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Religious Tolerance as Engine of Innovation

Abstract

We argue that, for a given level of scientific knowledge, tolerance and diversity are conducive to technological creativity and innovation. In particular, we show that variations in innovation within Prussia during the second industrial revolution can be ascribed to differences in religious tolerance that developed in continental Europe from the Peace of Westphalia onwards. By matching a unique historical dataset about religious tolerance in 1,278 Prussian cities with valuable patents for the period 1877-1890, we show that higher levels of religious tolerance are strongly positively associated with innovation during the second industrial revolution. Religious tolerance is measured through population's religious diversity, diversity of churches, and diversity of preachers and religious teachers, respectively. Endogeneity issues are addressed using local variation across cities, within counties. Estimates using preindustrial levels of religious tolerance address issues of reverse causality. As for the channels of transmission, we find significant complementarity between religious tolerance and human capital. Furthermore, we find that cities with higher levels of religious tolerance attracted a larger share of migrants. Finally, higher levels of religious diversity in the population translated into higher levels of religious diversity in the workforce by industrial sector. This result suggests that religious diversity did not generate labor market segmentation by denomination but might have fostered interaction of different denominations.

JEL-Codes: N130, N330, O140, O310, Z120.

Keywords: tolerance, openness, pluralism, diversity, innovation, patenting activity.

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1 Introduction

A culture of tolerance is key for the adoption and production of new ideas and for technological creativity. For a given level of scientific knowledge available, traditional societies closed to new ideas and progress will tend to be less creative. As argued by Mokyr (1990, p. 11-12), a society needs to meet three criteria to be technologically creative: 1) it needs a group of ingenious and innovative people willing and able to challenge the physical environment; 2) it needs economic and social institutions to provide the right incentives to encourage such a risky activity as innovation; 3) innovation requires diversity and tolerance. This paper is about the effect of diversity and tolerance on innovation.

To better understand the process of innovation, scholars have increasingly looked at history. However, most of the literature in economics and economic history has focused on the first two points mentioned above. There is a literature that investigates the role of upper-tail human capital, or knowledge elites, in innovation and technological progress (Mokyr, 2009, 2016). The idea is that there is a small but highly educated elite exposed to new ideas through books, pamphlets, and letters. At the same time there is a group of highly-skilled craftsmen, the "tweakers and tinkerers", that practically implement the new ideas (Meisenzahl and Mokyr, 2012). Recent studies have provided empirical evidence consistent with the notion that upper-tail knowledge played an important role in innovation (Squicciarini and Voigtländer, 2015; Cinnirella and Streb, 2017; Maloney and Valencia Caicedo, 2017). Another strand of literature studies, instead, the relationship between institutions and innovation (Donges, Meier and Silva, 2017). In particular, there is a relatively large literature on the impact of patent systems on innovation (Moser, 2016, 2013). The main conclusions in this literature are not clear-cut. However, there seems to be agreement that a too strong patent protection might discourage innovation.

We are not aware of empirical studies that systematically analyze the relationship between tolerance and innovation. We aim to fill this gap in the literature by analyzing the effect of *religious tolerance* on innovation in nineteenth-century Prussia. Imperial Germany, at the end of the nineteenth century, experienced a rapid increase in technological progress and was theatre of major technological innovations in different industrial sectors (Pierenkemper and Tilly, 2004). We argue that the culture of religious tolerance and diversity that developed from the Peace of Westphalia throughout the Age of Enlightenment created a social component important for the production of breakthrough inventions during the second industrial revolution. We show that it was not a single denomination or the level of human capital embedded in a religious group that affected innovation during the second industrial revolution. Instead, it was the level of religious tolerance measured through the presence of different denominations, churches, and preachers that had a significant impact on innovation. Our research thus complements the literature on the impact of upper-tail human capital and institutions on innovation.

To address this question we have created a unique dataset of 1,278 cities in 1871 Prussia for which we know the exact religious composition of the population from the census. The religions reported in the census are five: Protestant, Catholic, other Christian religion, Jew, other or no religion. We measure the level of religious tolerance and diversity in a city through the Herfindahl index which indicates the probability of sampling two individuals of different denominations. Religious diversity as a proxy for tolerance and openness of a society has been recently used also in Akcigit, Grigsby and Nicholas (2017*b*).

We match our city dataset with 1,740 *valuable patents* granted in Prussia in the period 1877-1890. Patents, although not the optimal measure for technological creativity, is the best proxy for innovation which is available in historical context (Streb, 2016). In our case patents are a good proxy for technological creativity as Prussia was at the technological frontier in sectors, such as chemistry and electrical engineering, where scientific knowledge was crucial and secrecy (an alternative to patenting) was less effective. Finally, since we only consider valuable patents, i.e. patents that were renewed for a period of at least ten years, we are confident of measuring relevant innovation and thus technological creativity.

By exploiting variation in the religious composition of the population across cities, *within county*, we consistently find that higher levels of religious tolerance, proxied by the index of religious diversity, have a strong positive impact on innovation during the second industrial revolution. In terms of magnitude, our baseline estimates suggest that one standard deviation increase in religious diversity increases the number of valuable patents by about 13 percent. This result is conditional on the literacy rate and on the number of different denominations in the city. Our estimates suggest also a non-linear impact of religious tolerance on innovation.

Our empirical strategy is not based on quasi-natural experimental evidence as we could not find any plausible exogenous variation in institutions, geography, or culture which exclusively affect religious tolerance. Our identification is based on the assumption that the variation in religious diversity across cities and within counties is not related to any omitted variable which has a separate impact on innovation. Since we include, beyond county fixed effect, also fixed effects for the number of denominations, we only exploit variation in the *relative size* of different religious groups between city within county.

We provide further support to our main findings using also municipality-level data from the preindustrial period. Using unique data on (i) the number of churches and (ii) the number of preachers and religious teachers by denomination for a subsample of large towns in 1816, we show that higher levels of religious tolerance in 1816 are strongly positively associated with innovation during the second industrial revolution. Importantly, this result is conditional on the type of economic activity and human capital levels of the towns in 1816. We provide also evidence based on variation across counties in 1871. Through this approach we can account for spillover effects and we can exploit additional variables which allow to shed more light on potential mechanisms.

