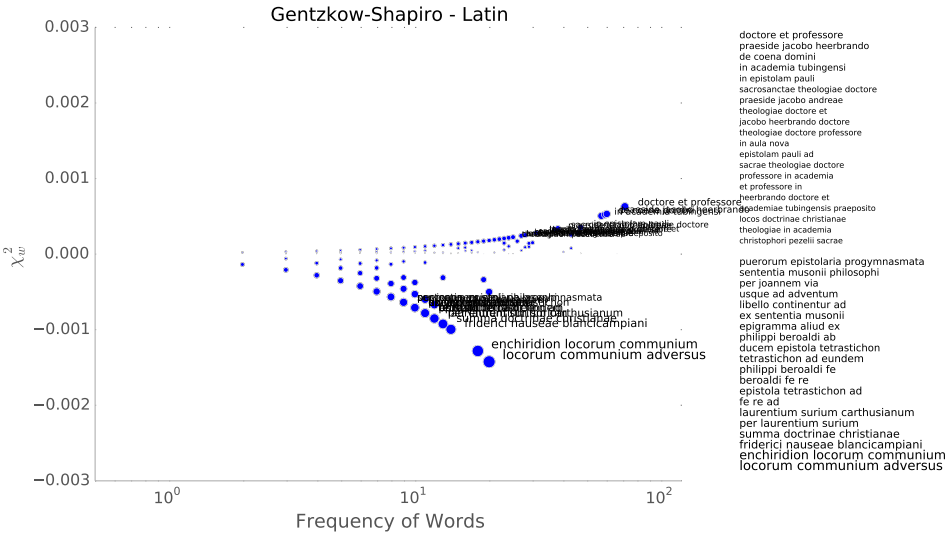


Figure B3: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin trigrams only.

define this as:

$$O_{rw} = \frac{f_{rw}}{1 - f_{rw}} \tag{14}$$

The odds ratio between Protestants and Catholics is $\theta_w^{(P-C)} = \frac{O_{Pw}}{O_{Cw}}$. It is common to work with the log-odds ratio on the grounds of symmetry:

$$\log \theta_w^{(P-C)} = \log O_{Pw} - \log O_{Cw} \tag{15}$$

The naive log-odds ratio has the undesirable property of the results being determined by the sampling variation. The variance decreases as words are used more frequently so that the measure promotes obscure words as helping to classify the religious denomination. Furthermore, it is unclear what to do when a word is used only by one group. In this case, the naive log-odds ratio is not well defined. We choose to overcome these problems through one of the model-based approaches of Monroe et al. (2008).

Introducing the assumption that the documents are multinomial random variables, we have for each group that the documents:

$$X_r \sim \text{MN}(\boldsymbol{q}_r, m_r) \tag{16}$$

Omitting the subscripts for the denomination and following the notation introduced in Section B.1, the maximum likelihood solution for the probabilities $\boldsymbol{q}$ is simply the

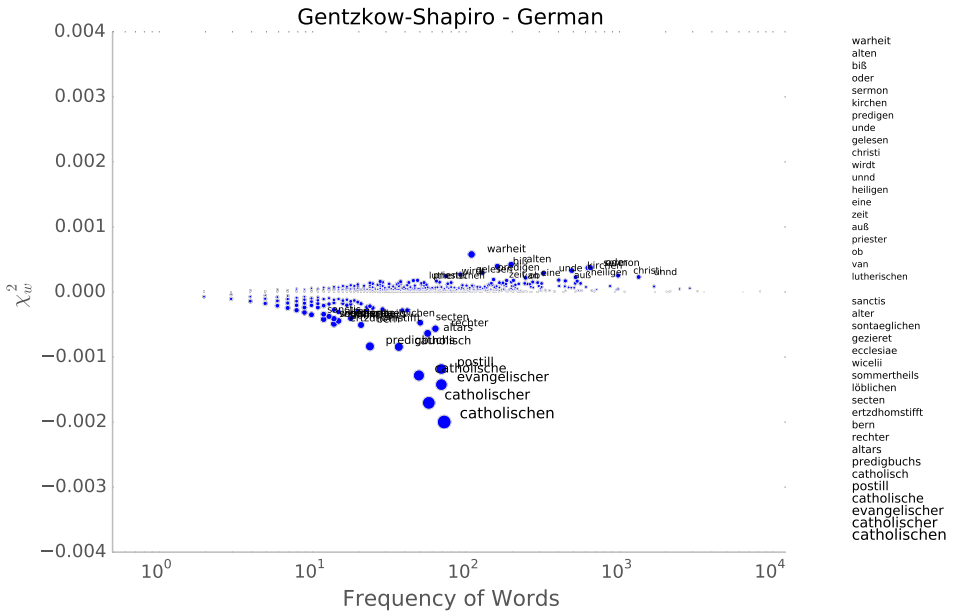


Figure B4: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German unigrams only.

frequencies of the words:

$$\hat{\boldsymbol{q}}^{\text{MLE}} = \boldsymbol{f} \tag{17}$$

This frequency-based solution, however, tends to overemphasize high-frequency words with high-sampling variability as belonging to one group or another when their semantic information in isolation is highly questionable. A natural way to alleviate this potentially problematic feature of the maximum likelihood solution is by adopting a Bayesian approach. In the Bayesian approach, we choose a sensible prior for $\boldsymbol{q}$ and obtain more salient results. Due to its conjugacy with the multinomial distribution, this prior will be the Dirichlet:

$$\boldsymbol{q} \sim \text{Dirichlet}(\boldsymbol{\alpha}) \tag{18}$$

where for the Dirichlet, $\boldsymbol{\alpha}$ is a vector of size W with $\alpha_i > 0 \forall i = 1, \ldots, W$. This prior has a tidy interpretation in terms of the solution of the model. Each term in the data is now treated as if it was observed another $\alpha_w - 1$ times. Taking advantage of the conjugacy of the Dirichlet to the multinomial, and defining $\alpha_0 = \sum_w \alpha_w$, the full Bayesian solution to the model is:

$$\boldsymbol{q} = \frac{\boldsymbol{x} + \boldsymbol{\alpha}}{m + \alpha_0} \tag{19}$$

We use these point-estimates to interpret the log-odds ratio in a probabilistic setting.

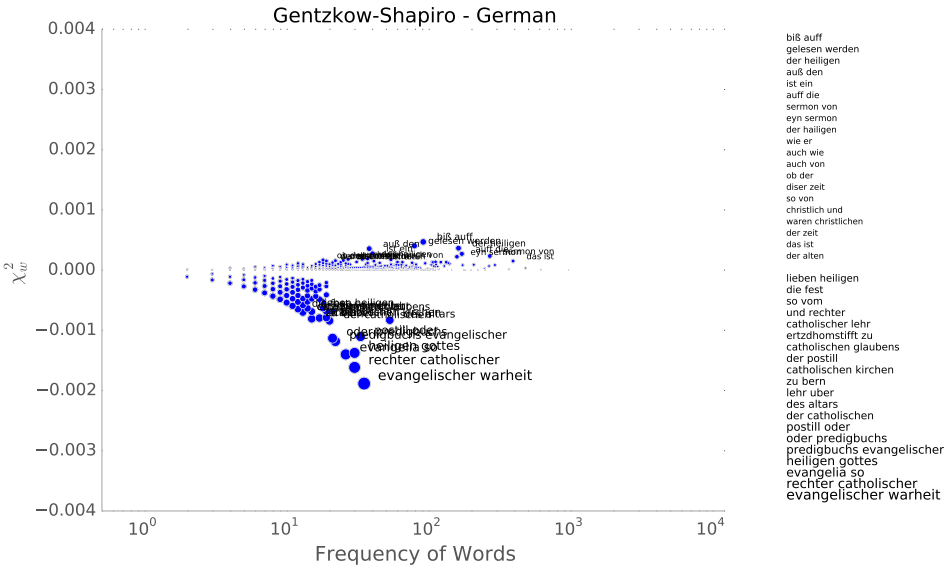


Figure B5: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German bigrams only.

First we obtain the log-odds ratio by plugging (19) in to (15):

$$\hat{\delta}_w^{(P-C)} = \log[\frac{x_{Pw} + \alpha_{rw}}{m_P + \alpha_{P0} - x_{Pw} - \alpha_{Pw}}] - \log[\frac{x_{Cw} + \alpha_{Cw}}{m_C + \alpha_{C0} - x_C w - \alpha_C Cw}] \tag{20}$$

Next we obtain the approximate variance for these point estimates:

$$\begin{aligned}\sigma^2\left(\hat{\delta}_w^{(P-C)}\right) = &\frac{1}{x_{Pw} + \alpha_{Pw}} + \frac{1}{m_P + \alpha_{P0} - x_{Pw} - \alpha_{Pw}} \\ &+ \frac{1}{x_{Cw} + \alpha_{Cw}} + \frac{1}{m_C + \alpha_{C0} - x_{Cw} - \alpha_{Cw}}\end{aligned} \tag{21}$$

This approximation assumes that the observed counts are much larger than the corresponding terms in the prior. Using the point-estimate and its variance we can compute z-scores of the log-odds ratios:

$$z_k^{(P-C)} = \frac{\hat{\delta}_w^{(P-C)}}{\sqrt{\sigma^2(\hat{\delta}_w^{(P-C)})}} \tag{22}$$

For the results presented here, we choose $Z < \Phi^{-1}(.05) \approx -1.64$ and $Z > \Phi^{-1}(.05) \approx 1.64$ to be the thresholds for inclusion.

Finally, we must choose an appropriate prior for our terms. Monroe et al. (2008) makes several suggestions from a fully uninformative prior where $\alpha_w = .01$ for each term to a Laplace prior which acts as an L1 regularization penalty and shrinks estimates to

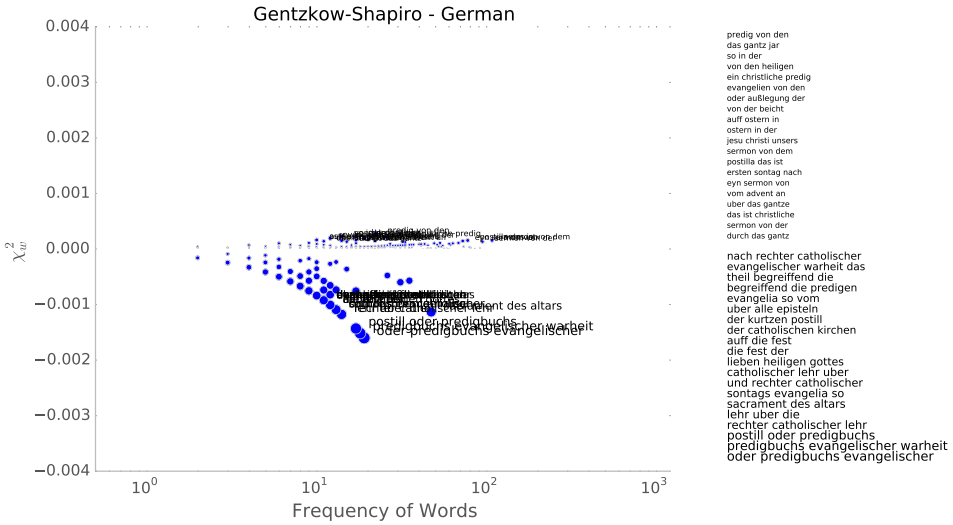


Figure B6: Gentzkow-Shapiro measure vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German trigrams only.

zero. We take a middle ground here since we will be doing subsequent modeling. We choose an informative Dirichlet prior. We use what we know about the expected usage of words in the non-religious texts to give us a sense of what words distinguish Protestant and Catholic language. Our prior is:

$$\alpha_w = \alpha_0 \boldsymbol{q}^{\text{MLE}} = \boldsymbol{f}\alpha_0 \tag{23}$$

where the frequencies $\boldsymbol{f}$ come from the non-religious texts. To avoid taking the log of zero, for any word that is in the support for the religious texts but only appears in either Protestant or Catholic texts and does not appear elsewhere in the non-religious titles, we assign a prior count of 1 before normalization. That is, we assume this term to be very rare but avoid taking the log of zero. α_0 determines how strong the prior is and, therefore, how much shrinkage occurs. Given that we observe many more counts for Protestant authors than Catholic authors, some care needs to be taken in choosing α_0.

The estimation uses as a base value 15% of the total number of n-grams for each n-gram for both Catholics and Protestants. This is equivalent to saying that for each n-gram for each denomination, we observe a sample that is 15% larger in which the frequencies of the language used is that of non-religious texts. This approach helps us separate out those features of the language that are particular to religious texts. Furthermore, by doing this for both German and Latin texts the analysis ensures that each prior used is conditional on the relative number of words for Protestants and Catholics and the choice of language. This approach guards against bias due to having relatively larger Protestant

Table B5: The number of phrases left after using the log-odds ratio with an informative prior for feature selection. Stop words are not removed

Language	unigrams		bigrams		trigrams	
	Protestant	Catholic	Protestant	Catholic	Protestant	Catholic
German	277	785	144	403	41	91
Latin	169	1013	68	1325	12	674

Table B6: The number of phrases left after using the log-odds ratio with an informative prior for feature selection. Stop words are removed

Language	unigrams		bigrams		trigrams	
	Protestant	Catholic	Protestant	Catholic	Protestant	Catholic
German	259	710	69	165	21	36
Latin	131	947	13	627	2	290

author output and/or the fact that Catholic author's tend to produce more Latin text than German text.

The results of applying this metric can be seen in Tables B5 and B6. The words chosen by each measure can be seen in Figures B7-B12. These results strongly suggest that the log-odds measure is more judicious than the χ^2 alternative. To assess this question formally we study predictive performance in the next subsection.

B.5 Performance

Figure B13 shows the performance of the classifier on the held-out test data from a single draw and highlights how well we predict prominent authors Martin Luther and Johannes Eck when they are omitted from training.

Figures B14, B15, and B16 provide common performance benchmarks for classification algorithims for the experiments described above. The measure contained in each figure is the F1-measure. The $F_\beta-$measure is defined

$$F_\beta = (1+\beta^2)\frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision} + \text{recall})} \tag{24}$$

where for the F_1-measures $\beta = 1$, giving the harmonic mean between precision and

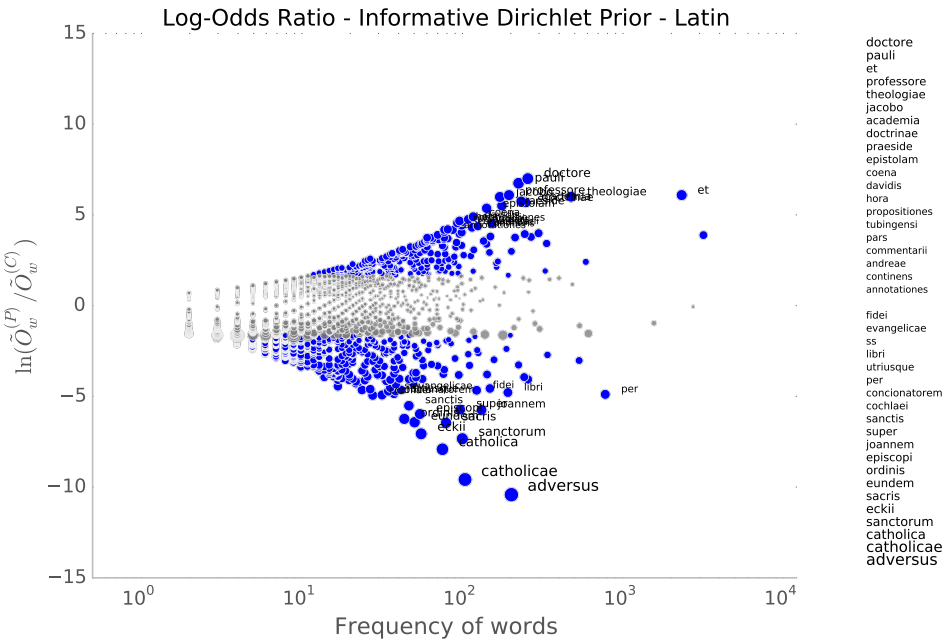


Figure B7: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin unigrams only.

recall.[81] Precision is analagous to the absence of Type I errors and is defined as

$$\text{precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}} \tag{25}$$

while recall is analagous to the absence of Type II errors and is defined as

$$\text{recall} = \frac{\text{true positive}}{\text{true postitive} + \text{false negative}} \tag{26}$$

The values for (25) and (26) come from the confusion matrix (contingency table) where

		Predicted Class	
		0	1
Actual Class	0	true negative	false positive
	1	false negative	true positive

In terms of performance, we prefer the log odds measure. While the Gentzkow-Shapiro measure has good performance on average, this is certainly the regularization performance of the estimator. The GS measure simply gives us more words to work with.

[81] Higher values of β may be used if one wants to weight recall more than precision.

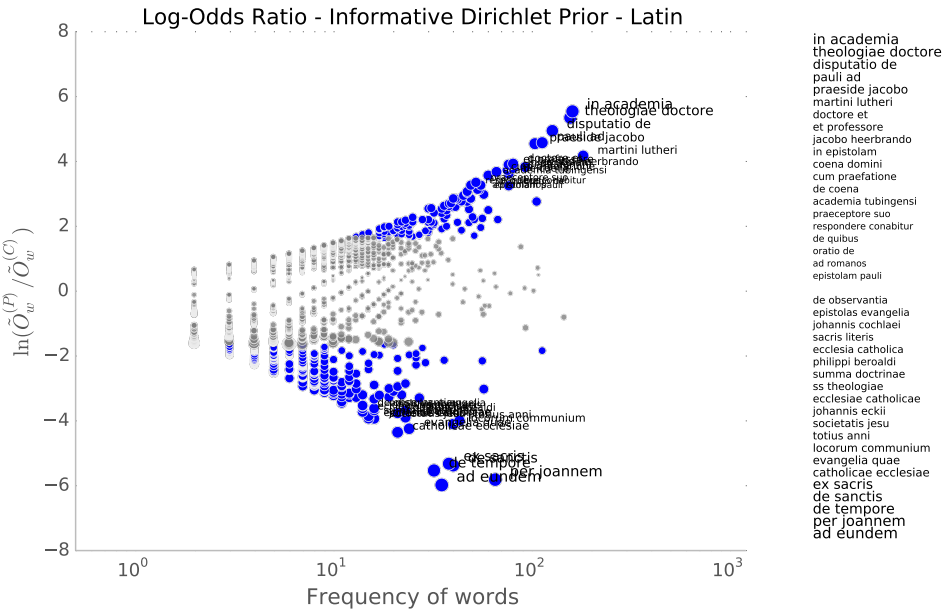


Figure B8: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin bigrams only.

We have the potential for a better estimate, but we also see some poor performance in the outliers. This suggests overfitting. The log-odds measure, on the other hand, leads to good average estimates and small variance. The model with no vocabulary selection does not perform as well on averge due to overfitting.

B.6 Heterogeneity of Language

One possible question is whether the language used shifts over the time period we study. This could happen, for example, if the language of the Reformation and Counter-Reformation changed as the agendas of the camps changed or if spelling norms were evolving.

Figures B17-B25 provide heatmaps of word occurence to document whether and how religious language evolved. The words are first sorted according to the first time they appear in use in a title. If the language was not evolving, we would expect the column associated with the first period to be large and the subsequent row to be randomly populated. While this is not the case, if the words were truly shifting, we would see a banded structure. Instead what we observe is simply an expanding vocabulary. In the first 10 years about half of all unigrams in the whole sample are used once and continue to be used.