Regarding the mechanism, we provide three important results consistent with the interpretation that tolerance and diversity act as "pull" factors for high-skilled migrants. First, we unveil a strong complementarity with human capital as we find that the impact of religious tolerance on innovation increases with literacy. Second, using data on the number of people born in the city, we find that higher levels of religious tolerance are positively associated with the share of migrants in a city. This result is consistent with recent findings of Akcigit, Grigsby and Nicholas (2017*a*) and Serafinelli and Tabellini (2017). Third, by means of detailed data on the religious composition of the workforce by industrial sector in 1882, we show that higher levels of religious diversity in the population translate into higher levels of religious diversity in the workforce *by industrial sector*. This result indicates that religious tolerance and diversity does not generate religious clustering in specific industrial sectors. This set of results thus suggests high-skilled migration and interaction between denominations as potential channels.

The claim that tolerance and diversity are important determinants of innovation and economic progress has a long tradition. Mokyr (1990, p. 182), citing Goldstone (1987), argues that "technological progress requires above all tolerance toward the unfamiliar and the eccentric". Goldstone (1987, p. 127-128), speculating on the reasons of the divergence between the West and the East in the 18th and 19th century, argues that "the answer is in fact in front of our nose: some states emerged from the 17th century crises overtly tolerant of internal diversity and innovation; others were overtly and emphatically hostile to innovation". He continues: "Cultural diversity and ferment seems likely to favor innovation, and tolerance of pluralism to enhance openness to taking risks, while enforcement of a state orthodoxy seems likely to result in repetition and elaboration of old models, and hostility to innovation and risk". Cipolla (1972, p. 52), speculating on the diffusion of innovations in Europe, maintains that the qualities that make people tolerant also make them receptive to new ideas.

More recently, Mokyr (2016) described how political fragmentation and competition in Europe created a competitive market for ideas which, in turn, favored the accumulation of useful knowledge, necessary for the technological progress of the industrial revolution. He argues that in the market for ideas, one of the most successful ones that spread out in Western Europe was the idea of tolerance (Mokyr, 2016, p. 234). Analyzing the factors that led to the industrial revolution in Britain, Mokyr praises also tolerance and pluralism as characteristics that "had important economic consequences". We argue that the evolution of religious tolerance, diversity, and pluralism can explain a significant part of the technological success of Germany during the second industrial revolution.

The paper is structured as follows: Section 2 discusses the related literature; Section 3 presents a brief chronology of religious tolerance in Europe; Section 4 describes the data; Section 5 introduces our regression analysis and section 6 presents the results based on

the city-level data; Section 7 provides further evidence using data at the county level; Section 8 concludes.

2 Related literature

Our paper relates to different strands of the literature. First, it is related to the literature on the historical determinants of innovation and in particular to the literature stressing the role of knowledge elites. In the spirit of Meisenzahl and Mokyr (2012) and Mokyr (2016), Squicciarini and Voigtländer (2015) analyze the role of Enlightenment and of knowledge elites in the context of industrializing France. They find that upper-tail knowledge, proxied by subscriptions to the Encyclopédie, increased local productivity in modern innovative technology. Cinnirella and Streb (2017) use county-level data to study the role of different types of human capital on valuable patents in nineteenth century Prussia. They find that useful knowledge embodied in master craftsmen was important for independent innovation in relatively traditional sectors and that literacy levels were more related to innovation at the technological frontier especially in large firms. Also in the context of upper-tail human capital, Maloney and Valencia Caicedo (2017) show the effect of engineers on technology adoption in 1880 U.S. and the impact on modern income levels. Dittmar and Meisenzahl (2016) document that cities that adopted the Reformation and that supported public goods provision, attracted upper-tail human capital and grew significantly more in the long-run. Cantoni, Dittmar and Yuchtman (2017) analyze how the reallocation of economic resources from religious uses to secular ones during the Protestant Reformation affected Europe's political economy landscape. They argue that the reallocation of upper-tail human capital might have set in motion a process of cultural change that culminated in the Age of Enlightenment.

Akcigit, Grigsby and Nicholas (2017*b*) investigate the main determinants of innovation at the micro and macro level. In particular, they link historical U.S. patents to state and county-level aggregates and match individual inventors to censuses for the period between 1880 and 1940. Among other results, they find that states with higher population density and states more geographically connected were more inventive and that inventors were more likely to migrate to innovative states. They also test the relationship between openness of a society and innovation. As in our paper, they use the Herfindahl index of religious membership to capture religious diversity and tolerance. They do not find any strong correlation between religious diversity and patents (Akcigit, Grigsby and Nicholas, 2017*b*, p. 30).

Our paper relates also to the literature on religious cultural traits and economic outcomes. In particular, there is an expanding literature which focuses on the causes and effects of the Protestant Reformation.[1] This literature is relevant for our study as they

[1] See Becker, Pfaff and Rubin (2016) for a recent and detailed literature review.

identify several possible confounding factors that need to be taken into account to disentangle the effect of religious tolerance on innovation. Becker and Woessmann (2009) show that Protestant counties were economically more prosperous because of higher levels of literacy and not because of a different work ethic. Cantoni (2015), looking at panel variation at city level, does not find any impact of Protestantism on city growth in the Holy Roman Empire in the period between 1300-1900. Rubin (2014) shows that the spread of the printing press favored the adoption of Protestantism.[2] Hornung (2014) analyzes the long-run impact on economic productivity of the exodus of French Huguenots in Germany towards the end of the seventeenth century. He finds that cities exposed to Huguenots community had a higher productivity in textile manufactories.

Botticini and Eckstein (2012) study how investments in human capital affected the economic history of Jewish populations. Akçomak, Webbink and ter Weel (2016) show that the Brethren of the Common Life, a religious community founded in the Netherlands in the 14th century, stimulated the accumulation of human capital and thus contributed to city growth. Andersen et al. (2017) argue that "Protestant" cultural traits such as hard work and thrift were already present in the Catholic Order of Cistercians. To support their argument, they show that English counties more exposed to Cistercian monasteries experienced faster productivity growth starting from the 13th century.

Squicciarini (2017) studies the impact of Catholicism on the diffusion of technical knowledge during the second industrial revolution. She finds that more religious district tended to have lower economic development. She argues that schooling is the main mechanism as more religious areas slowed down the introduction of technical curriculum in schools pushing, instead, religious education. This result is consistent with the studies of Bénabou, Ticchi and Vindigni (2013, 2015) who find a negative relationship between religiosity and innovation using modern data. To the extent that more religious tolerance implies less religiosity, our results can be interpreted as the "inverse" of Squicciarini's results for France. Serafinelli and Tabellini (2017) analyze the process of production and attraction of creative people in Europe. They find that city institutions like autonomy and political freedom played a crucial role in the production and attraction of creative people. Consistent with the results on religiosity of Squicciarini (2017), they find that cities that host religious institutions (Bishop or Archbishop) are less likely to attract creative people.

Becker and Pascali (2016) analyze the interactions between Protestants and Catholics with the Jewish community after the Reformation. The analysis is based on the notion that Protestants and Jewish became competitors in moneylending activities after the Reformation. Their main hypothesis is that Jews lost their comparative advantage in regions that became Protestants whereas they kept their advantage in regions that remained largely Catholic. They find that (i) Jewish persecutions were more prevalent in

[2] In a previous paper Dittmar (2011) has shown the effect of the printing press on urban growth.

Protestant areas where the Jews had already established themselves as moneylenders and (ii) the Reformation reduced the specialization of Jews in the financial sector in Protestant regions but not in Catholic ones. Their results suggest that the size of the Jewish community could depend on their occupation and on the size of the other denominations. In our regression analysis we show that our results are unchanged when controlling for the share of Jews in the population and accounting for historical Jewish persecutions. Furthermore, we also show that our results are robust to the introduction of a control for employment in the financial sector.

In our paper we argue that migration constitutes an important mechanism for our results. We therefore relate also to the literature on the effects of migration and cultural diversity on economic growth.[3] Alesina, Harnoss and Rapoport (2016) use an index of diversity based on people's birthplace and find that it is positively related to economic development. Peri (2012) finds positive effects of diversity on productivity of North-American states. He argues that the positive effect of diversity is due to the immigration of unskilled workers who promote specialization. Similarly, Ottaviano and Peri (2006) find that an increase in the cultural fractionalization of cities has a positive effect on productivity. Ager and Brückner (2013) study the relationship between diversity and economic growth in historical context, namely in U.S. during the age of mass migration (1870-1920). Exploiting within-county variation they find a positive effect of fractionalization on economic growth. Sequeira, Nunn and Qian (2017) find that locations with more historical immigration have today higher economic prosperity and more innovation.

Analyzing other dimensions of diversity, Ashraf and Galor (2013*b*) show that genetic diversity, determined by the prehistoric exodus from Africa, has a persistent hump-shaped effect on comparative development. Ashraf and Galor (2013*a*) further show that genetic diversity is an important determinant of ethnolinguistic heterogeneity. Spolaore and Wacziarg (2009) argue that genetic distance works as a barrier to the diffusion of development and, thus, explains incomes differences across countries.

3 Religious tolerance in the Holy Roman Empire

The Peace of Westphalia marked the end of the Thirty Years' War (1618-48) which started as a religious war between the Roman Catholic Church and the Protestants. As Mokyr puts it: "the catastrophic bloodshed during the Thirty Years' War convinced more and more people of the merits of tolerance and pluralism" (Mokyr, 2016, p. 219). The Peace of Westphalia regulated the rights of the three major Christian denominations: Catholic, Lutheran, and Calvinist. Jews and other small Protestant churches (i.e. the Mennonites) were generally excluded from the treaty. However, some territories, due to particular circumstances, formally extended toleration to other religious groups (Whaley, 2000).

[3] See Alesina and La Ferrara (2005) for an analysis of economic costs and benefits associated with diversity.

After the Peace of Westphalia it was no longer possible for a local ruler to oblige his subjects to follow him into another church. The year 1624 was taken as "base year" (*Normaljahr*) for the state of religion and church property. Therefore minorities that enjoyed privileges in a given territory before 1624 were granted protection by Imperial law. However, minorities which had no status before 1624 were guaranteed the right to emigrate (*ius emigrandi*) without being deprived of their property.

Arguments on tolerance found fertile soil within intellectual elites that were increasingly favourable to the ideas of greater religious tolerance (Mokyr, 2016). In particular, the ideas of intellectuals such as Locke who published "A Letter Concerning Toleration" in 1689 (Marshall, 2006) and Voltaire who published the "Treatise on Tolerance" in 1763 (Voltaire, 2000) received a strong echo in Germany. By the middle of the eighteenth century, the issue of religious tolerance became central theme of Enlightenment thinking.

However, one should not overestimate the impact of intellectuals and the aim of territorial rulers in granting religious freedom. In general, toleration edicts were granted from above by rulers in response to economic motives or for personal reasons like religious conversions (Whaley, 2000). Johnson and Koyama (2018) study the rise of religious freedom in Europe and argue that the rise of modern states was the necessary precondition for the rise of religious freedom. In particular, they argue that religious freedom was established to ensure social stability and equal treatment which, in turn, increased tax revenues used to finance costly wars. Therefore, according to Johnson and Koyama religious freedom in early modern Europe was the result of increasing state capacity and the need to govern through standardized rules applicable to all. Differential treatment by religion was no longer a viable solution as it was impossible to sustain or extremely costly.