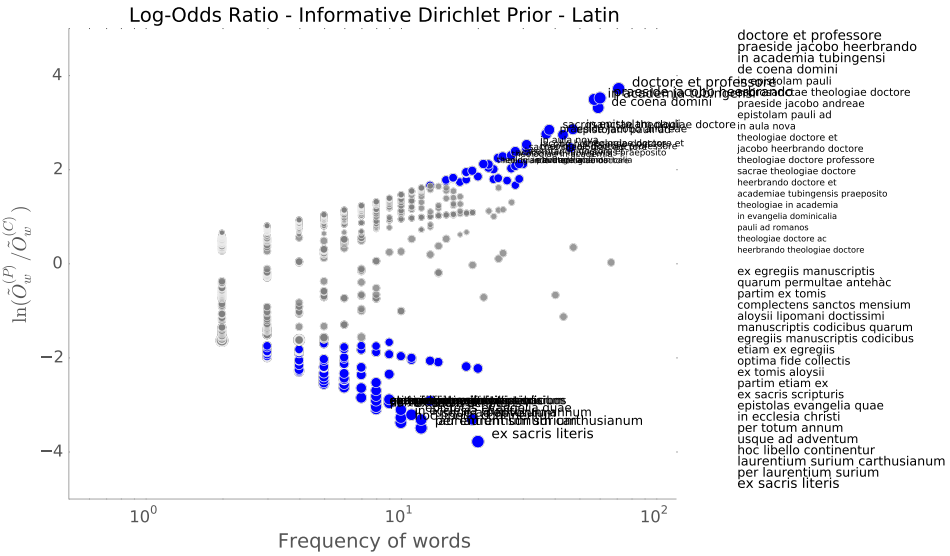


Figure B9: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. Latin trigrams only.

Classifying the nature of this change of language use is the subject of ongoing research. However, our sampling in our cross-validation experiments in Sections B.3 and B.4 is undertaken without respect to time. Our results indicate that we are still able to predict well despite the non-standard orthographies of German and Latin in the sixteenth century. Therefore, while we do think there are interesting findings to be made in studying the change of language, the results of the present study are not likely to depend on these issues.

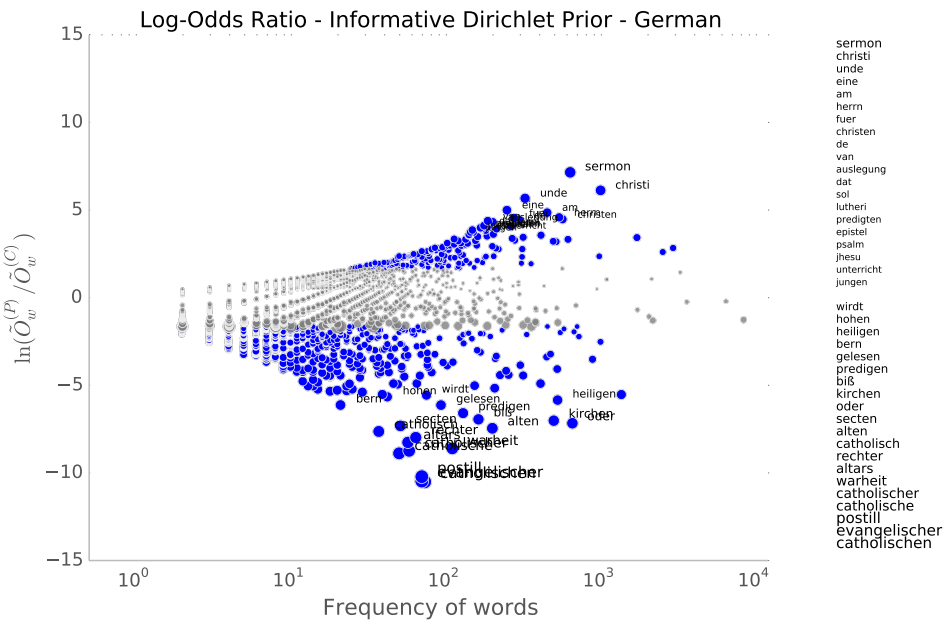


Figure B10: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German unigrams only.

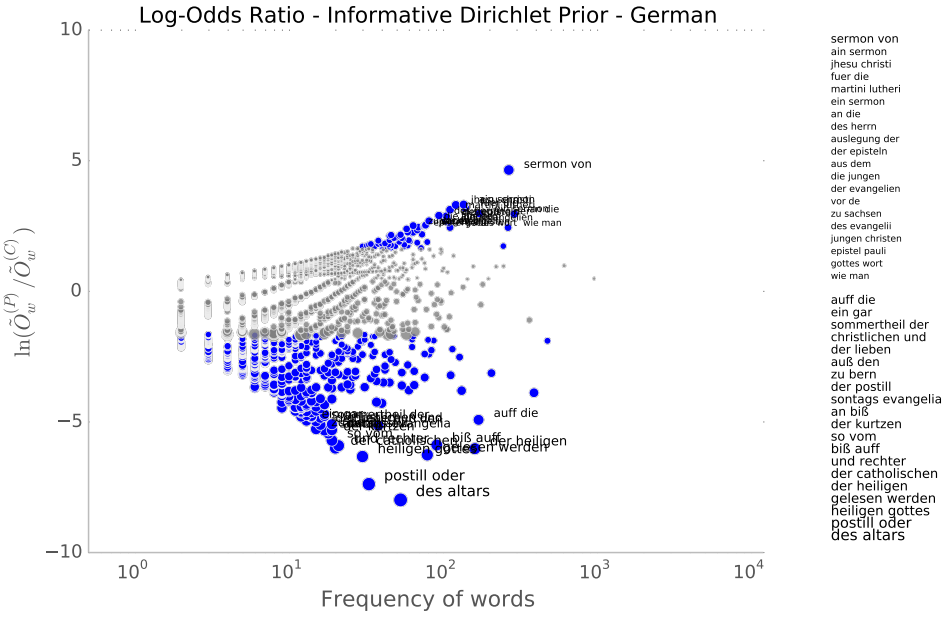


Figure B11: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German bigrams only.

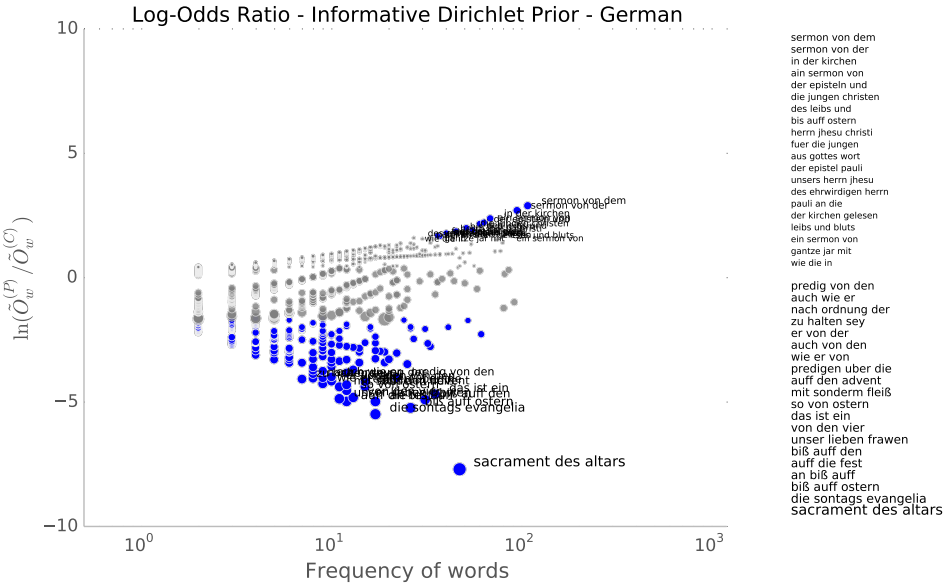
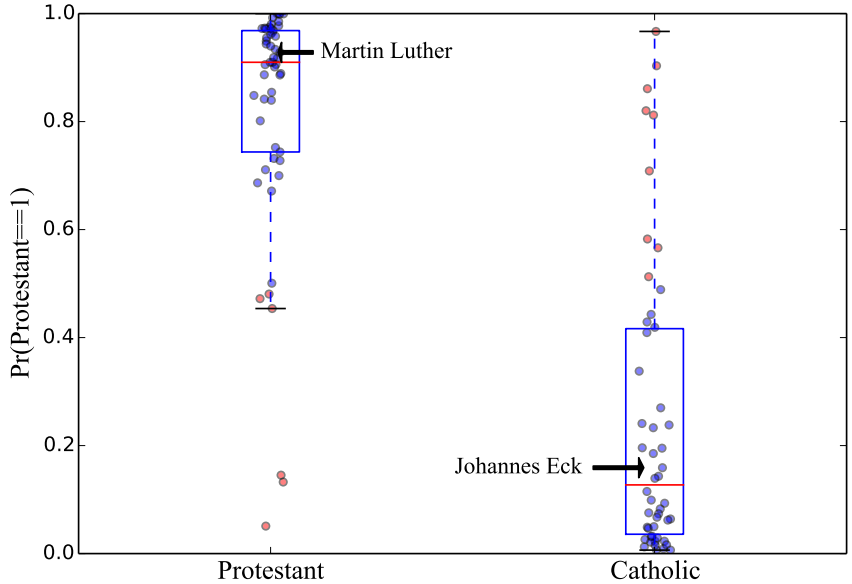


Figure B12: Log-odds ratio with informative Dirichlet prior vs. Frequency of words in log scale. The top 20 words for Protestants and Catholics are listed. German trigrams only.

Figure B13: Out-of-sample classification of religious authors



This graph presents the out-of-sample classification performance for a single draw from the data. The model is trained on 80% of the data and predicted on the held-out 20%. We present predictions for held-out Protestants (at left) and for held-out Catholics (at right). We highlight Martin Luther and Johannes Eck as the most important Protestant and Catholic authors in our held-out data.

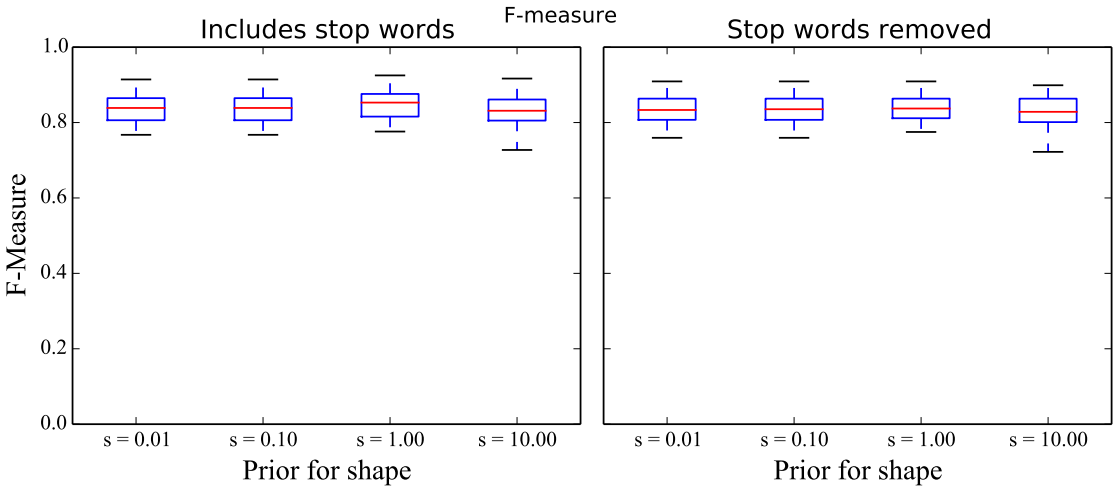


Figure B14: F1-score for 80:20 train:test split of data using Log-odds measure.

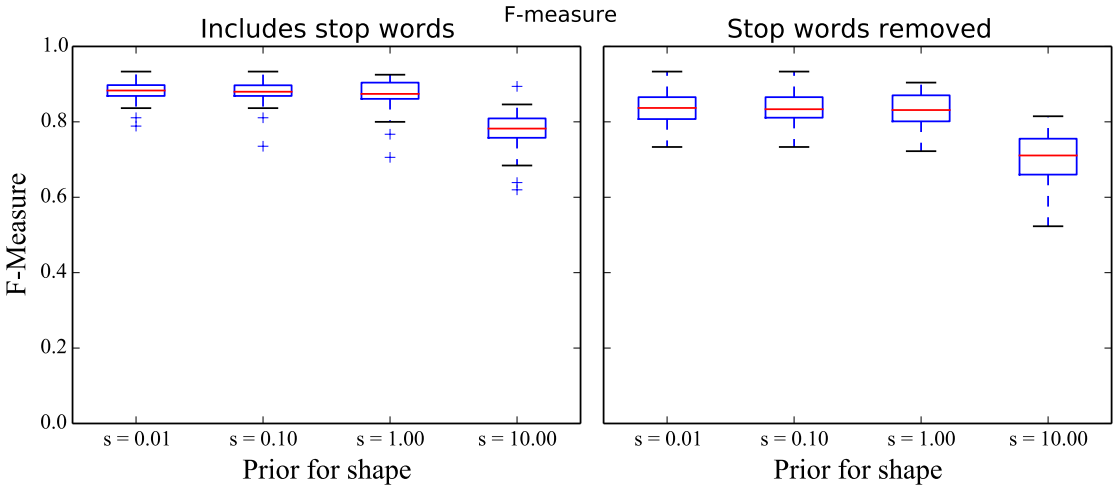


Figure B15: F1-score for 80:20 train:test split of data using Gentzkow-Shapiro χ^2 measure.

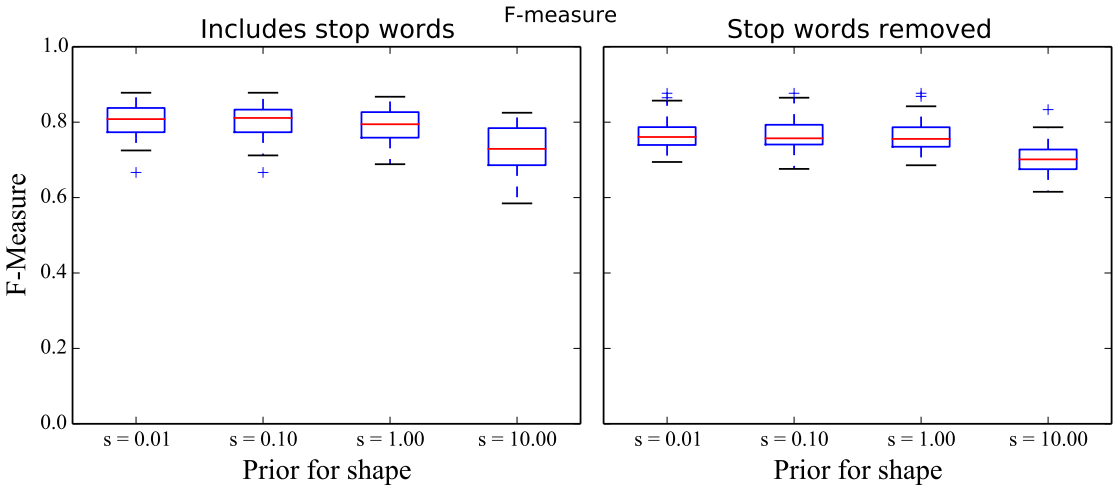


Figure B16: F1-score for 80:20 train:test split of data with no feature selection.

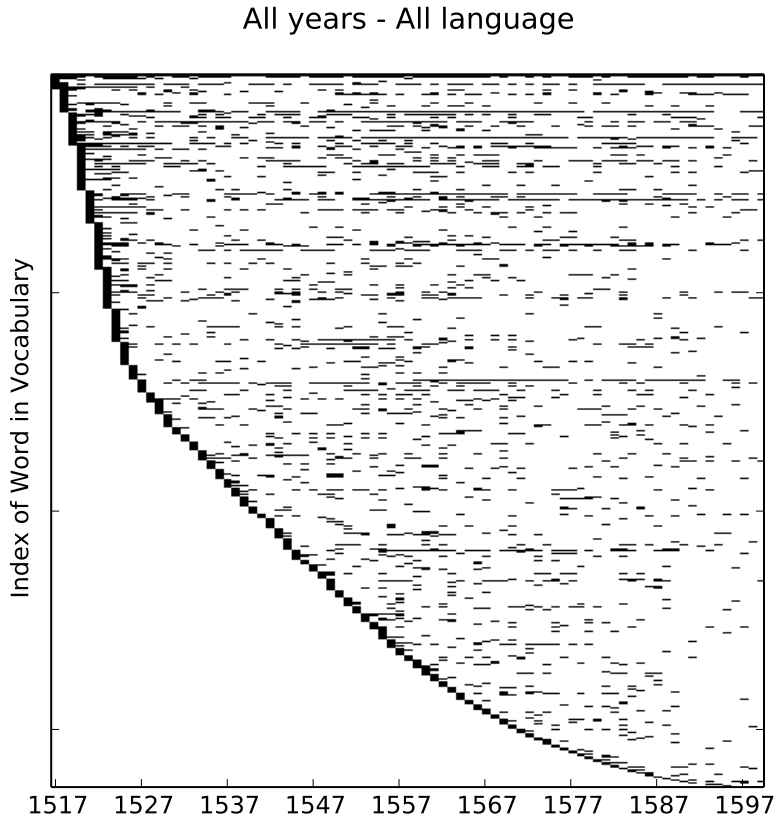


Figure B17: Heat map of word usage for each year in any language. Unigrams only.

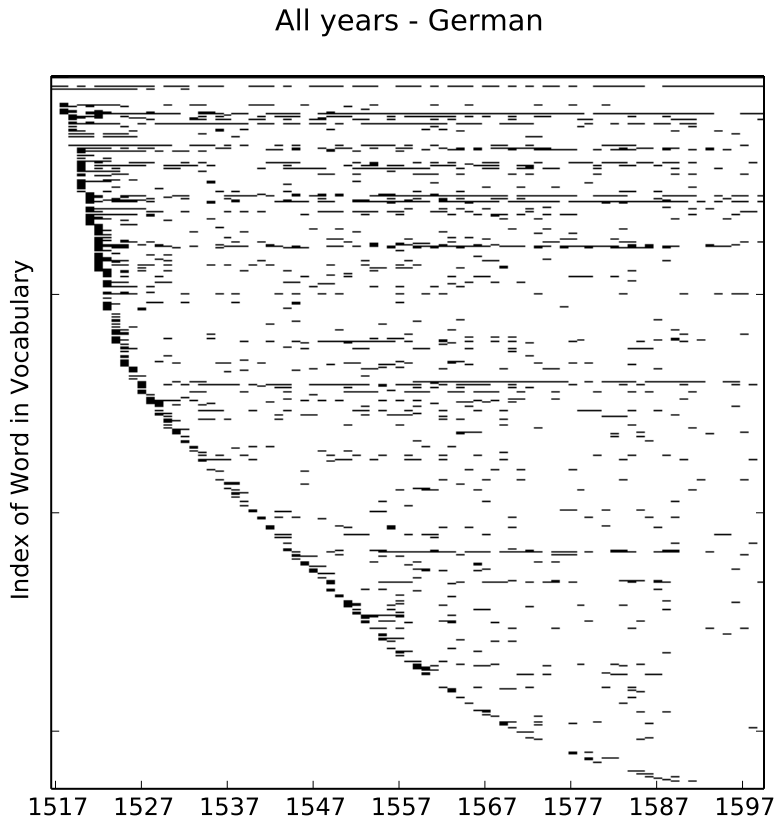


Figure B18: Heat map of word usage for each year in German. Unigrams only.

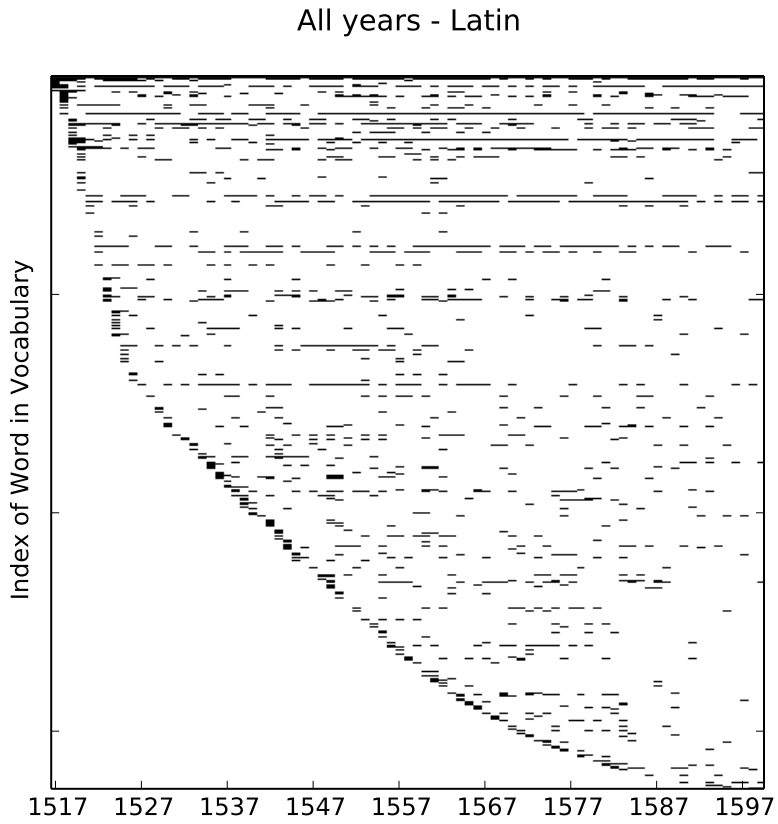


Figure B19: Heat map of word usage for each year in Latin. Unigrams only.