Mokyr (2016) argues that the politically fragmentation of Europe contributed to the creation of a competitive market for ideas which included also ideas of religious tolerance and openness to diversity. In fact, after the Thirty Years' War, German territories disintegrated into many independent states and it is plausible to assume that a sort of competition based on religious freedom arose. For example, the kings of Denmark granted religious freedom in Altona on the Elbe in an attempt to compete against the economically superior but intolerant Lutheran free Imperial city of Hamburg (Whaley, 1985).

On a larger scale, the competition between the Habsburg Empire and Brandenburg-Prussia also affected the evolution of religious freedom in the respective territories. In fact, many treaties enacted in Brandenburg-Prussia aimed at attracting communities that could contribute to economic prosperity as for example the Jews expelled from Vienna in 1670, the Huguenots expelled from France in 1685, and the Protestants forced out of Salzburg in 1732 (Whaley, 2000). In other cases, religious freedom was granted to accommodate conversions of princes and local rulers: in Brandenburg the first decree in 1614 was issued to ensure religious peace after the conversion of the Elector Johann

Sigismund to Calvinism in 1613. Similarly, the duchy of Sulzback (near Nuremberg), after the conversion of his ruler from Lutheranism to Catholicism, extended religious freedom including Jews and all types of sects (Whaley, 2000, p.186).

In the context of the Kingdom of Prussia, the Peace of Breslau (1742) defined the rights of the Catholic Church in the Silesian territories annexed in 1740-42. Policies aimed at asserting both territorial supremacy of Prussia and religious peace were undertaken also after the first partition of Poland in 1772. However, the first general Prussian toleration edict formally establishing equal legal status of the three major Christian Churches was published in 1788. The principle of freedom of conscience was included in the *Allgemeines Landrecht* issued in 1794. With this edict Prussia was obliged to grant freedom of religion and conscience to all the people, except to Jews. The position of the Jews was finally regulated in Prussia in 1812.

In sum, independently of whether religious tolerance originated from increasing state capacity and the need of equal fiscal treatment or from a competitive market for ideas, we argue that the resulting exposure to different denominations at the local level generated a culture of tolerance and openness which later fostered technological creativity and innovation. We will show that it was not a single denomination, neither the level of human capital in the city, nor the type of preindustrial economic activities that affected innovation during the second industrial revolution. Instead, it was the level of religious tolerance measured through the presence of different denominations, churches, and preachers that had a significant impact on innovation.

4 Data

We conduct the analysis at two different levels which allow also to exploit different sources of variation. We first analyze the relationship between religious tolerance and innovative activity for 1,278 municipalities with city rights in 1871. We use data from the 1871 population census which reports the number of resident people belonging to the following five religious groups: (i) Protestant, (ii) Catholic, (iii) other Christian, (iv) Jewish, and (v) a residual group. We proxy the level of religious tolerance in a city with the index of religious diversity constructed as 1−Herfindahl index.[4] The diversity index measures the probability that two randomly drawn individuals from the population belong to different religious denominations.[5] It is important to note that for Poles and Jews, ethnic and religious diversity often coincided. This is especially true for the cities east of the river Elbe characterized by a large share of Catholic Poles. In the regression analysis we will thus always account for differences between east- and west-Elbe cities. In the analysis at the county level we will also be able to disentangle diversity in religious denomination from ethnic-linguistic diversity.

[4]The index is constructed as follows: $\text{Div} = 1 - \sum_i s_i^2$, where s_i is the population share of denomination i.
[5]Note that the maximum value of diversity attainable with 5 religious denominations is 0.8.

Figure 1 displays the geographic distribution of the 1,278 cities in 1871. In the analysis at city level we will exploit variation across city, within county. Thus in the figure we have superimposed county borders to show the type of variation exploited in the regression analysis. It is important to note that in the regression analysis we will also include fixed effects for the number of religious denominations which varies from one to five.

Figure 2 shows the geographic distribution of religious tolerance, as proxied by religious diversity, at the city level. Darker red points indicate cities with higher levels of tolerance, whereas lighter yellow points indicate cities with low levels of religious diversity, i.e. religious tolerance.

For each city we have also information on the number of people able to read and write and population size. For 1,238 cities we can also construct the share of migrants as the original source reports the number of people born in the city. Furthermore, we will also include indicator variables for cities that belonged to the Hanseatic League, for Free Imperial cities, and for cities that had a university in the period 1700-1830 (Eulenburg, 1904).

We further measure religious diversity at city level using information on the religious denomination of students attending secondary schools in the winter semester 1873/74 in 307 municipalities that had at least one secondary school. We make use of a report on the conditions of secondary schools in Prussia which provides, for each secondary school, information on the religious denomination of attending students (Wiese, 1874). The secondary schools considered in the report are the following: *Gymnasium*, *Progymnasium*, *Realschule erster Ordnung*, *Realschule zweiter Ordnung*, und *höhere Bürgerschule*. We compute the index of religious diversity for each school and take the average at the city level in case there is more than one secondary school.

We analyze the relationship between religious diversity and innovative activity also at the county level. The 1871 census reports also at the county level the religious composition of the population by the above mentioned five groups. Yet, the county-level setting offers several advantages due to the large number of variables available at this higher level of aggregation. First, the analysis at county level accounts for potential spill-over effects of religious tolerance in neighboring municipalities not included in the list of cities or in rural areas. Second, the 1871 population census and the 1882 occupation census provide several variables which vary across denomination. For example, for the year 1871 we know the literacy level of the population by denomination; similarly, the 1882 occupation census reports employment data for several industrial and service sectors by denomination. This valuable information allows us to control for potential compositional effects and for religion-specific human capital levels. "Standard" control variables at the

county level include literacy rate, landownership inequality, urbanization rate, population density and an indicator for counties west of the river Elbe.[6]

Regarding the output variable, we measure innovation through the number of valuable patents granted in Prussia in the period 1877-1890 (Cinnirella and Streb, 2017). The primary source for the patent database is the annual "*Verzeichnis der im Vorjahre erteilten Patente*" published by the German patent office since 1877, which lists all patents granted in the preceding year. Among the universe of patents, we define as "valuable patents" those patents that were held for at least ten years (Streb, Baten and Yin, 2006). The German patent law, first introduced in 1877, was a system with periodical renewal fees (Seckelmann, 2006). The system allowed both independent individuals and firms to apply for patent protection that could last up to fifteen years. In order to keep a patent granted in force the patentee had to pay an annual renewal fee which grew from 50 Marks in the first and second year up to 700 Marks in the fifteenth year. We assume that, given the substantially increasing costs for holding a patent, considerations whether to renew the patent must have taken into account future returns of the patent. In fact, there is evidence that the mechanism worked as intended as 70 percent of all granted patents in Germany had been given up after just five years. Only about five percent of all patents reached the maximum protection of fifteen years (Streb, Baten and Yin, 2006, p. 352). Following this definition for valuable patents we identify 1,740 valuable patents granted to Prussian individuals and firms between 1877 and 1890. We use the stock of these valuable patents as a proxy for the level of innovation.[7]

Since patents' locations, cities, and counties have been georeferenced, a geographic matching between these entities through GIS technology is made possible.[8] To avoid possible mismatches due to (also small) differences in latitude and longitude of patentees' locations and cities, we assign a patent to a city if the patentee's location is within a 5 km radius from the city. For the county-level analysis we simply assign a patent to a county if the patentee's location is within the 1871 county borders.

Descriptive statistics of the main variables are reported in the appendix (Table A.1). In the upper panel we report descriptive statistics of variables available at the city level, whereas in the lower panel we report variables available at the county level. The average number of valuable patents in the 1,278 cities is 2.06 with a maximum value of 461 patents in Berlin; at county level the average number of patents is 3.84 with a maximum value

[6]The control variables used in the regression analysis are mainly drawn from the iPEHD, the ifo Prussian Economic History Database (Becker et al., 2014).

[7]We have decided to consider only patents until 1890 to avoid cumulative innovation and spillover effects between technological sectors which would be only indirectly related to tolerance. However, we can show that our baseline estimates are qualitatively identical if we consider the stock of patents granted in 1877-1900 or 1877-1914, respectively.

[8]We thank Simon Jäger, Natalie Obergruber, and Johannes Eigner for helping us with the georeferencing of the patents (Jäger, Obergruber and Eigner, 2017).

of 464 patents for the city-county of Berlin.[9] Average religious diversity across cities is 0.21. The highest level of religious diversity (0.67) is attained in the city of Tuchel (today *Tuchola* in Poland) with a 35 percent of Catholics, 33 percent of Protestants, and 32 percent of Jews. At the county level, average religious diversity is 0.19. Diversity has its minimum value of 0.002 in the county of Süderdithmarschen in Schleswig-Holstein (former Danish territory) which is composed of 99.9% of Protestant, 0.06% of Catholic, and 0.04% of Jews. The highest level of religious diversity is reached in the city-county of Posen with 51% of the population Catholic, 36% Protestant, 13% Jewish, and 3% belonging to other religions.

5 Measuring religious tolerance

Consistent with recent literature, we proxy the level of religious tolerance of a city through the index of religious diversity which measures the probability of sampling two individuals belonging to different religions. Akcigit, Grigsby and Nicholas (2017*b*), for instance, use the Herfindahl index of religious membership in the context of the U.S. to capture the extent to which different beliefs are tolerated and, therefore, as a proxy for the degree of openness to disruptive ideas. However, one could argue that having different denominations in a city does not necessarily imply a culture of religious tolerance. A broader concept of religious tolerance implies, for instance, the acceptance of different churches and freedom of worship.

To corroborate the notion that the index of religious diversity is a good proxy for religious tolerance, we show that religious diversity is strongly positively associated with the number of churches. This association is not trivial since the construction or existence of places of worship for religious minorities could have been denied. From the 1816 population census we have information on the *total* number of churches for 951 municipalities.[10] We argue that, in a religiously tolerant society, the number of churches per capita increases with the *size* of the denominations (i.e. the degree of diversity), conditional on the number of the different denominations.

In Figure 4 we show the relationship between the number of churches per 1,000 inhabitants in 1816 and religious diversity in 1871 for 946 cities. The relationship depicted in the figure is conditional on fixed effects for the number of denominations and on a binary indicator for cities west of the river Elbe. The data show a strong positive relationship which supports the notion that the index of religious diversity captures religious tolerance and pluralism. In section 6.3 we will show that our main proxy for religious tolerance is

[9] At the city level, Berlin has 3 fewer patents as these are located outside the 5 km buffer used to assign patents to cities.

[10] Only for a subsample of 172 large cities this information is available by denomination. We will exploit this information in the analysis of section 6.3.

highly correlated with other measures based on diversity of churches and diversity in the denomination of preachers and religious teachers.

6 City-level evidence

We begin our empirical analysis studying the relationship between religious tolerance and innovation for 1,278 cities estimating the following model:

$$\log(\text{patents p.c.} + 1)_{i,c} = \beta \, \text{Tolerance}_i + \boldsymbol{X}_i'\gamma + \delta_c + \varepsilon_{i,c} \tag{1}$$

where the dependent variable is the log number of valuable patents +1 per 10,000 people, granted in Prussia in the period 1877-1890 within 5 km radius of city i in county c. The log transformation "downplays" outliers with a high level of patents such as Berlin, Cologne, and Frankfurt am Main. The log transformation has also the desirable feature that the value of the dependent variable for cities with zero patents is also zero. The population used to standardize the number of patents is that for the year 1871. *Tolerance* is measured through the index of religious diversity of the population in city i in 1871. $\mathbf{X}$ is a vector of control variables which varies at the city level and includes the literacy rate and an indicator for whether the city is located west of the river Elbe. Importantly, we include also fixed effects for the number of religious denominations which vary across cities. In this way we only exploit variation in the *relative size* of religious groups in the population, for a given number of denominations which varies from 1 to 5. We include also 426 county-fixed effects δ_c which allow us to control for time-invariant geographical and institutional characteristics that vary between counties.[11]

In Figure 5 we show our relationship of interest for the 1,278 cities in 1871 conditional on fixed effects for the number of denominations and a binary variable for the cities west of the river Elbe. As one can see there is a positive relationship between the level of religious tolerance, proxied by religious diversity, and the log number of valuable patents in a city. The scatterplot also suggests the existence of decreasing marginal returns to religious tolerance. As we will see, this finding is substantiated by the regression analysis.