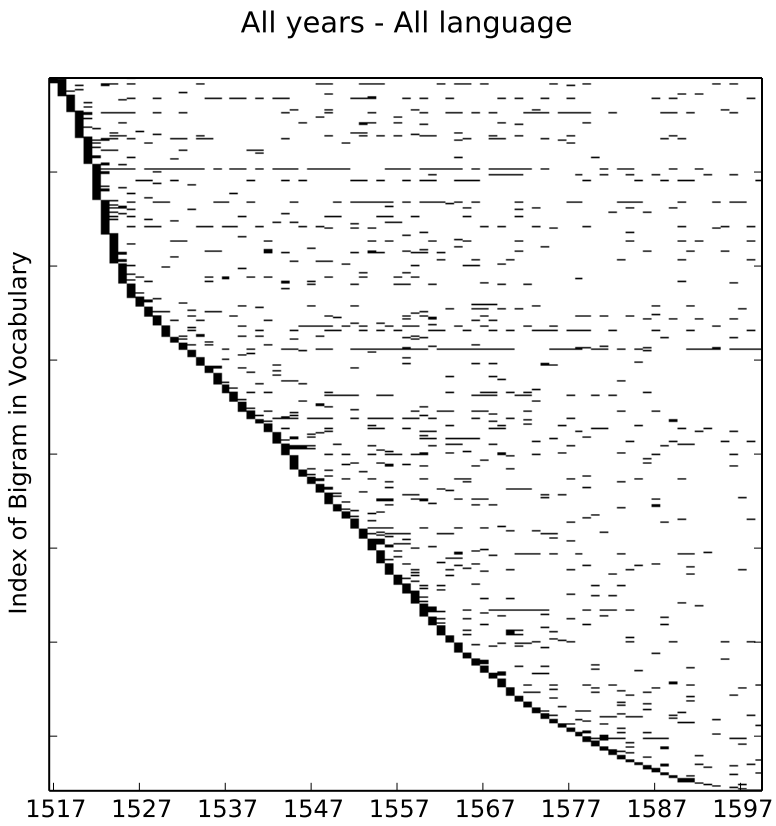


Figure B20: Heat map of word usage for each year in any language. Bigrams only.

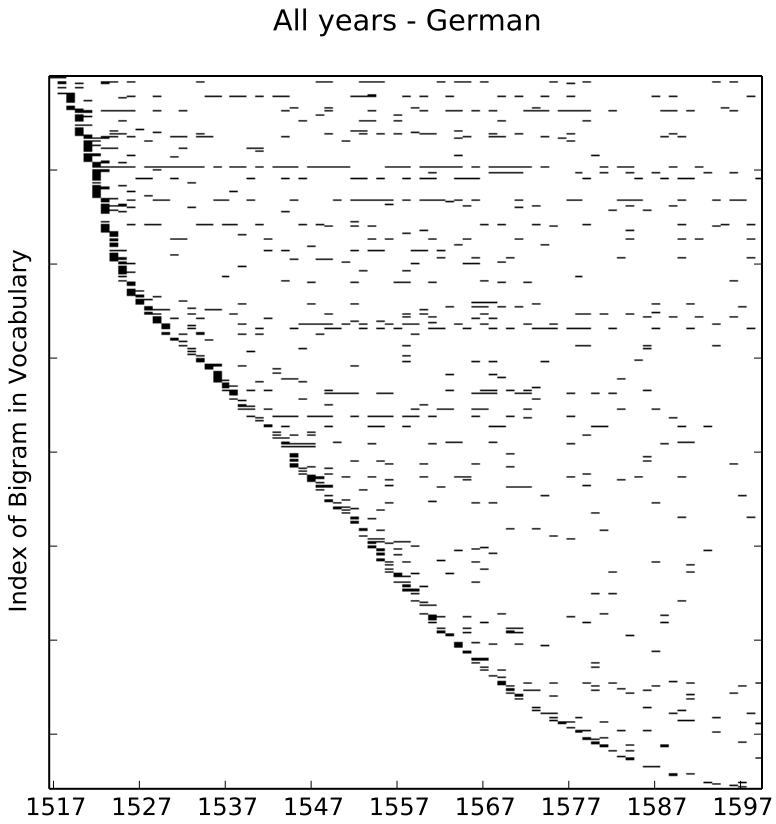


Figure B21: Heat map of word usage for each year in German. Bigrams only.

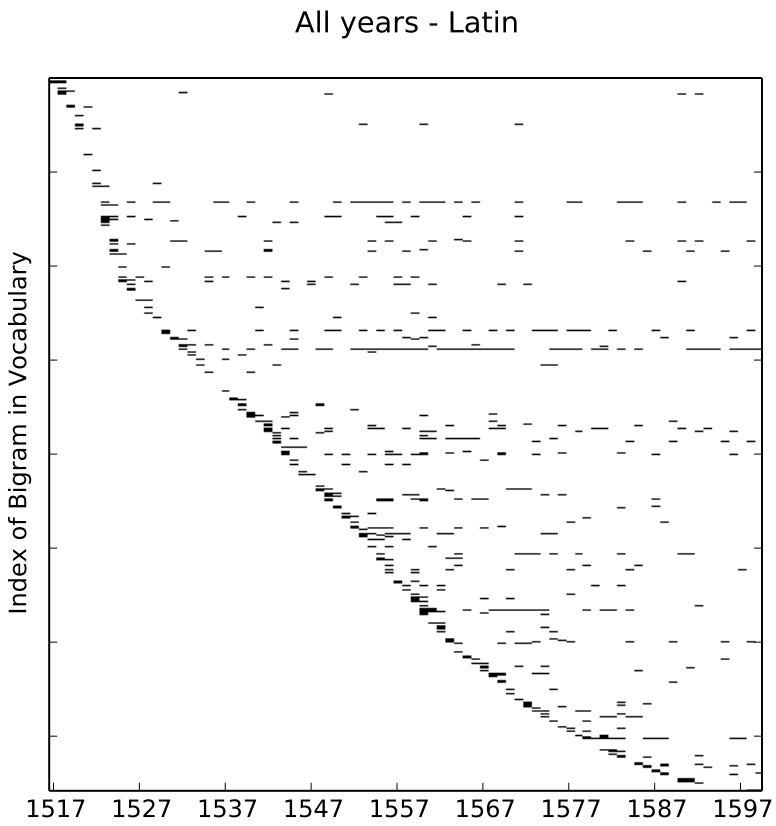


Figure B22: Heat map of word usage for each year in Latin. Bigrams only.

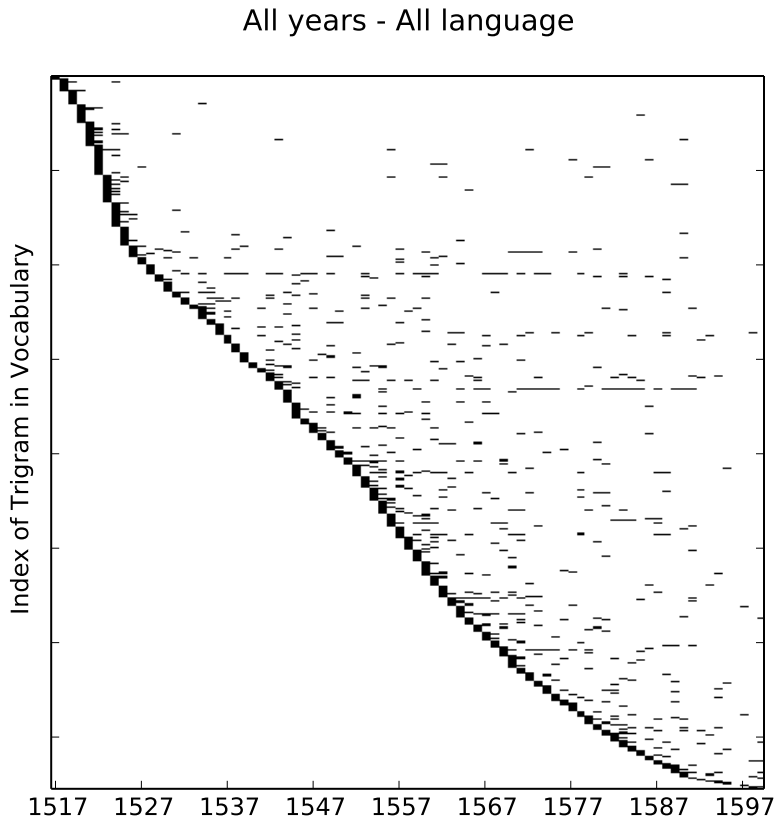


Figure B23: Heat map of word usage for each year in any language. Trigrams only.

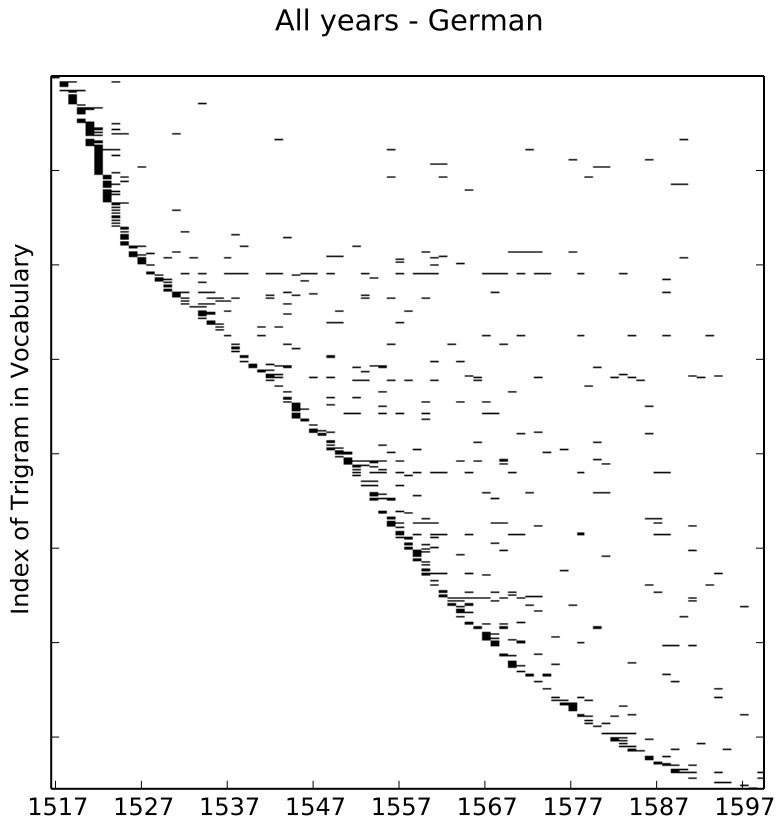


Figure B24: Heat map of word usage for each year in German. Trigrams only.

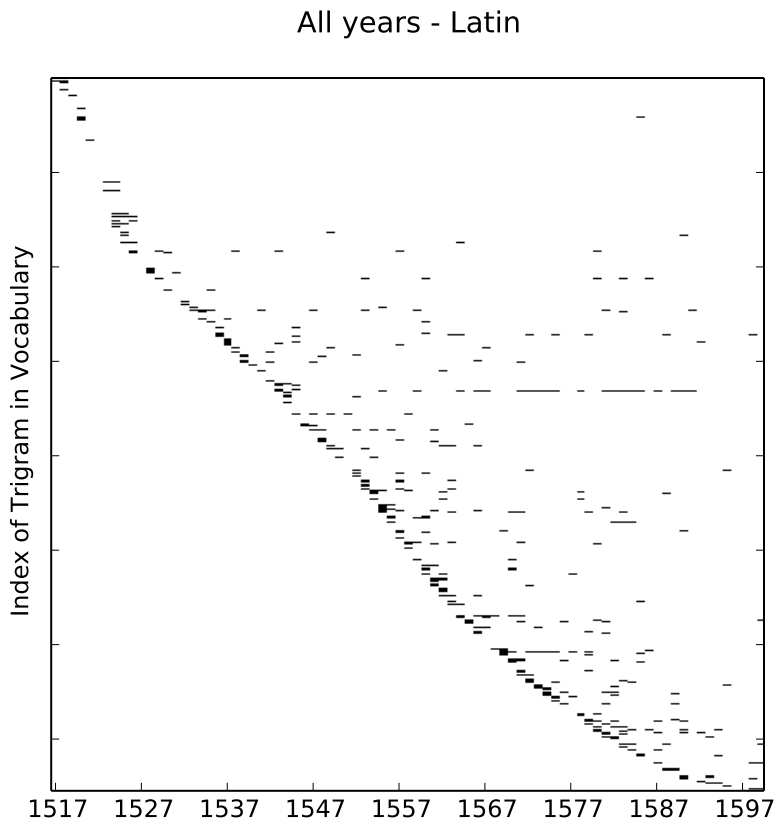


Figure B25: Heat map of word usage for each year in Latin. Trigrams only.

C Industrial Organization and Competition

C.1 The Margins for Competition

Our baseline analysis examines the local relationship between printer competition and book prices, and the local relationship between competition and output measured by the number publications printed in a city. In this section, we consider the quality of publications as a potential margin for competition and provide related discussion of competition over inputs.

It is natural to wonder whether competition led to changes in the quality of books printed. We test the hypothesis that variation in competition within-cities led to changes in the publication of leading authors. We focus our analysis on two outcomes that are proxies for author quality and for name recognition. First, we study whether a city printed any publications by an author who was in the top 10% of authors with the most printed editions across Europe over the *past* ten years. In this case, when we consider whether a given author printed in a given city in the year 1500 was in the top 10% of authors in the past, we calculate their position in distribution of total European publications by all authors between 1490 and 1499 (i.e. the past ten years). Second, we study whether a city printed any publications by an author who was in the top 10% of authors over the next ten years. In this case, when we consider whether a given author published in a given city in 1500 was in the top 10% of "future" authors, we assess that author's position in the European distribution 1501-1510 (i.e. the next ten years).[82]

We test whether variation in competition predicts changes in the publication of top authors by estimating regressions that correspond to our baseline specifications:

$$y_{jt} = \beta competition_{jt} + \theta_{j,decade} + \gamma X_{jt} + \epsilon_{jt}$$

The outcome y_{jt} is an indicator for city-years with top authors published. The independent variable $competition_{jt}$ measures either the number of active printers or is an indicator for the presence of at least two printers (in which case we also condition on an indicator for any printing). The $\theta_{j,decade}$ are city-decade fixed effects and X_{jt} is the number of total publications printed in a city-year. We include the X_{jt} to focus our analysis on variation in the publication of top authors conditional on the total number of publications printed. We adopt this approach in order to estimate over the same data as in our baseline analysis, which includes a number of years with zero publications, hence

[82] We obtain similar results when the reference group used to assess leading authors is defined more locally, e.g. to comprise authors who publish in the main vernacular language of a given city.

for which computing shares directly is not possible. We emphasize that the total number of publications is itself an outcome of variation in competition. For this reason, and because we do not have separate instruments for total publications and the publication of top authors, we interpret our estimates as suggestive correlations and not as direct causal statements.

Table C1 presents our estimates and shows that when competition increased the likelihood of a top author being printed increased. All estimates control for factors shared at the city-decade level (via city-decade fixed effects) and for the total number of publications in a given city-year. Column 1 shows that an additional firm was associated with a 1.8 percent increase in the likelihood a city would print a leading Europe author. Column 2 shows that in city-years with multiple printers the probability a leading author was published increased by 10 percent. Columns 3 and 4 show that the positive relationship between competition and publishing patterns was even stronger for authors who were *future* top European authors.

Table C1: Printer Competition and the Publication of High Quality Authors

	(1)	(2)	(3)	(4)	(5)	(6)
	Outcome: High Quality Author Printed				Outcome: Shift to	
	Top 10% in Past		Top 10% in Future		Future Top Authors	
Number of Printers	0.018***		0.029***		0.012***	
	(0.003)		(0.005)		(0.002)	
Indicator: Any Printers		0.189***		0.356***		0.168***
		(0.011)		(0.013)		(0.009)
Indicator: 2+ Printers		0.102***		0.174***		0.072***
		(0.014)		(0.016)		(0.014)
City-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21439	21439	21439	21439	21439	21439
Mean Outcome	0.32	0.32	0.45	0.45	0.14	0.14

This table presents regression estimates examining publication outcomes at the city-year level. "Number of Printers" is the count of printers active in a city-year. "Indicator: Any Printers" and "Indicator: 2+ Printers" are indicators for any activity and for more than one printer. The outcomes in columns 1-4 are indicators for top 10% authors printed in a given year. "Top 10% in Past" is an indicator that records whether or not a publication was printed in a city-year by an author who ranked in the top 10% of authors by number of different editions printed across Europe over the previous 10 years. "Top 10% in Future" is an indicator that records whether or not a publication was printed in a city-year by an author who ranked in the rop 10% of authors by number of different edications printed across Europe over the next 10 years. In columns 5 and 6, the outcome variable is the difference between the indicators for future and past top printers (future indicator minus past indicator) . Standard errors clustered by city-decade. All regressions control for city-decade fixed effects and the total number of publications in a city-year. Statistical significance at the 90, 95, and 99 percent confidence interval denoted "*", "**", "***". The regressions examine correspond to the estimates in the main text and examine all city-years in decades with some printing, including years with zero publications.f

Our estimates show that when printer competition increased, there was a significant

increase in the likelihood that printers would produce content that would in *future* be important. We observe this pattern in the panel, examining evidence across all European cities. The evidence is consistent with our findings examining the diffusion of the Protestant Reformation. The Reformation was arguably the largest and most important thought innovation in 1500s Europe. While the Reformation was a unique event, our evidence across Europe and across the 1500s indicates a similar pattern whereby competition in printing promoted the diffusion of new ideas that would subsequently "take off." Significantly, these results linking competition to variation in quality, measured by authors' pan-European publication record, are not driven by the Reformation itself. The results hold, for example, if we drop all observation from the Reformation era from the analysis. This indicates that there was a generic positive relationship between competition and the introduction of works by authors with higher quality publication records.

To interpret our results several observations are important. In this period, intellectual property rights were extremely weak and jurisdictional fragmentation made any enforcement across cities difficult if not impossible. Printers often published works without making payments to authors, and printers broadly did have the body of existing and known European literatures to select from, subject to their own incomplete information. However, author quality can be considered both an input and an output.

Narrative evidence indicates that printers sometimes competed directly over inputs. In Wittenberg, where Martin Luther was based, printers sometimes vied to print Luther. Printers also developed new inputs to differentiate and improve the quality of their products. The development of new fonts is particularly notable in this respect, however we find no clear relationship between competition and the adoption of new fonts when we study unique evidence on fonts from the period 1450-1500, which may reflect the absence of competition using fonts or that the development and adoption of fonts was a slow moving process that was not responsive to variation in competition at the frequencies we consider.

The evidence on printer competition over other inputs, including labor, is if anything more fragmentary. We acknowledge that competition over labor may have been salient. However, we note that while there is well-documented evidence of conflict *with* labor over the length of the day and the speed of the work process (Febvre and Martin 1958) and evidence of conflict between printers over piracy and business ethics (Reske 2007), the surviving narrative evidence does not emphasize competition over e.g. scarce journeyman print workers. We regard this as an area for potential future research and focus our analysis on observable dimensions of competition that were are able to analyse quantitatively: prices, the number of publications produced, and author quality, proxied

for by number of publications.