Our baseline estimates are shown in Table 1. In column 1 we estimate the relationship between religious tolerance and innovation conditional on literacy and being west of the river Elbe, *without* county and number of denominations fixed effects.[12] The coefficient is positive and highly significant. As expected and consistent with previous literature (Cinnirella and Streb, 2017), cities with a higher level of literacy are significantly more innovative. Cities west of the river Elbe tend also to have higher levels of innovation.

[11] In the appendix we report a set of robustness checks. In particular, we show that our baseline estimates are qualitatively the same if: we use a 2 km radius (instead of 5 km) to assign patents to cities (Table A.2); we estimate the baseline model without taking the logarithm of the dependent variable (Table A.3); we consider the stock of patents granted in 1877-1900 (Table A.4) or in 1877-1914 (Table A.5), respectively.

[12] As mentioned above, it is important to include always a control for west Prussia as religious diversity in the eastern regions captures also other dimensions of diversity such as ethnic and linguistic. In the analysis at the county level we will be able to directly disentangle religious diversity from ethnic-linguistic diversity.

In column 2 we include county fixed effects and thus exploit variation across cities, within county.[13] The coefficient for religious diversity becomes smaller but remains significant indicating that cities more religiously diversified are more innovative. It is important to note that this result is conditional on the level of human capital of the city proxied by the literacy rate.

In column 3 we further include fixed effects for the number of denominations. This is an important test since diversity based on the Herfindahl index increases by construction with the number of denominations. For the logic of our hypothesis it is also important to show that it is not only the presence of religious minorities that drives our result. Instead, we argue that it is the relative size of the denominations which exerts a positive impact on innovation. Indeed, the results in column 3 support our hypothesis that a more diverse and tolerant society has a positive impact on innovation. The coefficients for the number of denominations also indicate an important result: Although the coefficient for cities with 5 denominations is not significant ($n = 43$), the point estimates indicate that a larger number of denominations is positively related to innovation (cities with 3 denominations is the reference group). Taken at face value, cities with 4 or 5 denominations have, respectively, 17% or 21% more valuable patents than cities with 3 denominations. Regarding the effect of tolerance, the estimates in column 3 indicate that a standard deviation increase in religious diversity (0.19) is associated with an increase in the number of valuable patents by 13%.

The scatterplot in Figure 5 suggested a non-linear relationship between religious tolerance and innovation. It is plausible to assume that the impact of religious tolerance on innovation is stronger at lower levels of religious diversity. In other words, it is possible that after reaching a certain level of diversity, the inclusion of additional individuals of different denominations does not add to tolerance and thus to innovation. In columns 4 and 5 of Table 1 we test for non-linearity of the relationship between religious tolerance and innovation. In column 4 we adopt a quadratic functional form and find that the level of diversity which "maximize" the number of patents is 0.48. In column 5 we adopt a non-parametric approach and include dummies for quartiles of religious diversity (the first quartile is the reference group). The estimates indicate that the positive impact of diversity on innovation becomes significant from the 3rd quartile (0.27). The point estimate for the 4th quartile suggests a stronger effect for these cities (0.37), yet the coefficients for the 3rd and 4th quartile are not statistically different.

In Table 2 we explore the potential role of different religious majorities. The index of religious diversity based on the Herfindahl index is "symmetric" in the sense that we obtain the same value of diversity if a city has 70% Protestants, 20% Catholics and 10% Jewish people and another city has a composition of 70% Catholics, 20% Protestants and 10% Jews. In fact, one could argue that levels of religious tolerance varied if the

[13] The average number of cities within a county is three.

city was dominated by Protestants or Catholics.[14] In columns 1 and 2 we estimate our baseline model for 904 cities where Protestants are the relative or absolute majority; in the sample in column 3 and 4 Catholics represent the relative or absolute majority. The first thing to note is that, on average, innovation was more predominant in cities with a Protestant majority as shown at the bottom of the table. Religious diversity, instead, was higher in cities predominantly Catholic. We find a positive impact of religious tolerance on innovation in both samples (columns 1 and 3). Conditioning on the number of denominations (columns 2 and 4) does not change the results. The size of the coefficients suggests that the effect of diversity is larger in cities with Protestant majorities. Yet, the size of the standard errors does not allow us to make any strong claim. On the contrary, the coefficients for literacy show a very strong pattern: literacy is strongly related to innovation in Protestant cities whereas the coefficient is virtually zero in Catholic ones.

This observation leads to the question whether complementarities existed between religious tolerance and human capital. One way to address this question is by interacting our measure for religious diversity with the literacy rate. The results of such a specification are reported in column 5 of Table 2.[15] The estimates show that the positive impact of religious diversity on innovation increases with the level of human capital in the city proxied by the literacy rate.[16] To facilitate the interpretation of this result, in Figure 6 we plot the marginal effect of religious diversity at different levels of literacy rate with 95% confidence intervals. The histogram in the background shows the distribution of the literacy rate across the 1,278 cities. The figure shows a significantly positive marginal effect of religious diversity starting from a literacy rate of about 70%, which comprises more than 90% of our cities in 1871.

6.1 Alternative source of religious diversity

To test the robustness of our results, we propose a measure of religious tolerance originating from another contemporary source, namely from the denomination of secondary school students. Wiese (1874) published a report on the conditions of secondary education in Prussia and for all secondary schools he reported the number of attending students by the following denominations: Protestant, Catholic, and Jewish. We argue that the level of religious diversity at the secondary-school level is another good proxy for the level of religious tolerance and pluralism of the society.

[14] Whaley (2000), for example, argues that in Protestant Germany the development of natural law theories was a key argument for the extension of the limited toleration of the Peace of Westphalia.