C.2 Evidence on Anti-Competitive Practices

Both informal and formal anti-competitive practices are observed in historical printing. In Paris, informal alliances were used to prevent entrance by new competitors (Pettegree 2015). However, we also observe formal anti-competitive agreements: in 1552, four Parisian printers signed an agreement to produce jointly, split output equally, and to maintain a price floor for sales (Parent 1974; p. 141). In German printing, we similarly observe both formal contractual agreements and informal business relationships. In 1535, Johannes Oporinus formed a contractual partnership (*druckgemeinschaft*) in Basel with Thomas Platter, Balthasar Lasius, and Robert Winter (Reske 2007; p. 78). In Augsburg, Johan Otmar (active 1502 until death in 1516) coordinated production with Erhard Ogelin and Johann Schönsperger. In addition, evidence suggests printers engaged in "price wars" and quantity competition designed to capture market share and dissuade entrance. For example, André Wechel was a leading producer textbook producer in Frankfurt in the later 1500s. When competitors printed school books, Wechel unleashed, "a massive and systematic onslaught...aiming at little short of a monopoly...by putting into practice the commercial principle: if a competitor produces an edition, do the same" (Maclean 2009; p. 177).

C.3 Printer Deaths as Triggers for Legal Action

The main body of the paper emphasizes the fact that printer deaths unravelled business arrangements between printers. One dimension along which these effects frequently played out was legal. Printer deaths frequently triggered protracted and expensive legal action over assets and obligations, involving heirs and business partners. Maclean (2009; pp. 246-247) observes that in the 1500s:

> If the associations or companies of publishers had to be terminated because of death or disharmony, the resultant legal actions seem often to have been highly complex and expensive...The fact that associates had to proceed by letters of credit, often through proxies, led to a great deal of suspicion and dishonesty: the internal regulation of financial disputes through arbitrators who were colleagues and publishers (and who in turn, because of fundamental disagreement, were themselves forced in some cases to appoint an arbitrator to settle the matters they had been appointed to deal with) only worked if both parties engaged in the arbitration in good faith, which seems not always to have been the case. Non-appearance at agreed meetings, and non-compliance

with court orders seem to have been...a feature of commercial life..."

C.4 How Entrance Responded to Printer Deaths

Our baseline results show that printer deaths were associated with *increases* in the number of firms active. This section provides additional evidence on the dynamics of entry in response to printer deaths focusing on data from German-speaking cities. In the data on German-speaking cities we are able to track individual printers across cities and to test for and document the precise timing of entry responses to deaths. The evidence provides quantitative support for narrative history evidence on the operation of oligopolistic competition by highlighting how printer deaths led to rapid relatively responses in entry, including due to cross-city relocations.

To study how entrance responded to printer deaths, we examine the German subsample for which we have detailed microdata on all printers. In the German data, we can track the dates of entrance at which individual printers first appear as producers in given city media markets and document how the entrance of printers who produced business education content responded to (i) the deaths of printers who produced business education content and (ii) the deaths of printers who did not produce business education content.

To document how entrance responded to deaths, we estimate regressions studying how the binary outcome for having a new entrant relates to the timing of printer deaths:

$$entrant_{it} = \alpha_i + \delta_t + \sum_{\tau=-3}^{3} \beta_{t+\tau} death_{i,t+\tau} + \epsilon_{it} \tag{27}$$

Here $entrant_{it}$ is the binary variable for an entrant in city i in year t. These entrants include both new printers who established start-up firms and previously active printers who had been producers in other cities and relocated in response to deaths. City and year fixed effects are captured by α_i and δ_t. In some specifications I control for city-decade fixed effects. The parameters of interest are the $\beta_{t+\tau}$ which capture variation in entrance in the years just before a death (when $\tau > 0$), the year of death ($\tau = 0$) and the years following a death ($\tau < 0$). We estimate linear probability models with OLS.

Table C2 presents our estimates and shows entrance shifted positively with printer deaths. Column (1) shows that in a simple linear probability model with year and city fixed effects, the probability of an entrant rose by over 22% in years with printer deaths. Column (2) shows similar result restricting the identifying variation to within city-decade

periods. We also observe significant increases in entrance in the two years immediately following a printer death ($t = -1$ and $t = -2$). We see a comparatively small and weak positive effect on entrance one year before a death. This is consistent with deaths being partly anticipated (e.g. due to a printer being in ill-health, which would have been hard to maintain as private information in historical cities). Columns (3) and (4) show estimates restricting attention to the arrival of intercity entrants, defined as printers previously active in another city who relocate to the city in question. We observe a significant increase in intercity entrance with a one-year lag after printer deaths and with a smaller magnitude than for all entrances (including within-city entrants). This is consistent with social history evidence suggesting that relocation across cities was common but carried costs (Reske 2007).

Table C2: Printer Deaths and New Entrants

	(1)	(2)	(3)	(4)
	Binary Outcome: New Entrant of Specified Type			
	Any	Any	Intercity	Intercity
Printer Death $t = 2$	0.01	0.00	0.00	-0.00
	(0.03)	(0.03)	(0.01)	(0.02)
Printer Death $t = 1$	0.05*	0.04	-0.00	-0.00
	(0.03)	(0.03)	(0.01)	(0.02)
Printer Death $t = 0$	0.22***	0.21***	0.02	0.02
	(0.04)	(0.04)	(0.02)	(0.02)
Printer Death $t = -1$	0.16***	0.16***	0.05***	0.05**
	(0.03)	(0.04)	(0.02)	(0.02)
Printer Death $t = -2$	0.09**	0.08**	0.00	0.00
	(0.04)	(0.04)	(0.01)	(0.02)
Year Fixed Effects	Yes	No	Yes	No
City Fixed Effects	Yes	No	Yes	No
City × Decade Fixed Effects	No	Yes	No	Yes
Observations	4770	4770	4770	4770
R^2	0.22	0.29	0.07	0.16
Mean Outcome	0.13	0.13	0.03	0.03

This table presents results from regressions estimating the relationship between printer deaths and the appearance of new entrants in the German sub-sample. The outcome is a binary indicator for years with new entrants at the city-year level. In columns 1 and 2 the outcome is any new entrants. In columns 3 and 4 the outcome is any new entrants arriving from other cities, as documented in Reske (2007). The "Printer Death" variables are indicators for the presence of printer deaths in the current period ($t = 0$), future years ($t > 0$), and past years ($t < 0$). Standard errors clustered by city in specifications with city fixed effects and by city-decade where city-decade fixed effects are introduced. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C3 provides related evidence on how observed entrance by business education (merchant manual) producers increased in the precise year an incumbent business edu-

cation (merchant manual) producer died. Column 1 shows that entrance is 10 percent higher in years with business education deaths, relative to city fixed effects and year fixed effects. There is no anticipatory effect: In each of the two years before a death entrance is small, statistically insignificant, and the point estimates are negative. Column 2 studies variation within city decades and finds similar magnitude effects in the year of death that are estimated less precisely. Column 3 augments the estimating model to also examine the timing of deaths of printers who did not print business education content. Controlling for these "non-business" deaths does not change our estimates of the relationship between the deaths of business printers and entrance of business printers. If anything, in the precise year non-business printers die we see a decline in the likelihood a business printer enters a given city media market.

Table C3: Probability of New Entrant Producing Business Content

	(1)	(2)	(3)	(4)
	Binary Outcome: Entrance of Business Printer			
Business Printer Death t = 2	-0.04	-0.06	-0.04	-0.06*
	(0.03)	(0.04)	(0.03)	(0.04)
Business Printer Death t = 1	-0.02	-0.03	-0.02	-0.03
	(0.04)	(0.05)	(0.04)	(0.05)
Business Printer Death t = 0	0.10*	0.09	0.10*	0.09
	(0.06)	(0.07)	(0.06)	(0.07)
Business Printer Death t = -1	-0.01	-0.02	-0.01	-0.02
	(0.03)	(0.05)	(0.03)	(0.05)
Business Printer Death t = -2	-0.00	-0.02	-0.00	-0.03
	(0.03)	(0.04)	(0.03)	(0.04)
Non-Business Printer Death t = 2			-0.01	-0.00
			(0.01)	(0.01)
Non-Business Printer Death t = 1			-0.01	-0.01
			(0.01)	(0.01)
Non-Business Printer Death t = 0			-0.02*	-0.02
			(0.01)	(0.01)
Non-Business Printer Death t = -1			-0.01	-0.01
			(0.01)	(0.02)
Non-Business Printer Death t = -2			-0.00	-0.01
			(0.01)	(0.02)
Year Fixed Effect	Yes	No	Yes	No
City Fixed Effect	Yes	No	Yes	No
City × Decade Fixed Effect	No	Yes	No	Yes
Observations	4770	4770	4770	4770
R^2	0.07	0.13	0.07	0.13

This table reports estimates from linear probability models where the outcome is a binary variable (1/0) for the observation of an entrant in a given city-year who produces business education content. "Business Printer Death" denotes indicators for the death of a printer who produced business education content. "Non-Business Printer Death" denotes indicators for the death of printer who did not produce business education content. Leads and lags of these variables are as follows. "Business Printer Death t = 2" is an indicator for a death occurring two years in the future. "Business Printer Death t = 1" is an indicator for a death occurring one year in the future. "Business Printer Death t = 0" is an indicator for a death occurring in the current year. two years in the future." is an indicator for a death in the current year. "Business Printer Death t = -1" is an indicator for a death occurring one year in the past. "Business Printer Death t = -2" is an indicator for a death occurring two years in the past. Where city and year fixed effects are independent, standard errors are clustered by city. In specifications with city-decade fixed effects, standard errors are clustered by city-decade. Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D Merchant Printing and Economic Outcomes

This Appendix presents additional evidence that support the findings in the main body of the paper. First, we present evidence on the "match groups" we use to focus on the implications of variation in merchant manual publication induced by our instrument (printer deaths) within narrow cells of ex ante similar cities. Second, we present first stage estimates for the IV regressions reported in the main text. Third, we present evidence on the special role of the deaths of specialized merchant manual printers by studying the implications of the deaths of other types of printers. Fourth, we present evidence on the implications of shocks to merchant printing that occurred at different times in different cities. Fifth, we present evidence on the relationship between merchant printing and individual achievement.

D.1 Matching Cities Based on Ex Ante Similarity

The baseline results in the main text include estimates that examine variation in growth across *ex ante* similar cities matched on the basis of similar pre-1500 printing profile. Cities are matched at described in Table D1 based on their initial output quantile and on whether they were high (above mean) or low (below mean) producers of scientific publications and, separately, educational publications.[83]

D.2 First Stage Estimates for IV Analysis of Merchant Manuals and City Growth

In the main body of the text we present IV estimates of the impact of merchant manual publications on local population growth. These results are presented in Table 10, along with F-statistics from the first stage estimates. In this subsection we present the corresponding first stage estimates.

Table D2 presents first stage estimates of the relationship between merchant manuals and printer deaths. In Columns 1-4 the outcome is the number of merchant manuals published 1500-1600. In columns 5-8 the outcome is the log of the number of titles published plus one. Panel A examines all cities and uses the measure of printer deaths constructed from publications (the publications measure). Panel B examines German-speaking cities and uses the measure of printer deaths from publications. Panel C examines German-

[83] Excercises that restrict analysis to only German-speaking cities maintain within-group variation by consolidating the data in terms of four matching groups.

Table D1: Variation in Instrument within Control Groups

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Print Media 1445-1499				Cities and Shocks 1500-1600		
Matching Group	Mean Titles	Output Quantile	High Science	High Education	Total Cities	Merchant Death IV	Other Death
1	0.0	1	No	No	133	6	22
2	1.4	2	No	No	13	0	6
3	2.0	2	No	Yes	2	0	0
4	10.4	3	No	No	26	5	15
5	21.3	3	No	Yes	12	4	9
6	16.5	3	Yes	No	4	0	1
7	30.0	3	Yes	Yes	2	0	1
8	413.9	4	No	No	17	9	12
9	421.2	4	No	Yes	13	6	8
10	266.8	4	Yes	No	12	5	9
11	602.2	4	Yes	Yes	5	2	4

The construction of matching groups based on 1454-1499 media output. Column 7 records the number of cities experiencing the death of a printer whose firm produced business education content. Column 8 records the number of cities experiencing the death of printer whose firm did not produce business education.

speaking cities and uses teh measure of printer deaths from biographical records (the biographical measure). Other controls are as described in the main text.

D.3 Robustness of Baseline Results

In this section we provide evidence on the role of non-merchant printer deaths that supports our main results. We examine the deaths of non-merchant printers as a potential source of variation in non-merchant supply that could have correlated with growth and as a type of placebo. We find no evidence that variation in output driven by non-merchant printer deaths shifted growth. We then provide additional evidence showing that our baseline results are not driven by overall variation in printer deaths.

The baseline results in the main text examine the relationship between merchant manual publications and city growth and use the deaths of merchant manual printers as a source of exogenous variation. In this section we show that the deaths of other types of printers induced some variation in other types of publication, but that these induced variations had minimal growth effects.

Table D3 presents 2SLS estimates of the relationship between city growth and non-business output induced by the deaths of non-merchant printers. We find minimal re-

Table D2: First Stage Estimates of the Relationship between Printer Death IV and Merchant Manuals

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Baseline All Cities – Printer Deaths from Book Inscriptions								
	Merchant Manuals				Ln Merchant Manuals			
Deaths of Merchant Printers	10.345***	10.252***	10.195***	10.270***	0.334**	0.311**	0.270***	0.261***
	(0.643)	(0.686)	(0.709)	(0.796)	(0.126)	(0.122)	(0.082)	(0.081)
Observations	269	269	269	269	269	269	269	269
R^2	0.81	0.81	0.81	0.83	0.59	0.61	0.82	0.83
Panel B: German Cities – Printer Deaths from Book Inscriptions								
	Merchant Manuals				Ln Merchant Manuals			
Merchant Printer Deaths	9.659***	9.681***	9.387***	9.584***	0.643***	0.632***	0.511***	0.485***
	(2.283)	(2.338)	(2.397)	(2.320)	(0.092)	(0.098)	(0.090)	(0.092)
Observations	70	70	70	70	70	70	70	70
R^2	0.78	0.78	0.79	0.85	0.79	0.79	0.90	0.93
Panel C: German Cities – Printer Deaths from Biographical Data								
	Merchant Manuals				Ln Merchant Manuals			
Merchant Printer Deaths	10.072***	10.126***	9.991***	10.514***	0.640***	0.628***	0.518***	0.534***
	(1.023)	(1.035)	(1.073)	(1.353)	(0.046)	(0.054)	(0.041)	(0.057)
Observations	70	70	70	70	70	70	70	70
R^2	0.92	0.92	0.92	0.94	0.83	0.83	0.93	0.96
Death Other Printers		Yes	Yes	Yes		Yes	Yes	Yes
Ever Manuals			Yes	Yes			Yes	Yes
Match Group Fixed Effects				Yes				Yes

This table presents first stage regression estimates studying merchant manual publishing outcomes. These regressions correspond to the 2SLS estimates presented in Table 10. The dependent "Merchant Manuals" outcome is the count of merchant manuals published 1500-1600. The "Ln Merchant Manuals" outcome is the log of manuals ($\ln[manuals + 1]$). "Deaths Other Printers" is an indicator for other printer deaths. "Ever Manuals" is an indicator for cities that ever produced business education content. Match group fixed effects are as discussed in the text. All regressions control for population in 1500, pre-1500 printing, port location, the presence of historic universities, navigable rivers, latitude, longitude, and country fixed effects. Panel A presents estimates examining all European cities and measures merchant printer deaths as recorded in books (the publications measure). Panel B presents estimates examining German-speaking cities and measures merchant printer deaths as recorded in books as the IV (the publications measure). Panel C presents estimates examining German-speaking cities and measures merchant printer deaths as recorded in biographical data (the biographical measure). Standard errors clustered at the country level. Statistical signficance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

lationship between any induced variation in non-business publishing and growth. In columns 1-3, we examine variation in the number of non-business books and find virtually no relationship between induced variation in these books and growth. In columns 4-6 we examinate variation in the log of the number of non-business books. Here we find a relatively weak and statistically insignificant relationship between induced variation and growth and a weak first stage (F-Statistics all below 5).

Table D3: IV Analysis of City Growth Using Deaths of Non-Merchant Printers

	(1)	(2)	(3)	(4)	(5)	(6)
	Outcome: Ln Growth 1500-1600					
Non-Merchant Books	0.0000	0.0000*	0.0000			
	(0.0000)	(0.0000)	(0.0000)			
Ln Non-Merchant Books				0.0604	0.0665	0.0527
				(0.0439)	(0.0478)	(0.0570)
F-Statistic on IV	84.87	86.81	89.63	2.19	4.25	3.41
Observations	269	269	269	269	269	269
Deaths Merchant	Yes	Yes	Yes	Yes	Yes	Yes
Ever Manuals		Yes	Yes		Yes	Yes
Control Groups			Yes			Yes

This table presents IV estimates of city growth and non-business publishing. The outcome is log city growth 1500-1600: $ln(POP_1600/POP_1500)$. Deaths of non-merchant printers are the IV for non-merchant books. "Death Merchant" is an indicator taking the value of 1 for cities where deaths of business education printers is observed. "Ever Manuals" is an indicator for cities ever producing merchant manuals. Control groups fixed effects are described in the text. All regressions control for city population in 1500, pre-1500 printing, port location, the presence of historic universities, navigable rivers, latitude, longitude, and country fixed effects. Standard errors clustered at the country level. Significance at the 99%, 95%, and 90% confidence level denoted "***", "**", and "*".

The baseline IV estimates includes controls for the presence of other, non-merchant printer deaths (Table 10). A natural question would be whether results change when we control for the *number* (count) of other printer deaths. In this section, we show that our results controlling for the number of others are very similar and even stronger using the biographical measure. Table D4 reports these additional specifications and shows that the magnitudes of the IV estimates are virtually unchanged. Panel A presents estimates for all cities using the measure of deaths from book inscriptions. The estimates are slightly less precise than the baseline in the main text and within control groups are not statistically significant. However, Panel C shows that when we example the biographic data on all deaths, the estimates are larger, highly significant, and more precisely estimated than in any of the baseline specifications when we control for the count of other printer deaths.

These findings document the significant relationship between upper tail knowledge and growth and strongly suggest that supply side variations in knowledge contributed

Table D4: IV Estimates of the Growth Impact of Merchant Manuals

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Baseline All Cities – IV from Book Inscriptions								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.004**	0.003*	0.002*	0.002				
	(0.001)	(0.002)	(0.001)	(0.001)				
Ln Merchant Manuals					0.117***	0.111**	0.084	0.074
					(0.031)	(0.051)	(0.061)	(0.057)
Observations	269	269	269	269	269	269	269	269
F Statistic on IV	258.60	369.13	259.05	242.95	7.04	3.21	5.65	5.62
Panel B: German-Speaking Cities – IV from Book Inscriptions								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.007***	0.005**	0.003	0.004				
	(0.001)	(0.002)	(0.002)	(0.004)				
Ln Merchant Manuals					0.101***	0.076**	0.075**	0.101
					(0.020)	(0.030)	(0.028)	(0.070)
Observations	70	70	70	70	70	70	70	70
F Statistic on IV	139.78	335.65	434.65	185.79	15953.70	10965.03	1809.88	31.03
Panel B: German-Speaking Cities – IV from Biographical Data								
	Outcome: Ln Growth 1500-1600							
Merchant Manuals	0.008***	0.006**	0.005	0.005				
	(0.003)	(0.003)	(0.003)	(0.003)				
Ln Merchant Manuals					0.124***	0.101**	0.116**	0.123**
					(0.033)	(0.042)	(0.056)	(0.057)
Observations	70	70	70	70	70	70	70	70
F Statistic on IV	97.00	68.27	60.84	65.62	189.77	113.24	131.46	132.83
Death Other Printers: Cuunt		Yes	Yes	Yes		Yes	Yes	Yes
Ever Manuals			Yes	Yes			Yes	Yes
Match Group Fixed Effects				Yes				Yes

This table presents instrumental variable estimates of the relationship city growth and merchant manual supply. The dependent variable is: $ln(POP_{1600}/POP_{1500})$. "Merchant Manuals" is the count of merchant manuals. "Ln Merchant Manuals" is the log of manuals ($\ln[manuals + 1]$). "Deaths Other Printers: Count" is the count of other printer deaths. "Ever Manuals" is an indicator for cities that ever produced business education content. Match group fixed effects are as discussed in the text. All regressions control for population in 1500, pre-1500 printing, port location, the presence of historic universities, navigable rivers, latitude, longitude, and country fixed effects. Panel A presents estimates examining all European cities and uses merchant printer deaths recorded in books as the IV (the publications measure). Panel B presents estimates examining German-speaking cities and uses merchant printer deaths recorded in books as the IV (the publications measure). Panel C presents estimates examining German-speaking cities and uses merchant printer deaths recorded in biographical data as the IV (the biographical measure). Standard errors clustered at the country level. Statistical signficance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

to growth. The key identifying assumption here is that the deaths of business education printers impacted city-level growth only through their impact on the quantity of specialized merchants' manuals produced at the city-level. It is unlikely that this specific type of premature printer death impacted city growth through channels besides the impact on the supply of business education books. But the identification rests on the assumption that these particular deaths are not themselves positively correlated with other factors that drove variations in growth through non-media market channels.