[15] In this specification the literacy rate is centered at the mean to make the interpretation of the main effect more realistic as in 1871 Prussia there were no cities with zero literacy rate.

[16] Since literacy captures only basic knowledge, it is possible that the complementarity between tolerance and human capital is even larger.

We construct the index of religious diversity for each school and we average it out at the city level.[17] A problem with this alternative data source is that secondary schools were mainly present in relatively large and economically advanced cities, where a sufficiently large demand for secondary education existed.[18] We have therefore to keep in mind that these estimates refer to a selected sample.

The sample with secondary schools consists of 307 cities with an average value of religious diversity of 0.24. After assigning the patents located within a 5 km radius, the average number of valuable patents in the cities is 5.3. The relatively high number of patents confirms the notion that cities with secondary schools were economically more advanced. However, the results of Table 4 using secondary students' religious diversity are fully consistent with pattern shown so far. Due to the low number of observations and the small variation within number of denominations, in these estimations we cannot include neither county nor number of denominations fixed effects. That is why the results have only a suggestive value.

In column 1, where we only include a control for the cities west of the river Elbe, the coefficient for religious diversity is significantly positive and virtually identical in size to the coefficient of our baseline specification with county and number of denominations fixed effects (Table 1, column 3). The main result remains unaffected when we control for the "extent" of secondary education in the city by including the absolute number of secondary schools and the share of secondary students in the population (column 2).

To account for heterogeneity across cities, in column 3 we include a set of controls for distances which aims at capturing potential confounding factors related to trade (distance to nearest river and to medieval route), institutions (distance to Free Imperial city), and advanced education (distance to university). Indeed, a higher distance to these factors is negatively related to innovation. The impact of religious tolerance remains significantly positive and of the same size.

Finally, in column 4 we test for non-linearity including dummies for quartiles of religious diversity. The results are very similar to the estimates in Table 1, column 5, where we use the level of religious diversity in the population.

6.2 Historical preconditions

A causal interpretation of our results is based on the assumption that variation in the relative size of religious groups in the population within county and for a given number of religious denominations is orthogonal to the error term, i.e., it is not related to unobserved characteristics related to innovation. In order to make the identifying assumption more stringent, in Table 3 we account for historical characteristics which could

[17] Regarding the number of secondary schools, 83 percent of the cities have 1 secondary school, 12 percent 2 schools, and the remaining 5 percent 3 or more schools.

[18] See for example Semrad (2015) on how the introduction of secondary schools affected economic outcomes in nineteenth-century Bavaria.

have affected the religious composition of the population and have a persistent impact on innovation. An important result of Serafinelli and Tabellini (2017) is that city institutions like autonomy and political freedom mattered for the attraction and production of creative talents. To disentangle religious tolerance effects from effects related to other city institutions, we include in the regression analysis indicators for Free Imperial cities (column 1) and for having belonged to the Hanseatic League (column 2). Cantoni and Yuchtman (2014) have shown that medieval universities played a large role in expanding economic activity. Medieval universities likely attracted people from different cultures and religions increasing thus the level of religious diversity. In column 3 we include a binary variable for cities having a university operating in the period 1700-1830 based on Eulenburg (1904).

As one can see, the inclusion of these controls does not affect our coefficient of interest and the variables themselves are not significantly related to innovation. This non-result for Free Imperial cities, which enjoyed ample economic and political autonomy, is probably due to the low variation within counties. In fact, without county fixed effects the coefficient for Free Imperial cities is positive and highly significant.[19]

The various treaties that, from the end of the Thirty Years' War, institutionalized religious freedom and tolerance generally regarded only the three main Christian religions: Catholic, Protestant, and Calvinism. Jewish and other minorities (for example the Mennonites) were generally not included (Whaley, 2000). As already mentioned above, Becker and Pascali (2016) have recently shown that, because of competition in moneylending activities (i) Jewish persecutions were more prevalent in Protestant areas where the Jews had already established themselves as moneylenders and (ii) the Reformation reduced the specialization of Jews in the financial sector in Protestant regions but not in Catholic ones. Their results suggest that the size of the Jewish community could depend on the size of the other denominations. To account for this potential endogeneity issue, we control for the share of Jewish people in the city (column 4) and we also include a dummy variable for cities which persecuted Jews at least once in the period 1100-1800 through a pogrom or an expulsion (column 5).[20] The estimates in column 4 show that, conditional on the share of Jewish in the city, a higher level of religious diversity is still positively associated with innovation. Interestingly, a larger share of Jews is negatively related to innovation.[21] An explanation for this finding might be that Jews were especially engaged in the service sector where patentable innovations hardly occurred in the late nineteenth-century. Accounting for cities that historically persecuted Jews does not

[19]The coefficient indicates that Free Imperial cities have 37% more valuable patents (estimates not shown but available upon request).

[20]The data on Jewish persecution at city level come from Anderson, Johnson and Koyama (2016).

[21]This result is consistent with the historical narrative about the limited role of the Jewish community on innovation (Mokyr, 2016).

change our coefficient of interest and it is not related to innovative activity at the end of the nineteenth century.

Another historical event which can potentially affect our results is the settlement of Huguenots in Prussian territories occurred around 1700. The Huguenots were French Protestants who fled France as the Edict of Nantes, which granted religious freedom to Protestants, was revoked in 1685. Approximately 200,000 Huguenots fled France and between 16,000 to 20,000 went to Brandenburg-Prussia. This exodus is particularly interesting for our study since Huguenots were particularly skilled and they might have had a persistent impact on economic productivity and innovation. In fact, Hornung (2014) studied the productivity effects of Huguenots' migration and finds a substantial long-term effect of Huguenots settlement on the productivity of textile manufactories. In column 6 we include a dummy variable for cities which had a Huguenots colony in 1700.[22] We do not find any significant impact of Huguenots colonies on innovation. This result is not surprising as the Huguenots in Germany specialized mainly in the textile sector which was not one of the leading innovative sectors during the second industrial revolution in Germany.