D.4 Individual Achievement

Our baseline results show that the deaths of merchant printers generated shifts in individual achievement in city-cohorts exposed to these deaths in late adolescence and early adulthood (Section 7.1). Here we present additional evidence showing that our results are robust to dropping individual cities. Specifically, we replicate our baseline analysis in repeated subsets of the data. In each subset of the data we drop one individual city from the analysis and re-estimate our baseline specification:

$$people_{it} = \alpha_i + \delta_t + \sum_{\tau=-3}^{3} (\beta_\tau death_{i,\tau}) + \epsilon_{it}$$

The outcome $people_{it}$ is the number of people born in a city-decade observed in the *Deutsche Biographie*. The parameters of interest are the β_τ, which capture how individual achievement responded to the timing of shocks to the business education press, measured by the death of a merchant printer ($death_{i,\tau}$) at the city-decade level. Cities and decades are indexed i and t. The timing of shocks is indexed relative to individuals' decade of birth by $\tau = 0, 1, 2, ...$ occur in the decade of birth, the decade in which an individual turned 10, and the decade in which an individual turned 20, respectively. The α_i and δ_t are city and decade fixed effects.

Table D5 presents our findings and shows that our baseline results are robust. Our baseline estimate was that city-cohorts exposed to the death of a merchant printer produce 0.39 additional high achievement individuals as recorded in the *Deutsche Biographie*. Table D5 shows that when we drop individual cities the point estimate ranges from 0.27 to 0.45 and is always statistically significant at the 90 percent level.[84]

[84]The cities whose omission leads to the largest decline in the point estimate is Augsburg. Excluding Augsburg, the point estimate drops to 0.28 with the t-statistic 1.70.

Table D5: Shocks to Merchant Printing and Bourgeois Achievement

Outcome: Count of High Achievement Bourgeois Individuals in a City-Cohort Parameter Estimate: Exposure to Merchant Printer Death in Decade Cohort Turns 20					
City Excluded	Estimate	Std. Error	City Excluded	Estimate	Std. Error
Aachen	0.395	0.193	Kassel	0.392	0.192
Altenburg	0.392	0.192	Koeln	0.389	0.212
Annaberg	0.395	0.193	Lauingen	0.389	0.191
Augsburg	0.274	0.161	Legnica	0.359	0.199
Bamberg	0.391	0.189	Leipzig	0.358	0.189
Basel	0.448	0.198	Luebeck	0.342	0.196
Bautzen	0.393	0.192	Magdeburg	0.357	0.200
Berlin	0.394	0.191	Mainz	0.432	0.204
Braniewo	0.432	0.199	Memmingen	0.392	0.192
Braunschweig	0.408	0.195	Metz	0.395	0.193
Bremen	0.395	0.193	Muenchen	0.406	0.185
Coburg	0.398	0.191	Muenster	0.393	0.192
Dortmund	0.392	0.192	Mulhouse	0.407	0.199
Dresden	0.386	0.192	Noerdlingen	0.386	0.192
Duesseldorf	0.392	0.192	Nuernberg	0.371	0.200
Eisenach	0.394	0.190	Regensburg	0.392	0.192
Eisleben	0.385	0.191	Reutlingen	0.392	0.196
Elblag	0.386	0.194	Rostock	0.392	0.190
Emden	0.392	0.192	Salzburg	0.392	0.190
Erfurt	0.426	0.194	Schwaz	0.392	0.192
Frankfurt Am Main	0.361	0.201	Soest	0.392	0.192
Frankfurt An Der Oder	0.392	0.192	Speyer	0.388	0.194
Freiberg	0.393	0.192	St-Gallen	0.392	0.192
Freiburg	0.410	0.192	Strasbourg	0.386	0.206
Gdansk	0.433	0.200	Szczecin	0.416	0.208
Goerlitz	0.395	0.195	Torgau	0.388	0.192
Gotha	0.389	0.192	Trier	0.397	0.192
Graz	0.392	0.190	Tuebingen	0.452	0.188
Halle	0.392	0.192	Ulm	0.381	0.191
Hamburg	0.354	0.191	Wien	0.392	0.190
Hannover	0.385	0.191	Worms	0.398	0.191
Heidelberg	0.431	0.199	Wroclaw	0.359	0.199
Hildesheim	0.391	0.193	Wuerzburg	0.390	0.193
Innsbruck	0.392	0.192	Zerbst	0.393	0.192
Kaliningrad	0.438	0.187	Zuerich	0.375	0.195

This table presents point estimates of the effect of merchant printer deaths on individual achievement in bourgeois occupations at city-cohort level for cohorts exposed to these deaths in the decade they turn 20 years old. The outcome is the number individuals in a city-cohort observed in the *Deutsche Biographie*. Cohorts are defined as individuals born in the same decade. The estimates in this table correspond to the results reported in Table 11 (row 2, column 3). The difference is that in this table each row presents the regression estimate when one city is dropped from the dataset. All regressions include city and region-cross-time fixed effects and additional leads and lags of merchant printer deaths as in Table 11. Standard errors are clustered by city.

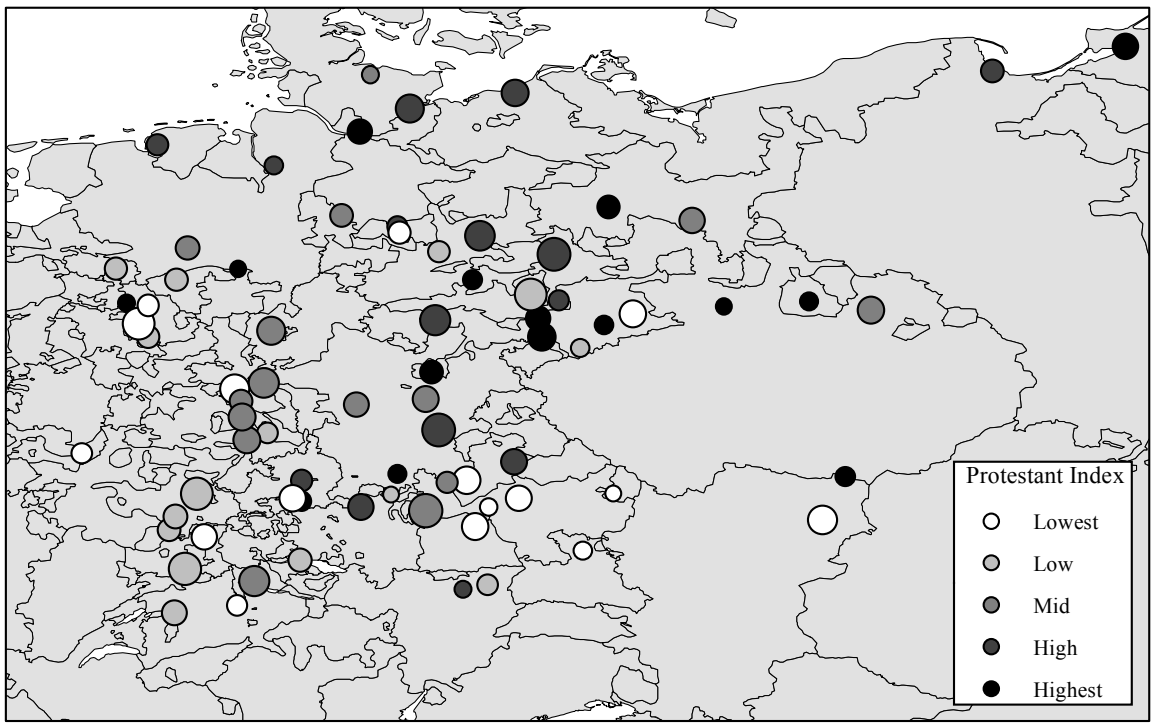
E Competition, Religious Printing, and Institutional Change

E.1 Local Variation in Printing and Institutional Change

Our baseline results document local variation in the dissemination of Protestant publications and in city-level institutional change. This subsection presents the data graphically.

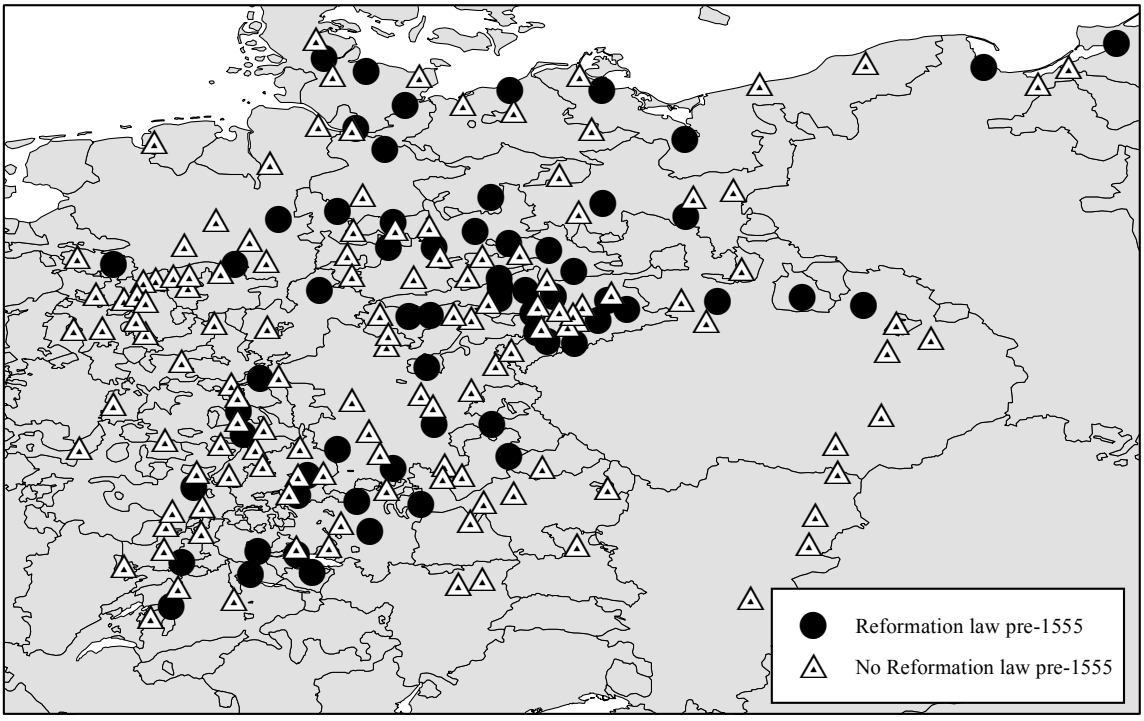
We study variation in content and institutional change both across Germany and at the local level across neighboring cities. Figure E1 maps the location of printing cities, with markers shaded to reflect the intensity of Protestant publishing (i.e. the average value of classified religious media) and scaled to reflect the total number of publications produced between 1518 and 1554. The pattern of institutional change also varied at the local level. Figure E2 maps the geographic distribution of city-level legal reform and shows the spatial heterogeneity of institutional change, including across neighboring cities in the same territory.

Figure E1: Religious Printing in German Cities During the Reformation



This map shows the locations of cities that produced religious publications after 1518. Markers are shaded to reflect the intensity of Protestant content. Darker markers reflect a higher Protestant share in religious publication. We measure the Protestant share as the mean across classified religious publications. Markers are scaled to reflect the total number of publications produced..

Figure E2: Cities that did and did not pass Reformation laws



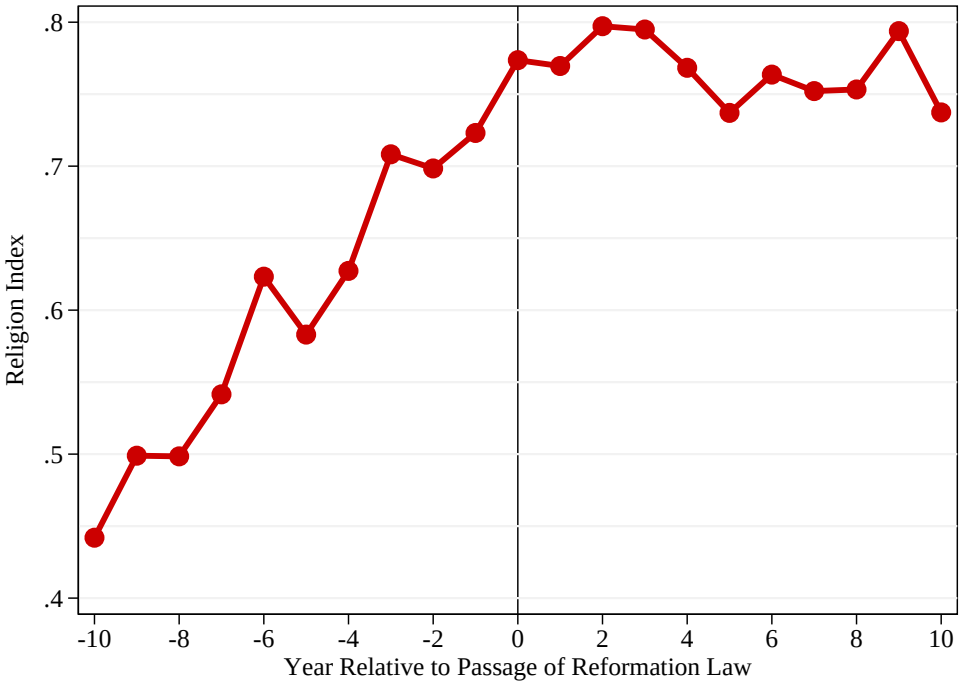
This map shows the locations of cities that did and did not pass Reformation laws before 1555. Cities that passed Reformation laws are designated with circles, cities that did not are triangles.

E.2 The Timing of Changes in Religious Printing in Cities that Adopted Institutional Change

The main text focuses on the relationship between religious printing in the first years of the Reformation and subsequent institutional change. The results we report in the main text focus on Protestant printing between 1517 and 1521 – before any city-level Reformation laws were passed – and the subsequent passage of these laws. However, institutional change occurred in different cities at different times. Here we examine how the religious content evolved before and after institutional change in those cities that did pass Reformation laws. To do this, we index time such that $t = 0$ is the year a given city passed its first Reformation law. We then examine the mean content in the religious media across cities (individual Protestant publications are indexed 1, individual Catholic publications are indexed 0).

Figure E3 presents the evidence and shows that (1) the Protestant share of religious printing was steadily increasing in the years immediately before institutional change and (2) remained stable thereafter.

Figure E3: Religious Ideas in the Media Before and After Institutional Change



This graph presents the mean of the religion index before and after the passage of Reformation laws (Protestant = 1, Catholic = 0). We restrict analysis to cities that did pass legal reforms and present the mean religion index with time centered at year 0, defined as the year in which each city's first Reformation law was passed.

E.3 The Salience of City-Level Variation and of City-Level Institutional Change as an Outcome

This section provides further discussion to explain the salience of city-level variation in the diffusion of Protestant ideas and of city-level institutional change as an outcome.

In addition to the observations in the main text, the chronology of events supports our study of city-level variation in the diffusion of the Reformation. In 1521, Luther was summoned to the Diet (parliament) of the Holy Roman Empire at Worms to present his views in light of Papal charges against him. Frederick the Wise, the Elector of Saxony in which Wittenberg was located, helped arrange this hearing and provided important though highly qualified support for Luther. The hearing at Worms led to the Edict of Worms (1521), which was issued by the emperor and forbade support for Luther in thought or deeds and called for his arrest.[85] The Edict of Worms was not, however, enforced: Protestant printing was not seriously censored in the years between 1521 and

[85]Frederick himself was, in personal religious practice, a traditional Catholic committed to rituals Luther came to denounce. After the hearing at Worms, Frederick put Luther under a form of protective house arrest at the Wartburg castle, and eventually received an exemption from the Edict of Worms for his territory.

1524 and Luther was not detained (Creasman 2012; Pettegree 2015).

For several years, Protestant ideas thus spread in the media and shifted the religious and political landscape specifically in cities. Brady (1985; p.153) observes:

> "The tide of books, pamphlets, and broadsides quickly became a flood...The cities, centers of all communications, oral, visual, and written, learned and lay, became the breeding ground for a mighty movement, though for a few years the "Luther affair" seemed to disappear from the stage of Imperial [i.e. supra-local] politics. The rulers of the towns [i.e. city councils and magistrates], however, knew quite well what was going on inside their walls, and it troubled them."

Over the initial years of the Reformation, the city-level factors were the key determinants of the diffusion of the Reformation. Dickens (1966; p. 74) writes:

> "By 1524-5 Luthers disciples held control in Erfurt, Gotha, Magdeburg, Nuremberg, Bremen, Altenburg and a host of smaller places. In Catholic Cologne and at Jena there were strong radical [Protestant] movements... cities did not, it is true, adopt a uniform policy throughout the years of crisis between 1522 and 1555. Their attitudes were strikingly modified by secular traditions and local circumstances."

The "secular traditions" Dickens flags here can be considered as quasi-fixed demand-side differences across cities, whereas "local circumstances" can be understood to comprise time-varying differences across cities that potentially involve both demand-side and supply-side factors. Our argument is that printer deaths just before the Reformation provided a source of exogenous variation in local circumstances that was effectively on the supply-side.

There are several considerations that lead us to similarly examine institutional change at the city-level as an outcome.

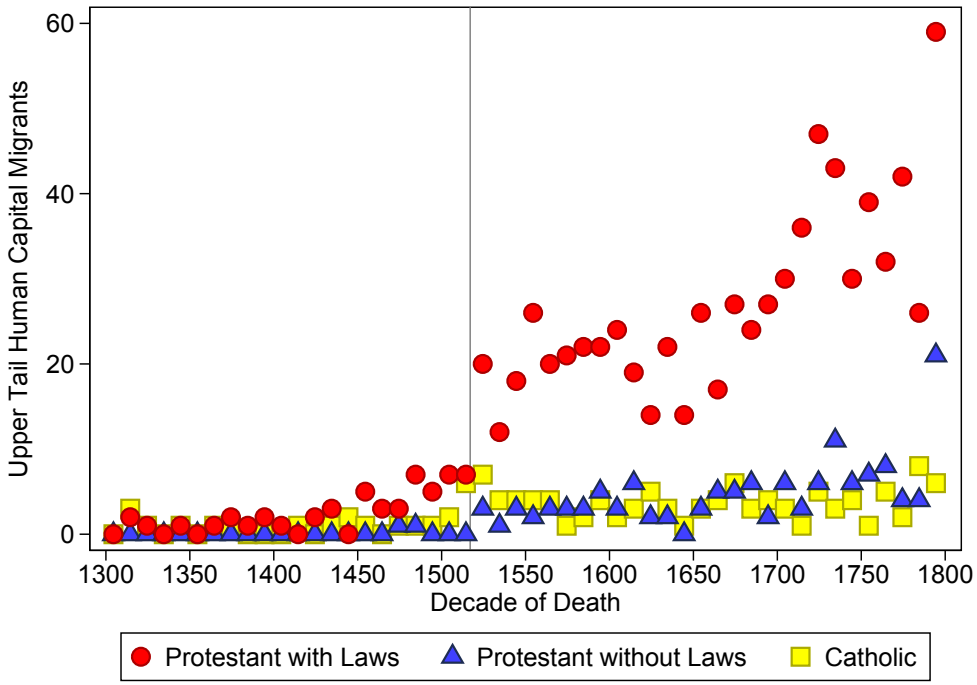
First, the institutional innovations of the Protestant Reformation were first pioneered at the city level and are interesting in their own right (Hamm 1994; Sehling et al. 1909-2013). Institutional changes occurred first at the city-level and provided models later territorial-level legal change.

Second, the institutional changes we study as outcomes should be interesting to economists in and of themselves. They not only reformed church services, they also established compulsory mass public education and broadly expanded the provision of public goods at the city-level.

Third, the institutional changes we study as outcomes were associated with significant variation in later *economic* outcomes. Cities that formalized institutional change during the Reformation (1) subsequently experienced significantly faster long-run population growth lasting over several centuries and (2) began to produce and attract more upper tail human capital. These differences between cities that did and did not adopt institutional change are observed even within territories, strongly suggesting that the formalization of new social arrangements mattered over and above variation in development that "lived" at the regional level and reflected regional culture or the policies and preferences of territorial lords. These facts are documented in Dittmar and Meisenzahl (2018).

To illustrate the salience of the distinction between cities with and without institutional change, here we present summary data on the migration of high-achievement individuals recorded in the *Deutsche Biographie*.

Figure E4: Institutional Change and the Migration of High Achievement Individuals



This graph presents evidence on the number of high achievement migrants moving to German cities that did and did not adopt institutional change during the Reformation. Individual-level data on migrants are drawn from the *Deutsche Biographie*. Migrants are defined as individuals observed dying in a given destination but born in some other location. This figure distinguishes cities that adopted institutional change ("Cities with Laws"), cities that adopted Protestantism without formalizing institutional change at the city level ("Protestant without Laws"), and cities that remained Catholic ("Catholic"). See Dittmar and Meisenzahl (2018).

E.4 Protestant Ideas in Print and Binary Measures of Religion

In this section, we present evidence on the relationship between our measure of Protestant ideas in print and binary measures of city-level religion examined in previous research. We study the relationship between Protestant printing and Cantoni's (2014) binary measure of city-level Protestantism, which captures *religion* and thus is distinct from our measure of institutional change (laws). We use regression analysis and estimate models:

$$(\text{protestant publications})_i = \alpha + \beta(\text{protestant religion indicator})_i + \gamma X_i + \epsilon_i$$

The dependent variable "protestant publications" is either the count of publications or an indicator for cities producing at least 50 Protestant publications. The key explanatory variable "protestant religion indicator" records which cities that became Protestant in the 1500s, whether or not city-level institutional change is observed. The X include all institutional and media market controls in the main text and, in some specifications, geographic grid cell fixed effects.

Table E1 presents our results and shows that there is no significant relationship between city religion and Protestant printing, where we measure Protestant printing by the number of publications or with a binary variable for cities with at least 50 Protestant publications. Results are similar for other thresholds for Protestant printing.[86]

E.5 Protestant Content versus Martin Luther's Work

Our classification of content provides significant new information on the diffusion of Protestant ideas. As discussed in the text, our classification of content provides evidence on religion in the media (i) in cities where no religious publications were produced by leading authors and (ii) for the majority of titles, which are by unknown or little known authors. In addition, the classification provides substantive evidence for our interpretation of the relationship between competition and diffusion that appears less precisely when we look just at leading known authors.

To illustrate, we present estimates of the relationship between initial competition (market structure) and the post-1517 diffusion of Martin Luther's work. Table E2 presents regression where the outcome is the diffusion of Luther's works and the specifi-

[86] Note that the number of observations in these regressions is somewhat smaller than in our baseline analysis because we restrict our analysis to cities for which Cantoni (2014) classifies religion. Cantoni (2014) does not classify religion for several of the smaller cities in our data or for several cities outside contemporary Germany.

cations correspond to our baseline estimates in Tables 8 and 9.

E.6 Religious Printing in the Early Reformation

This section presents estimates examining religious printing during the first years of the Reformation, i.e. 1518 through 1521. Our baseline results in the main text focus on religious printing 1518-1554. Here we narrow the focus to examine the relationship between initial competition and religious printing before any city-level institutional changes occurred (i.e. through 1521). These results thus also corroborate the IV analysis examining the relationship between early Reformation printing and institutional change, measured by the adoption of Reformation laws.

Table E3 presents estimates religious publication outcomes: the binary outcome capturing whether at least 10 or 25 publications were printed 1518 to 1521 and the count of religious publications (25 publications puts cities above the 90th percentile). We estimate our baseline specifications using an OLS specification for the binary outcome and both OLS and negative binomial models for the count data. In the OLS specifications, we find that cities with more than one printer produced more Protestant publications than cities with just one printer and, interestingly, that having just one printer *negatively* predicts Protestant publications relative to the reference group of cities with no initial printers. However, we do find a positive effect of "Any Printers" on Protestant output in the count

Table E1: Binary Measure of Protestantism and Printing Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Protestant Printing Outcomes					
	Count of Publications			Binary: 50+ Publications		
Protestant Religion Indicator	34.04	-21.89	8.94	-0.01	0.03	0.09
	(23.39)	(31.86)	(54.31)	(0.04)	(0.08)	(0.13)
Controls		Yes	Yes		Yes	Yes
Grid Cell Fixed Effects			Yes			Yes
Observations	149	149	149	149	149	149
R^2	0.00	0.57	0.60	0.00	0.52	0.56

This table presents regression estimates of the relationship between Protestant printing outcomes and a binary measure of city-level religion. In columns 1 to 3 the outcome is the number of Protestant publications. In columns 4 to 6 the outcome is a binary variable for cities with at least 50 Protestant publications. The independent variable "Protestant Religion Indicator" measures city-level religion and is from Cantoni (2014). Controls are the complete set of controls in Table 8. Grid cell fixed effects are fixed effects for 3×2 degree grid cells (approximately 210 kilometer cells). Standard errors reported in parentheses are clustered at the state level. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

Table E2: The diffusion of Luther versus all Protestant content

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Outcome: Publications by Martin Luther							
			Binary Outcome					
	Count Outcome		10+	10+	25+	25+	50+	50+
Number of Printers	8.49		0.05		0.02		0.03	
	(8.53)		(0.03)		(0.03)		(0.02)	
Indicator: Any Printers		-13.82		0.05		-0.11*		0.01
		(10.83)		(0.07)		(0.06)		(0.02)
Indicator: 2+ Printers		115.36		0.18		0.17		0.13
		(88.19)		(0.12)		(0.12)		(0.10)
Observations	191	191	191	191	191	191	191	191

This table presents regression estimates of the relationship between the number of firms active 1508-1517 and the number of publications of Martin Luther's work printed 1518-1554. In columns (1) and (2), the outcome variable is the the count of Luther's works published. In columns (3) to (8), the outcome variables are indicators for thresholds of Lutheran publications. All specifications control for the complete set of controls in Table 8. Standard errors reported in parentheses are clustered at the state level. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

data models.[87] For Protestant printing we find a consistently positive although sometimes imprecisely estimated relationship between competition and printing. For Catholic printing, we do find a positive effect of competition on the likelihood of crossing the low threshold of 10 Catholic publications – but no effect for for any other outcome, including the count data outcomes.

Table E3: Religious Printing in First Years of Reformation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Protestant Publications				Catholic Publications			
	Indicator:		Count		Indicator:		Count	
	10+	25+	OLS	NB	10+	25+	OLS	NB
Indicator:	-0.08	-0.05**	-8.48	2.72**	-0.06	-0.05***	-2.26	1.42
Any Printers	(0.10)	(0.02)	(5.02)	(1.17)	(0.09)	(0.01)	(2.09)	(1.38)
Indicator:	0.20**	0.17	25.56	2.62*	0.27***	-0.00	3.41	0.52
2+ Printers	(0.10)	(0.10)	(20.44)	(1.41)	(0.09)	(0.03)	(2.54)	(1.57)
Observations	191	191	191	191	191	191	191	191

This table presents regression estimates examining the relationship between religious outcomes in the initial years of the Reformation (1518-1521) and measures of initial competition. All specifications control for the complete set of controls in Table 8. In columns 1,2, 5, and 6 the outcome is a binary variable measuring whether the number of publications crossed the specified threshold and estimates are OLS. In columns 3, 4, 7, and 8 the outcome is the count of publications and estimates are either OLS or negative binomial (NB). Standard errors reported in parentheses are clustered at the state level. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

[87] In a count data model with region fixed effects, we find that the "2+ Printers" effect is *larger* in magnitude than "Any Printers" effect, with both positive and highly significant.

E.7 Religious Printing and Institutional Change

In the main text we report estimates examining the relationship between publications printed in the first three years of the Reformation and the subsequent adoption of a city-level Reformation law (*Kirchenordnungen*). We examine the adoption of a Reformation law as a measure of institutional change. We focus in the main text on religious printing over the first three years of the Reformation (1518 to 1521) because this was the period before any Reformation laws were adopted, which may themselves have had some influence on printing.

Our baseline instrumental variable results examine how institutional change at the city level varies with potentially endogenous Protestant printing as measured by the log of the number of Protestant publications plus one (Table 13 above). We instrument for this measure of publications with printer deaths in the period just prior to the Reformation. This analysis embodies a functional form assumption (the logarithmic transformation) and conventionally but arbitrarily adds one to zero observations.

To provide sensitivity analysis for our baseline results, in this section we consider the relationship between institutional change and alternate measures of publications. Specifically, we examine how institutional change varied with measures based on the count of publications. To examine the evidence on counts from another perspective and to avoid conditional-on-positive bias, we construct measures that record whether the count variable (our measure of Protestant printing) crosses distributional thresholds (Angrist 2001).

We estimate IV regressions in which the first stage examines how printer deaths were related to the probability that Protestant publications printed 1518 to 1521 crosses two thresholds: (1) whether any Protestant publications were printed and (2) whether at least 25 Protestant publications were printed. Our IV estimates then examine how induced variation in these binary measures of religious printing explains variation in the ultimate institutional change outcome, i.e. the adoption of a Reformation law 1521 to 1554. We implement our analysis replicating the set of specifications presented in Table 13 (main text). We present first stage and IV estimates, and for further illustration IV probit estimates, that are broadly consistent with our main results.

Table E4 presents our sensitivity analysis. In columns 1 to 4, we examine variation in whether a city printed any Protestant publications 1518 to 1521. In columns 5 to 8, we examine variation in whether a city printed 25 Protestant publications 1518 to 1521. Panel A presents first stage estimates. We find that printer deaths are associated with a 16-18 increase in the probability of a Protestant publication in the first years of the

Reformation controlling for the number of printers in the previous period (column 1) and controlling for city population (column 2). However, that our point estimates decline by about 50 percent and become imprecise when we control for city characteristics and grid cell effects (columns 3 and 4). When we examine variation in printing at least 25 Protestant publications, which puts cities in the top decile of the distribution for Protestant output between 1518 and 1521, we find that printer deaths are a significant explanatory factor. Controlling for the number of printers, a printer death increases the probability of observing 25 Protestant publications by 32 percent (column 5). This declines to 23 percent controlling for city population (column 6) and to 14 percent when we include our complete set of controls, and remains at 13 percent when we introduce grid cell fixed effects. Panel B presents our IV estimates, which correspond to the results presented in the main text. As in the main text, we find that (1) variation in Protestant printing, induced by printer deaths, is a positive predictor for institutional change and (2) this relationship becomes weaker and less precisely estimated when we introduce our complete set of controls and grid cell fixed effects. Notably, however, our estimates are large in magnitude. With one exception the IV estimates are greater than one, implying that predicted probability of institutional change would be outside the unit interval for cities with Protestant publications crossing the designated thresholds. This reflects both the functional form assumptions of the underlying linear probability model and the nature of our data, in which the identifying variation lives in a small number of observations, as discussed in the main text. In Panel C, we present IV probit estimates which embody different functional form assumptions, together with marginal effects. We present these estimates with further caveats, acknowledging that our IV is not continuous and that IV probit may not deliver consistent estimates in our context. We view these results therefore as suggestive evidence that broadly supports the view that shocks to printer competition influenced religious change, rather than well-identified causal effects.

E.8 Evidence Supporting Printer Death IV

Our baseline analysis examines the deaths of printers as a source of exogenous variation in competition that can be used to examine the relationship between industrial structure in media markets on the eve of the Reformation and subsequent diffusion.

The exclusion restriction for identification is that printer deaths shifted competition and only through this channel impacted the subsequent diffusion of Protestant ideas in the media. As noted in the main body of the paper, a natural question is whether printer deaths actually impacted the diffusion of Protestant ideas by shifting the age composition of printers or firms. In particular, we wondered whether printer deaths shifted age mix

Table E4: Protestant Publications and Institutional Change IV Estimates

Panel A: First Stage	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Outcome: Protestant 1517-1521: Any				Outcome: Protestant 1517-1521: 25+			
Printer Deaths 1508-1517	0.18***	0.16**	0.07	0.09	0.09**	0.11***	0.13***	0.13*
	(0.06)	(0.07)	(0.08)	(0.12)	(0.04)	(0.03)	(0.03)	(0.06)
Firms 1498-1507	0.10***	0.09***	0.04	0.04	0.09***	0.09***	0.05***	0.05***
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.02)
Observations	191	191	191	191	191	191	191	191
Panel B: IV Estimates								
	Outcome: Reformation Law Passed 1521-1554				Outcome: Reformation Law Passed 1521-1554			
Protestant 1518-1521: Any	1.21***	1.11*	2.59	1.04*				
	(0.30)	(0.62)	(2.53)	(0.59)				
Protestant 1518-1521: 25+					2.40*	1.59**	1.47	0.71
					(1.37)	(0.64)	(0.93)	(0.63)
Firms 1498-1507	-0.06	-0.05	-0.08	-0.02	-0.15	-0.10	-0.04	-0.01
	(0.05)	(0.07)	(0.11)	(0.04)	(0.12)	(0.07)	(0.06)	(0.05)
Observations	191	191	191	191	191	191	191	191
F Statistic on IV	8.65	4.93	0.76	0.58	4.57	11.13	13.43	4.25
Panel C: IV Probit								
	Outcome: Reformation Law Passed 1521-1554				Outcome: Reformation Law Passed 1521-1554			
Protestant 1518-1521: 1+	2.91***	2.71***	3.78***	3.78***				
	(0.47)	(0.95)	(0.36)	(0.38)				
Protestant 1518-1521: 25+					6.59***	5.32*	7.66***	7.13***
					(1.43)	(2.87)	(2.26)	(2.46)
Observations	191	191	191	181	191	191	191	181
Marginal Effect	0.11	0.09	0.13	0.09	0.04	0.24	0.68	0.23
Population in 1500		Yes	Yes	Yes		Yes	Yes	Yes
Controls			Yes	Yes			Yes	Yes
Geographic Grid Cell FE				Yes				Yes

This table presents IV regression estimates examining the institutional change outcome. Panel A studies first stage outcomes that measure Protestant publications printed 1518 to 1521. In columns 1-4 the first stage outcome is a binary variable for printing any Protestant publications. In columns 5-8, the first stage outcome is a binary variable for at least 25 Protestant publications. The IV is the number of printer deaths 1508-1517. Panel B presents IV estimates where the outcomes is the adoption of a city-level Reformation law by 1554. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Panel C presents IV probit estimates. In panel C all specifications include "Firms 1498-1517" and the number of observations falls in columns 4 and 8 due to the presence of several grid cells with no identifying variation. Controls are: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Standard errors are clustered on territories (principalities) of the Holy Roman Empire or on geographic grid cells where fixed effects are introduced. Geographic grid cells are 2 degree × 3 degree (approximately 210km×210km). Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

towards younger and/or more risk taking printers or firms, which might have been more likely to print Protestant content.

We test the hypothesis that printer deaths impacted the diffusion of ideas via their impact on the age composition of firms, by constructing information on the distribution of firm age and testing whether variations in firm age across cities are associated with variations in content. We examine firm age because it is observed for all firms, whereas printer age is frequently not observed due to missing information on printers' dates of birth. We consider how several measures of firm age respond to printer deaths, and find no evidence that changes in the age distribution induced by deaths mattered for diffusion. For example, we replicate our baseline IV research design examining religious printing outcomes with changes in measures of firm age as the endogenous independent variable and printer deaths serving as the IV. For example, wee study the minimum and mean firm age at the city level. Table E5 presents our estimates and shows that induced variations in these measures of age have weak and statistically insignificant relationship to the diffusion of Protestant ideas, that the first stage is insignificant, and that the point estimates are indeed positive (i.e. cities with shifts towards older firms printed slightly *more* religious content).

E.9 Robustness of Results to Alternate Measure of Firms

Our baseline evidence on firms is from (Reske 2007). In this section we present results using the alternate measure of firms constructed from publications data. These estimates show that our results are robust to using the alternate measure of firms. Table E6 shows that the relationship between initial 1508-1517 the number of firms and the subsequent diffusion of Protestantism strengthens when we use the alternate biographical measure as the explanatory variable or as an instrumental variable (IV) for the measure of firms from publications. Because the publications data includes a fringe of very small producers on whom biographical data does not exist, this suggests that the important variation is not induced by minor printers who appear in just a few book inscriptions, but by variation in the number of more substantial firms. The measure of firms from publications is likely to be noisy for two principal reasons. First, there are a few people named on the front pages of individual books whom it seems unlikely were ever truly independent printers. Second, because ambiguities in naming variations may lead us to treat as distinct printers differently named individuals. (Further discussion in main text and data appendix.)

Table E5: Changes in the Firm Age Distribution and Religious Printing During the Reformation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Religious Printing on Change in Mean Firm Age								
	Outcome: Protestant Publications				Outcome: Catholic Publications			
	Count	10+	25+	50+	Count	10+	25+	50+
Change Mean Firm Age	116.70	0.12	0.12	0.16	49.23*	0.19	0.21	0.04
	(139.16)	(0.08)	(0.08)	(0.12)	(25.56)	(0.20)	(0.18)	(0.04)
Observations	191	191	191	191	191	191	191	191
F Statistic on IV	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Panel B: Religious Printing on Change in Minimum Firm Age								
	Outcome: Protestant Publications				Outcome: Catholic Publications			
	Count	10+	25+	50+	Count	10+	25+	50+
Change Minimum Firm Age	90.86	0.09	0.09	0.12	38.33	0.15	0.16	0.03
	(138.41)	(0.09)	(0.09)	(0.13)	(32.36)	(0.21)	(0.20)	(0.04)
Observations	191	191	191	191	191	191	191	191
F Statistic on IV	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57

This table presents 2SLS estimates of relationship between measures of initial firm age and post-1517 religious publication, using printer deaths as the instrument for measure of firm age. Panel A studies variation in religious publication driven by changes in mean firm age induced by printer deaths. Columns 1 and 5 examine count outcomes: the number of publications (Protestant or Catholic). Columns 2-4 and 6-8 examine binary outcomes recording whether the number of religious publications crosses designated thresholds. Panel B studies variation in religious publiation driven by changes in minimum firm age induced by printer deaths. "Change in Minimum Firm Age" and "Change in Mean Firm Age" are the changes in minimum firm age between 1498-1507 and 1508-1517. All specifications control for the number of firms active 1498-1507 and for a complete set of categorical indicators for population in 1500. Additional "Controls" are as in Table 8. Standard errors reported in parentheses are clustered at the state level. Free cities are classed following the Euratlas coding as belonging to "small states" rather than as individual unique territories. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*", respectively.

Table E6: Comparing baseline and alternate measure of firms

	Ln Protestant 1518-1554			
	[1]	[2]	[3]	[4]
Firms 1508-1517 – Baseline	0.36***	0.46***		
	(0.09)	(0.11)		
Firms 1508-1517 – Evidence from Books			0.13**	0.17***
			(0.05)	(0.06)
Observations	191	191	191	191
Controls	Yes	Yes	Yes	Yes
Grid Cell Fixed Effects		Yes		Yes

This table presents regressions using our baseline measure of firms from biographical data (Reske 2007; 2015) and an alternate measures of firms constructed from printer inscriptions on historical books. All regressions use the complete set of controls from Table 8. Columns [2] and [4] introduced grid cell fixed effects for 3×2 degree grid cells. Standard errors clustered on grid cells. Significance at the 99%, 95%, and 90% levels denoted "***", "**", and "*".

E.10 Protestantism in Books Measured Continuously

In the main text, we study the relationship between printer competition and counts of religious publications, classified as either Protestant or Catholic. Our baseline analysis counts religious publications as Protestant or Catholic based on our classification of authors. We classify the authors of religious publications as Protestant (Catholic) when predicted Protestantism is 0.5 or higher (lower). Here we show that similar results hold when we study the relationship between printer competition and a continuous measure of religious content. We replicate our main analysis, aggregating measures of Protestant and Catholic publication content. However, instead of examining the count of books classified as Protestant or Catholic, we examine the total sum of Protestant and Catholic content measured continuously at the publication level. To be clear, this analysis assigns the publications of a given author the estimated classified probability of being Protestant (or Catholic). Table E7 presents estimates examining the relationship between having more than one printer and religious printing, measured continuously, and corresponds to Table 8 in the main text. Table E8 presents estimates examining how variation in the number of firms relates to religious printing and corresponds to Table 9 in the main text. Our results are broadly consistent with the main text findings. We find that: printer competition was associated with more religious output; the point estimates for Protestant content are somewhat stronger than for Catholic; and the magnitudes are similar to our baseline estimates. However, in some specifications, the results for Catholic-type content are slightly larger using the continuous measure than using our baseline classification, and the Protestant estimates are slightly smaller than in the baseline. The example of Martin

Luther's output may help explain why this is the case. Our classifier finds that Luther's language is approximately 95% Protestant and 5% Catholic. When we examine the continuous measure of content, 5% of Luther's book content is considered as Catholic-type content, and only 95% as Protestant-type content. Given the overall quantative dominance of Protestant printing, an implication is that the continuous measure will lead to a net increase in Catholic content quasi-mechanically. We acknowledge that arguments can be made for studying the continuous measure of content. However, most religious writers were unambiguously partisans of Protestantism or Catholicism, even when their language shared some features with that of their opponents. Our baseline classification strategy reflects this fact.

E.11 Potential Interactions Between Printer Competition and Initial Political Institutions

Our analysis focuses on how variation in competition among printers just before the Reformation shaped the subsequent diffusion of Protestant media at the city-level. A natural question is whether the implications of competition in the media varied with the *ex ante* institutional environment.

Historical research on the role of potential institutional heterogeneity in the diffusion of the Reformation has focused on the role of "free and imperial cities." Under the constitution of the Holy Roman Empire, free cities were jurisdictionally subject to the emperor and thus not subject to a local prince. In contrast, "territorial cities" (like Wittenberg) were *de jure* subject to a regional prince. Moeller (1972) famously argued that free cities were key early centers for the development and reception of Protestant ideas, and that free cities played a lead role in the diffusion process. Subsequent research has shown that Protestantism also diffused rapidly in territorial cities (Hamm 1994; Rüth 1991). Indeed, as we indicate in the main text, narrative evidence indicates that territorial cities enjoyed substantive and extensive forms of jurisdictional autonomy that made them locations where the Reformation could and did emerge, including in Wittenberg (Whaley 2011). That said, the argument in Moeller (1972) strongly suggests that free cities had features, over and above printing, that facilitated the spread of Protestantism. Related research points to the fact political decentralization varied across regions. For example, Brady (1985) examines the *prospect* of cities achieving even greater autonomy and figuratively "turning Swiss", especially when near to the subset of free cities clustered in what is now Switzerland.

The historical literature invites two key questions that relate to our larger interpreta-

Table E7: Competition Before 1517 and Religious Content During the Reformation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Protestant Publications 1518-1554								
	Count Protestant		Binary: Protestant Count Crosses Threshold					
	Count	Count	10+	10+	25+	25+	50+	50+
Indicator: Any Printers Before	11.71	-5.27	0.18	0.21*	0.18	0.21*	0.16*	0.17*
	(31.60)	(33.82)	(0.12)	(0.11)	(0.12)	(0.11)	(0.09)	(0.10)
Indicator: 2+ Printers Before	226.75	251.04	0.22	0.26**	0.23**	0.28***	0.19	0.21*
	(186.60)	(200.05)	(0.14)	(0.12)	(0.11)	(0.10)	(0.13)	(0.12)
Observations	191	191	191	191	191	191	191	191
Panel B: Catholic Publications 1518-1554								
	Count Catholic		Binary: Catholic Count Crosses Threshold					
	Count	Count	10+	10+	25+	25+	50+	50+
Indicator: Any Printers Before	-6.95	-4.48	0.11	0.13	0.08	0.09	0.07	0.08
	(12.58)	(13.28)	(0.12)	(0.10)	(0.12)	(0.13)	(0.09)	(0.11)
Indicator: 2+ Printers Before	16.78	16.44	0.24*	0.29**	0.06	0.09	0.06	0.07
	(15.82)	(16.85)	(0.12)	(0.11)	(0.15)	(0.13)	(0.10)	(0.09)
Observations	191	191	191	191	191	191	191	191
Geographic Grid Cell Fixed Effect		Yes		Yes		Yes		Yes

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Indicator: Any Printers Before" is an indicator for cities with any firms active 1508-1517. "Indicator: 2+ Printers Before" is an indicator for cities with multiple firms active 1508-1517. Panel A presents studies Protestant printing. Panel B studies Catholic printing. In columns (1) and (2) the outcome is the sum of book-level classification probabilities for Protestant or Catholic. Outcomes are modelled using OLS. In columns (3) to (8) the outcome is an indicator for the sum of classified religious content (probabilities) crossing designated thresholds and regressions are OLS. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Specifications with geographic fixed effects include fixed effects for 210×210 kilometer grid cells. Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "Protestant − Catholic difference: 2+ Printers" designates tests of the hypothesis that the estimated effects of variation in "Indicator: 2+ Printers" are the same for Protestant and Catholic publication outcomes. The p-value "count outcome" reports p-values testing the equality of the reported estimates for "Indicator: 2+ Printers Before" when the outcome is (i) Protestant publications and (ii) Catholic publications. The p-value labelled "normalized count outcome" reports the same test results examining otherwise identical regression estimates in which the outcome is the normalized count Protestant or Catholic publications. Normalized counts are demeaned and divided by the standard error for a given type of religious publication.

Table E8: OLS and IV Analysis of Competition and Religious Publications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Protestant Publications 1518-1554								
	OLS				IV			
	Outcome: Count or Binary				Outcome: Count or Binary			
	Count	10+	25+	50+	Count	10+	25+	50+
Number of Printers Pre-Reformation	33.31*	0.06**	0.06**	0.05	125.73**	0.12*	0.12*	0.19***
	(18.01)	(0.02)	(0.03)	(0.03)	(56.12)	(0.06)	(0.07)	(0.07)
Observations	191	191	191	191	191	191	191	191
Panel B: Catholic Publications 1518-1554								
	OLS				IV			
	Outcome: Count or Binary				Outcome: Count or Binary			
	Count	10+	25+	50+	Count	10+	25+	50+
Number of Printers Pre-Reformation	18.20*	0.05*	0.01	0.03	64.43**	0.10*	0.25***	0.27***
	(10.26)	(0.03)	(0.04)	(0.03)	(25.96)	(0.06)	(0.09)	(0.07)
Observations	191	191	191	191	191	191	191	191
Panel C: First Stage for IV								
					Outcome: Firms Pre-Reformation			
Printer Deaths 1508-1517					0.99***	0.99***	0.99***	0.99***
					(0.14)	(0.14)	(0.14)	(0.14)
F Statistic on IV					52.50	52.50	52.50	52.50
Observations					191	191	191	191
Printer Deaths 1508-1517					9	9	9	9

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Number of Printers Pre-Reformation" is the count of firms active 1508-1517. Panel A presents studies Protestant printing. Panel B studies Catholic printing. In columns (1) and (5) the outcome is the number of books classified as Protestant or Catholc. In all other columns, the outcome is an indicator for the number of publications crossing designated thresholds. Panel C presents first-stage estimates for the IV. The outcome is the number of firms pre-Reformation. The IV is the number of printer deaths 1508-1517. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. IV estimates additionally control for the lagged number of firms active (firms active 1498-1507). Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "Protestant − Catholic difference" designates tests of the hypothesis that the estimated effects of variation in "Number of Printers Pre-Reformation" are the same for Protestant and Catholic publication outcomes. The p-value labelled "count outcome" reports p-values testing the equality of the reported estimates when the outcome is (i) Protestant publications and (ii) Catholic publications. The p-value labelled "normalized count outcome" reports the same test results examining otherwise identical regression estimates in which the outcome is the normalized count Protestant or Catholic publications. Normalized counts are demeaned and divided by the standard error for a given type of religious publication.

tion of the role of printing. The first concerns how competition in printing interacted with a city's own pre-existing institutions to influence the diffusion of the Reformation. The second concerns whether and how competition in printing interacted with pre-existing regional institutions and regional decentralization.

Our findings indicating that economic competition among printers fostered the diffusion of radical ideas invite a question about the role of pre-existing city-level institutions. We specifically argue that economic competition among printers mattered because it promoted the diffusion of ideas that otherwise faced barriers to entry in 1500s Germany, and in our econometric analysis control for pre-existing institutions including free city status. A natural next question is whether the competition effects are indeed stronger in cities where political and institutional barriers were otherwise higher. We test this by examining whether competition mattered *more* in cities where the institutional environment may have been otherwise somewhat less favorable to the diffusion of a new religion, i.e. in the territorial cities. Equivalently, our first question is whether economic competition had a *weaker* relationship to printing outcomes where the barriers to religious innovation were lower, i.e. in free cities.

Our historical analysis suggests that city-level factors were critical in the diffusion of the Reformation but leaves open a question concerning whether economic competition may have interacted with regional factors. The political decentralization of Germany is widely viewed as having contributed to the diffusion of the Reformation (Pettegree 2015). This motivates our second question: did economic competition in the local media matter more or less in *regions* where political decentralization was greater? The relationship here is theoretically ambiguous. To the extent the city-level factors were critical and autonomous, we might not expect city-level factors to interact with regional factors. However, it is natural to wonder whether regional factors may have mattered in a manner similar to that suggested for city-level factors. We thus investigate whether city-level competition among printers had different implications in *regions* that were more decentralized, and specifically in regions in which more cities had free imperial status.

To answer these questions, we estimate regressions of the form:

$$publications_i = \alpha competition_i + \beta(competition_i \times inst_i) + \phi inst_i + \epsilon_i \qquad (28)$$

We examine two measures of institutions ($inst_i$). We first examine the differential implications of competition in cities that were free cities. We then investigate the potential differential implications of competition for cities in areas with many free cities. We operationalize this by calculating the number of free cities within 100 kilometers of any given city. We then study whether the relationship between printer competition and publishing

outcomes is different for cities in areas with above median number of free imperial neighbors, which we heuristically call "decentralized areas." To be clear, the free cities were clustered in space: most notably in Southwest Germany and the Swiss Confederation, but also along the Rhine, and in Northern Germany. In effect, our analysis asks whether printer competition had different implications in cities in these more decentralized parts of the Holy Roman Empire. We examine how Protestant publications vary with competition and these interactions in regression models that otherwise replicate specifications from Tables 8 and 9. We emphasize that what is new here is our examination of the interactions: all our baseline estimates control for the direct of free city status on outcomes. It is also important to be clear here that 148 of the 191 cities that we study were territorial cities (i.e. 77 percent). Only 43 were free cities.

Table E9 presents our results examining the differential impact of competition in free cities. We find that the relationship between printer competition and the publication of Protestant books was weaker in free cities. When we compare cities with competition and cities with multiple firms the direct effect of competition shared among all cities is much larger than in our baseline results where we do not disaggregate: the differential effect of competition in free cities is negative, large, and becomes statistically significant for higher output thresholds. When we study variation in the number of firms competing, the direct effect common across all cities is again substantially larger than in our baseline analyses, while the differential effect of variation in the number of firms is negative for free cities. In all specifications, we find that the direct effect of being a free city was positive but relatively modest in magnitude and imprecisely estimated.

These results examining the interaction between printer competition and city institutions suggestive correlations. Our results suggest that printer competition may have been particularly salient in territorial cities, which arguably were characterized less comprehensive forms of municipal autonomy. While we interpret these results modestly, they are consistent with economic competition in the media being all the more important where political freedoms were more limited. Relatedly, we observe that the direct effect of free city status was, indeed, positive but that the estimates of this direct effect are both small in magnitude and imprecisely estimated, conditional on other observables.

Table E10 presents our estimates examining the interaction between printer competition and regional political decentralization. These estimates suggest much more limited if any interaction between printer competition and regional factors. This is not surprising given the salience of city-level factors in shaping the diffusion of the Reformation. That said, when we examine the implications of having more than one firm, we find some limited evidence that the differential effect for cities in more decentralized areas is

Table E9: Interaction between Printer Competition and City-Level Institutions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome: Protestant Publications 1518-1554								
	Protestant	Binary: Count Threshold			Protestant	Binary: Count Threshold		
	Count	10+	25+	50+	Count	10+	25+	50+
Any Printers	13.30	0.22*	0.29**	0.15*				
	(35.19)	(0.12)	(0.11)	(0.08)				
2+ Printers	371.44	0.28	0.42***	0.49***				
	(308.70)	(0.17)	(0.12)	(0.13)				
2+ Printers × Free City	-261.00	-0.16	-0.39**	-0.34**				
	(250.17)	(0.15)	(0.15)	(0.14)				
Number of Printers					59.82	0.12***	0.18***	0.17***
					(42.54)	(0.04)	(0.04)	(0.04)
Number of Printers × Free City					-30.52	-0.08***	-0.12***	-0.10***
					(29.40)	(0.03)	(0.02)	(0.02)
Free City	28.23	0.05	0.01	0.04	30.64	0.09	0.05	0.07
	(35.81)	(0.08)	(0.07)	(0.06)	(36.37)	(0.08)	(0.07)	(0.05)
Observations	191	191	191	191	191	191	191	191
p-Value Competition for Free City	0.25	0.41	0.78	0.17	0.11	0.10	0.06	0.04

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Any Printers Before" is an indicator for cities with any firms active 1508-1517. "2+ Printers" is an indicator for cities with multiple firms active 1508-1517. "2+ Printers × Free City" interacts indicators for multiple firms and for free city status. "Number of Printers" is the number of firms active 1508-1517. Outcomes are modelled using OLS. In columns (2) to (4) and (6) to (9) the outcome is an indicator for the number of publications crossing designated thresholds and regressions are OLS. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "p-value: Competition for Free City" is the p-value on the sum of the direct competition effect and the free city interaction, where the direct competition effect is either "2+ Printers" or "Number of Printers".

negative but imprecisely estimated (columns 1-4). At a high level this is consistent with our findings on competition in territorial cities themselves: here our results indicate that where *regional* political decentralization was more pronounced, the relationship between competition in printing and output was on net weaker. While our interpretation is again modest, this is consistent with economic competition mattering somewhat more in regions where the political autonomy of municipalities was in general more limited. When we examine variation in the number of firms, our findings concerning the differential variation explained by competition in cities located in decentralized regions are even weaker and more mixed.[88]

E.12 Graphical Summary of Printer Competition and Protestant Printing

The main text presents estimates examining the relationship between measures of printer competition before the Reformation and subsequent religious printing. This subsection provides a graphical summary of the analysis. We plot measures of residual Protestant media against our two measures of printer competition: the number of printers and, separately, indicators for cities with zero, one, or multiple (2+) printers. We estimate a residual for each measure of Protestant publication outcomes that we examine in the paper: the count of Protestant publications; the log of the count of Protestant publications plus one; and indicators for at least 10, 25, and 50 Protestant publications. For each of these measures of publication outcomes, we estimate residuals by regressing the outcome on the complete set of control variables in the baseline analysis, except our measures of printer competition. We then plot the residuals against our measures of printer competition.

Figure E5 presents this summary of the evidence. This figure illustrates that the positive relationship between printer competition and Protestant publication is not driven by the three cities with more than 10 printers. One of these cities was Cologne, in which the city council was motivated to oppose Protestantism for economic reasons and was exceptional in its success in suppressing Reformation activism (Scribner 1976). Cologne remained Catholic. Absent Cologne, the positive relationship between measures of printer competition and Protestant printing would be even stronger.

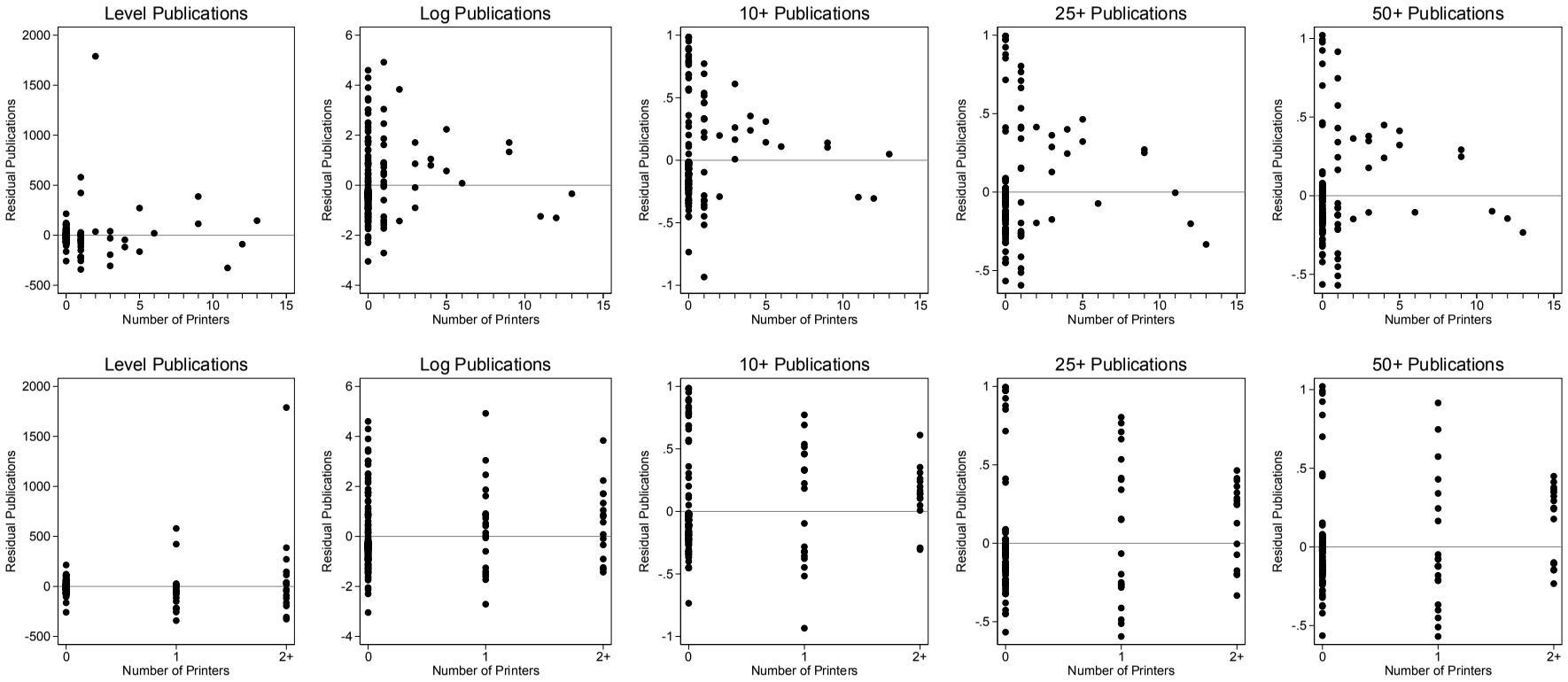
[88] We acknowledge that these results reflect one *proxy* measure of political decentralization, but find similarly modest evidence for any regional interactions when we examine other proxies.

Table E10: Interaction between Printer Competition and Regional Decentralization

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome: Protestant Publications 1518-1554								
	Protestant	Binary: Count Threshold			Protestant	Binary: Count Threshold		
	Count	10+	25+	50+	Count	10+	25+	50+
Any Printers	8.82	0.21*	0.30**	0.15*				
	(37.51)	(0.12)	(0.11)	(0.09)				
2+ Printers	369.58	0.25*	0.33**	0.40***				
	(345.30)	(0.14)	(0.13)	(0.13)				
2+ Printers × Decentralized	-225.27	-0.08	-0.19*	-0.15				
	(293.87)	(0.14)	(0.11)	(0.10)				
Number of Printers					42.14	0.05	0.10**	0.09*
					(31.68)	(0.04)	(0.05)	(0.05)
Number of Printers × Decentralized					-55.41	0.03	-0.13	-0.03
					(129.77)	(0.18)	(0.16)	(0.15)
Decentralized	21.56	0.01	-0.00	-0.00	3.50	0.01	-0.00	-0.01
	(20.86)	(0.07)	(0.04)	(0.05)	(29.47)	(0.07)	(0.05)	(0.05)
Observations	191	191	191	191	191	191	191	191
p-value: Competition for Decentralized	0.24	0.12	0.00	0.00	0.17	0.01	0.00	0.00

This table presents regression estimates of the relationship between the structure of city printing before the Reformation and the production of religious media during the Reformation. "Any Printers Before" is an indicator for cities with any firms active 1508-1517. "2+ Printers" is an indicator for cities with multiple firms active 1508-1517. "2+ Printers × Decentralized" interacts indicators for multiple firms and for cities in decentralized regions, measured with an indicator for having above median number of free cities within 100 km ("Decentralized"). "Number of Printers" is the number of firms active 1508-1517. Outcomes are modelled using OLS. In columns (2) to (4) and (6) to (9) the outcome is an indicator for the number of publications crossing designated thresholds and regressions are OLS. All specifications control for: Latin Media pre-1517 and Vernacular Media pre-1517 measured in hundreds of titles; Religious Media pre-1517 measured as the share of titles on religious topics; distance to Wittenberg measured in hundreds of kilometers; indicators for Hansa cities, ecclesiastical rule cities, prince bishroprics, cities on navigable rivers, and cities ever printing pre-1517. Population in 1500 is controlled for with fixed effects for bins: unknown (omitted), 1000-5000, 6000-1000, 11000-25000, 26000+. Standard errors are clustered on historic territories (principalities) of the Holy Roman Empire (see Appendix A). Statistical significance denoted * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. "p-value: Competition for Decentralized" is the p-value on the sum of the direct competition effect and the decentralized interaction, where the direct competition effect is either "2+ Printers" or "Number of Printers".

Figure E5: Protestant Publications and Printer Competition



This graph presents evidence on the relationship between measures of residual Protestant publications and printer competition. Residual Protestant publications are estimated by regressing Protestant publication outcomes on the complete set of controls from the baseline analysis. The measures of Protestant publications are: the count ("Level Publications"); the log of the count plus one ("Log Publications"); and indicators for at least 10, at least 25, and at least 50 Protestant publications ("10+ Publications", "25+ Publications", and "50+ Publications", respectively). Printer competition is measured by the number of printers before the Reformation or by indicators that categorize cities as having zero, one, or at least two printers before the Reformation.

E.13 The Price of Religious Pamphlets

This subsection provides evidence on the prices for religious pamphlets. In the early 1520s, a typical pamphlet of 32 pages cost approximately 1/3 of the daily wage for an artisan, equivalent to the price of a hen or 1 kg of beef (Edwards 1994). Table E11 presents transaction prices for a number of Protestant publications in our data. This data are consistent with the prices recorded for pamphlets in the Colón data.

E.14 The Role of Reprinting in the Transmission of Religious Publications

While religious publications were traded and transported between cities, transport costs were sufficiently high that print media typically spread through reprinting rather than inter-city trade: "with shipping overland expensive and printing relatively cheap, a work generally spread by reprinting" (Edwards 1994; p. 8). Because high transport costs limited trade, historians observe that local production provides a measure of local exposure to content (Edwards 1988; 1994).

The evidence in our database on the locations in which publications were printed supports view that transport costs led to reprinting. In Appendix E.13 we present price data from market transactions involving a number of religious pamphlets in our data. In the price data, we observe the purchase of publication by Johannes Bugenhagen, who worked on the team with Luther that translated the Bible into German and who wrote the city Reformation laws for Hamburg, Braunschweig, and Lübeck. In the price data we observe the purchase of a pamphlet by Bugenhagen in 1525 (*Ein sendbrief uber eyne frage vom Sacrament*). In 1525, this publication was independently printed in Erfurt, Altenburg, Wittenberg, Nürnberg, Speyer, and Augsburg. Erfurt and Altenburg are approximately 115 kilometers apart. Nürnberg and Augsburg are less than 150 kilometers apart. Erfurt and Wittenberg are approximately 200 kilometers apart by road. Similar patterns of reprinting are observed for other religious publications in our data. In 1518, Martin Luther's pamphlet on indulgences (*Ein sermon von dem Ablaß und gnade*) was published in Augsburg and Nürnberg (150 kilometers), Wittenberg and Leipzig (75 kilometers), as well as in Brauschweig (175 kilometers from Wittenberg), and Basel.

Table E11: Market Prices for Protestant Media

Author	Title	Year	Price in Pfennig	Price in Daily Wage
Staupitz, Johann von	Ein nutzbarliches bchlein von der entlichen volziehung ewiger fuersehung	1517	8	0.33
Luther, Martin	Eyn sendbrieff an den Bapst Leo. den czehenden	1521	3	0.13
Wittenberg - Rat	Newe ordnung der stat Wittenberg. M.D.XXII. jar. Des newen Bischoffs zu der Lochaw verhor und disputation vor dem Bischof von Meissen	1522	3	0.13
Anonymous	Ernstlich handlung der Universitet zu Wittenberg an den durchlechtigsten hochgebornen Churfürsten und Herren. Hertzug Friderich von Sachsen, die Mesz betreffendt	1522	4	0.17
Hutten, Ulrich von	Ein clagschrift des hochberuemten und eernuesten Herrn Ulrichs von hutten gekroeneten poeten und orator an alle Stend Deütscher nation	1520	3	0.13
Luther, Martin	Warum des Papstes und seiner Jünger Bücher verbrannt	1521	3	0.13
Rhegius, Urbanus	Anzaygung dasz die Romisch bull mercklichen schaden in gewissin Manicher menschen gebracht hab und nit Doctor Luthers leer	1522	8	0.33
Luther, Martin	Von den newen eckischen bullen und luegen	1521	3	0.13
Bugenhagen, Johann	Ein sendbrief uber eyne frage vom Sacrament. Item eyn unterricht von der beycht und Christlichen absolution	1525	1	0.04
Sickingen, Franz von	Ein sendbrieff so der edel und ernuest Franciscus von Sickingen seinem schweher dem edlen unnd ernuesten iuncker diethern von henschuchheym zu underrichtung etzlicher artickel Christliches glaubens kürtzlingen zugeschickt hadt.	1522	3	0.13
Hutten, Ulrich von	Vormanung an die freien uund Reich Stette Teutscher nation	1522	2	0.08
Anonymous	Der Ritterschafft, brderliche vereynigug, geselschafft oder verstentnu jüngst zu Landaw fürnemlich Gott zu lob unnd dann folgendt merung gemeynes nutz auch frderung fridens und rechtenßuffgricht.	1522	2	0.08
Anonymous	Artickel und ursprung der waldenser: und der armen von Lugdun auch Joannis wicleffen und Joannis hussen.	1523	3	0.13

Prices from Martin Brecht, "Kaufpreis und Kaufdaten Einiger Reformationsschriften," *Gutenberg Jahrbuch* (1972, pp. 169-173). We take 24 Pfennigs as the daily wage of an artisan following Edwards (1994).

F Transport Costs and Exposure to Trade

In this section we present additional historical evidence on the determinants of transport costs and investigate whether the implications of local competition varied with exposure to inter-city trade.

Historical Evidence

The inter-city trade in print media faced significant cost barriers. Transport was generically costly in early modern Europe. Print media were in addition both heavy and susceptible to damage due to water and humidity (Dittmar 2011). Even on rivers, weather could impose significant transpost costs. For example, "ice on the rivers and flooding often affected transport arrangements, and much confusion resulted" (Flood 2010; p. 325). Travel by sea was faster but also posed risks to book cargos: Hernando Colón, whose book purchases we study, experienced the loss in transport of almost 1,000 books that he attempted to ship via sea back to Sevilla in the early 1500s (Dondi 2010). Sometimes weather interacted with other factors to take a toll on the intercity book trade. This is indicated by the experience of the great Nürnberg printer Anton Koberger, publisher of the famous *Nürnberg Chronicle* (*Liber Chronicarum*, 1493), when he attempted to transport a consignment of books through Bad Wimpfen, 150 kilometers from Nürnberg. In 1506, Koberger wrote a letter to a fellow businessman in which he described the fate of this consignment:

> "I am sorry to say that when the carrier came via Wimpfen, he was waylaid. The robbers led the carrier together with the wagon off the road into a wood where they broke into the barrels and looked for money. Later it rained and half the books in the three barrels were drenched and damaged. There went my profit." (Quoted in Flood 2010; p. 332)

Historians observe that due to the magnitude of transport costs, local production provides a measure of local exposure to content (Edwards 1988; 1994). Transport costs were sufficiently high that print media typically spread through reprinting rather than inter-city trade (Edwards 1994; p. 8). Outside printing cities, information on the range of available print media was incomplete and many books were not offered for sale, implying high shadow prices. Flood (1998; p. 55) observes that during the Reformation, "Outside the towns where books were printed or which were main centers of the burgeoning book trade the public were dependent on what itinerant traders offered them and on word of mouth." During the reformation, pamphlets in particular were typically printed in the market where they were to be sold and not for export (Pettegree 2000).

Exposure to Trade, Printer Competition, and Book Markets

A. Motivation for analysis

Our baseline analyses in the main text show that local competition mattered for prices and quanties. We find that when competition increased in a city, prices fell and the number of different books printed rose in that city (Tables 5, Table 6). These findings indicate that local competition mattered for behavior.

Here we consider a related question that helps us interpret the nature of competition in printing: did competition and printer behavior interact with inter-city trade? In particular, we investigate whether the impact of local competition on behavior varied with a city's exposure to trade.

To address this question, we test whether the positive relationship between competition and quantities, and the negative relationship between competition and prices, held for cities that were close to other printing cities. We use measures of a given city's proximity to other printing cities as proxies for that city's exposure to the inter-city trade in books. We thus investigate potential heterogeneity in how a given level of observed local competition – proxied for by the number of printers in a given city – maps into market outcomes and behavior.

We find that variation in local competition is a large and highly significant predictor of outcomes in book markets even for cities exposed to trade. We show this by investigating the relationship between competition and outcomes for cities located very close to other cities with printing, e.g. within 50 or 100 kilometers, as shown below.

B. Interpretive implications

The potential interpretive implications of the interaction between printer competition and trade motivate our empirical tests. Significantly, our characterization of competition, in which collusion was prevalent, and an alternative interpretation in which collusion was not salient, may imply different predictions concerning the *interaction* between city industrial organization and inter-city trade.

Suppose collusive behavior among printers within cities was not important. Absent collusion, variation in local industrial organization would potentially be less salient for more "open" cities. Intuitively, a city with an apparent local monopoly or multi-firm oligopoly could, due to its openness to trade, be a location with more competitive conduct. In this case, we would predict that the mapping between local industrial organization and outcomes would be weaker in cities more exposed to trade.

Suppose instead collusive behavior among local printers was prevalent. Cartels generically face challenges in (1) monitoring behavior and deterring defection from the collusive equilibrium; (2) selecting and coordinating the behavior of cooperating firms; and (3) preventing entry and expansion by non-cartel firms (Levenstein and Suslow 2006). Monitoring was relatively easy in printing: output was highly differentiated, printers identified themselves on books, and the social world of printing was small (Febvre and Martin 1958). The challenge of preventing entry and expansion by non-cartel firms, and perhaps indirectly the challenge of coordinating behavior within the cartel, may have increased with trade. Indeed, under collusion the mapping between variation in industrial organization and outcomes could be *stronger* for cities more exposed to trade. This would reflect the fact that the ability to maintain a collusive equilibrium would decline more rapidly in the number of local printers where the exposure to trade expanded the size of the competitive "fringe" outside the cartel.[89]

To fix ideas consider a simple model. Assume that all printers in a given city are potential participants in a collusive arrangement, i.e. "cooperators." Assume that where it is active, the inter-city book trade has an effect equivalent to adding one non-cooperative printer to local industrial organization, a foreign "never cooperator." This formulation invites a natural question we can test in the data: Is there a difference in how the number of potential cooperators translates into price and quantity outcomes when we compare settings with and without the presence of a foreign "never cooperator."

C. Empirical tests and results

We investigate how differences in exposure to inter-city trade shaped the relationship between local industrial organization and outcomes in local book markets. We use a city's proximity to other cities with printing as a measure of potential exposure to inter-city trade. We use the number of printers active in a city as a measure of industrial organization and competition.

We first test whether the relationship between local market structure and prices was different in cities that were close to other cities with printing. We examine the book price data and estimate regressions of the form:

$$p_{ijt} = \beta competition_{jt} + \phi(competition_{jt} \times close_{jt}) + \theta_{j,decade} + \lambda distance_i + \gamma X_i + \epsilon_{ijt}$$

[89] We emphasize that the theory of oligoply and cartels provides what Tirole has termed an "embarassment of riches," accomodating a large set of behavioral predictions, and acknowledge that our discussion is suggestive rather than definitive. Stronger behavioral responses to variation in competition in more trade-exposed cities, could reflect differential incentives to punish defection in these locations or the greater precarity of cartels exposed to competition from the outside.

where p_{ijt} is the logarithm of the price of book i purchased in city j at year t and $competition_{jt}$ records the number of printers active in this city-year. Proximity to another city with printing is measured by $close_{jt}$, an indicator which takes the value of 1 if another printing city is within 50 km or 100 km. The $\theta_{j,decade}$ are city-decade fixed effects and $distance_i$ is the logarithm of distance in kilometers between the city where the book was purchased and the city where it was printed plus one. The X_i are book characteristics including: indicators for whether a book was printed in another city, book format (folio, quarto, octavo, or other), illustrations, multicolor ink, and 37 content categories; the number of number of pages and book age. We extend the analysis to examine the variation in price associated with the transition from monopoly to competition, and the relationship between prices and printer deaths, which had implications for local competition that we examine in detail below. Our design can be understood as providing reduced form evidence on (1) how inter-city trade shaped competitive conduct and (2) how and why industrial organization influenced competition and ultimately outcomes.

Table F1 presents our estimates and indicates that the relationship between industrial organization and prices is *stronger* for cities close to other printing cities. Generically, when the number of printers increases, prices fall significantly. An additional printer is associated with a 25 percent decline in book prices within a city-decade, controlling for book characteristics (column 1). This is our baseline estimate from the main text. When we examine the implications of being within 50 kilometers of a neighboring city with printing, we find that (1) the common effect of an additional printer shared across all cities is -0.20 and (2) the additional effect of an additional printer in a city close to another city with printing is -0.25 (column 2). This incremental effect is highly significant and indicates that the effect of an additional printer in cities exposed to this proxy for trade is a price decline of approximately 45 percent within city-decades.

We also investigate whether exposure to intercity trade shifted the manner in which industrial organization mapped into the number of different publications printed in a city. We test whether variation in industrial organization had a stronger or weaker relationship for cities that were more exposed to intercity trade due to their proximity to neighboring cities with printing. We estimate regressions that parallel the above, but examine city-year level data on publications as in our baseline analysis in the main text. We estimate regressions:

$$publications_{jt} = \beta competition_{jt} + \phi(competition_{jt} \times close_{jt}) + \theta_{j,decade} + \epsilon_{jt}$$

Table F2 presents our results and shows broadly similar results. We find that variation in competition predicts publication outcomes for cities near other printing cities. We find

Table F1: Printer Competition, Intercity Trade, and Book Prices

	(1)	(2)	(3)
	Outcome: Ln Price		
Number of Printers	-0.25***	-0.20***	-0.21***
	(0.07)	(0.04)	(0.04)
Number of Printers × Printing in 50 km		-0.25***	
		(0.07)	
Number of Printers × Printing in 100 km			-0.18**
			(0.07)
Ln Transport Distance	0.36***	0.36***	0.36***
	(0.08)	(0.08)	(0.08)
City-Decade Fixed Effects	Yes	Yes	Yes
Book Characteristics	Yes	Yes	Yes
Observations	2035	2035	2035
With Variation	1168	1168	1168

This table presents regression estimates examining book prices in the Cólon data. "Number of Printers" is the count of printers active in a city-year (the publications measure from book inscriptions). "Printing in 50 km" and "Printing in 100 km" are indicators for the presence of another city with printing within 50 or 100 kilometers. "Book characteristics" comprise: log number of pages; age of book measured in years since publication; indicators for format (folio, quarto, octavo), multicolor ink, illustrations, and for books not subject to intercity trade (i.e. purchased where printed); and fixed effects for 37 types of book content. Standard errors clustered by city-decade. Statistical significance at the 90, 95, and 99 percent confidence interval denoted "*", "**", "***". "With Variation" reports the number of data points with variation in "Number of Printers" within city-decades. For the 1168 observations with within city-decade variation, the mean of "City Printing within 50 km" is 0.26 and the mean of "City Printing within 100 km" is 0.31.

no significant difference in the relationship between the number of firms and the number of publications for cities more exposed to trade (columns 2 and 3). However, the point estimates for this difference are positive, consistent with the price evidence above. We find a positive and borderline significant difference in how the transition from monopoly to competition translated into publication outcomes for cities with printing neighbors within 50 kilometers, i.e. those most exposed to trade (column 5). This positive effect becomes weaker and insignificant when we examine proxy for trade exposure using 100 kilometer distance as our threshold (column 6). These results confirm that competition was related to publication outcomes in cities where potential competition from imported books was most likely. While weaker than our price results above, this evidence on quantities suggests that variation in the number of firms active may have mapped somewhat more sharply into changes in competitive conduct precisely where trade was most salient.

While we emphasize that our evidence is only suggestive, these findings (1) confirm that variation in competition explains behavior even in the cities that were the most strongly exposed to inter-city trade and (2) are consistent with historical evidence indicating the importance and fragility of collusion in printing.

Table F2: Competition, Intercity Trade, and Publications

	(1)	(2)	(3)	(5)	(5)	(6)
	Outcome: Publications					
Number of Printers	2.68***	2.65***	2.59***			
	(0.44)	(0.45)	(0.46)			
Firms × Printing in 50 km		0.14				
		(0.22)				
Firms × Printing in 100 km			0.12			
			(0.15)			
Any Printers				2.12***	2.02***	1.84***
				(0.12)	(0.15)	(0.26)
2+ Printers				2.13***	1.62***	1.53**
				(0.19)	(0.32)	(0.74)
Any Printers × Printing in 50 km					0.23	
					(0.24)	
2 + Printers × Printing in 50 km					1.24*	
					(0.66)	
Any Printers × Printing in 100 km						0.36
						(0.32)
2 + Printers × Printing in 100 km						0.79
						(0.95)
City-Decade Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21439	21439	21439	21439	21439	21439

This table presents regression estimates examining the number of publications printed in a given city-year. "Number of Printers" is the count of printers active in a city-year (the publications measure from book inscriptions). "Printing in 50 km" and "Printing in 100 km" are indicators for the presence of another city with printing within 50 or 100 kilometers. Standard errors clustered by city-decade. Statistical significance at the 90, 95, and 99 percent confidence interval denoted "*", "**", "***".

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