Finally, in column 7, we include all the control variables simultaneously. The main result on the impact of religious tolerance on innovation remains unaffected.

6.3 Evidence from preindustrial towns in 1816

So far we have shown that our proxy for religious tolerance measured in 1871 is positively and robustly associated with valuable innovation, also conditional on historical conditions as shown in Table 3. In this section we show that alternative proxies for religious tolerance measured in the preindustrial period, namely in 1816, are also significantly and robustly associated with innovation. The evidence presented in this section is very important as we make use of likely superior measures of religious tolerance, although for a smaller sample of cities. Furthermore, by measuring religious tolerance with data in 1816 we address the issue of reverse causality.

The population census of 1816 reports separate statistics for 172 large towns and 857 small towns. The part on large towns reports detailed information on different aspects of the religious structure of the towns. In particular, we know not only the number of people but also the number of churches and number of preachers (and religious teachers) by the following denominations: Lutheran, Calvinist, Catholic, and Jewish.[23] Instead for the 857 small towns we only know the number of people who are Protestants (without distinction between Lutheran and Calvinist), Catholic, and Jewish; the number of churches is only

[22] We thank Erik Hornung for making the data available to us.

[23] As for the number of preachers and religious teachers, the variables are only available for Lutheran, Calvinist, and Catholic.

provided in total and not by denomination; the number of preachers is not provided at all.

Thus, we use the information available for the 172 large towns in 1816 and construct an index of religious tolerance based, respectively, on the diversity of churches and on the diversity of preachers & religious teachers (henceforth "diversity of preachers"). These proxies are probably superior measures of religious tolerance as they capture the very nature of tolerance which is the freedom of practicing, worshipping, and teaching a religion. We argue that a higher number of churches of different denomination captures higher levels of tolerance as only recognized denominations were allowed to exercise their faith in public, either in churches or chapels (Whaley, 2000, p. 179). The average level of diversity for, respectively, churches and preachers are 0.45 and 0.30, thus higher than the index of religious diversity based on the population (see Table A.1 in the appendix). We can match 166 of the large towns in 1816 with cities in 1871 and we run our baseline estimates to test the relationship between the indexes of diversity in 1816 and innovation in the second industrial revolution.[24] Due to the low number of observations we cannot include neither county fixed effects nor fixed effects for the number of denominations.

The presence of different churches and of different religious preachers is also strongly related to the size of the religious groups. Therefore, in order to disentangle the concept of religious tolerance from size effects, we include in the regression analysis the share of Catholics and the share of Jews in the population (the share of Protestants is the reference group). We include also the usual indicator for towns west of the river Elbe.

The baseline estimates with the new indexes for religious tolerance are presented in column 1 and 3 of Table 5.[25] As one can see, both proxies for religious tolerance in 1816 are positively related to innovation during the second industrial revolution. The size of the coefficients is consistent with the magnitude of the coefficients estimated when using the population religious diversity in 1871. Also consistent with the results of Table 3, we find that the share of Jewish population in 1816 is negatively associated with innovation.

The 1816 census reports also information on the economic structure of large and small towns. In particular, the census reports the following variables for each town: (i) the number of factories, mills, and warehouses; (ii) the number of traders and merchants; (iii) the number of craftsmen;[26] (iv) the number of textile looms. We also know for each town the number of primary school teachers. These variables can thus be used to control for the production structure of the towns and for levels of human capital. The inclusion of these variables in the regression analysis allows us to test the extent to which the impact of

[24] By construction, the matched sample is constituted by relatively large cities in 1871. In the matched sample the average city size in 1871 is 23,471 while the average city size in whole sample in 1871 is 6,226.

[25] The correlation between diversity of churches and diversity of preachers is 0.65; the correlation between, respectively, diversity of churches and diversity of preachers with population religious diversity in 1871 is 0.52 and 0.51.

[26] The trades reported in the census are baker, butcher, tanner, shoemaker, tailor, carpenter, cartwright, blacksmith, cooper, cord maker.

religious tolerance on innovation operates through the contemporary production structure of the towns. It is indeed plausible to assume that higher levels of religious tolerance in 1816 are associated with economic progress which, in turn, has a positive impact on innovation. The number of factories, mills, and warehouses are expected to account for economic progress. The same we assume for the number of primary school teachers. On the contrary, a larger number of craftsmen and of textile looms are expected to capture a more "traditional" economy.

In columns 2 and 4 we include controls for the number of teachers per 100 children aged 0-14, the number of factories (mills and warehouses) p.c., the share of merchants, the share of craftsmen and the p.c. number of looms.[27] Indeed, we find that differences in levels of human capital proxied by the number of primary school teachers in 1816 are strongly positively related to innovation. On the contrary, towns with a high presence of merchants tend to be less innovative towards the end of the nineteenth century. Importantly, the impact of religious tolerance remains significant and of similar size compared to the previous estimates. This result suggests that the impact of religious tolerance on innovation does not operate through the production structure of the city. As we will see in the next section, it is the share of migrants in a city that constitutes an important mechanism explaining these reduced-form estimates.

We can also use the population's religious diversity in 1816 to test its long-run impact on innovation during the second industrial revolution. Information on the denomination of people in 1816 is available for both large and small towns. Thus in column 5 we regress the log number of valuable patents in 1877-90 on religious diversity in 1816, only controlling for towns west of the river Elbe. The coefficient for religious diversity is highly significant. Yet, the size of the coefficient is smaller compared to the estimates using the other proxies for tolerance as in column 1 and 3. This finding supports our argument that the indexes of religious tolerance based on churches and preachers are likely superior with respect to the index based on population's religious diversity. In this case the coefficient for the population's religious diversity suffers from attenuation bias.[28] However, the samples in columns 1-3 and in column 5 are not directly comparable as the latter includes also small towns with few innovation in the later period.

After the inclusion of controls for human capital and for the production structure (column 6), the coefficient for population religious diversity becomes smaller in size and it is significant only at the 10% level.

[27] The number of observations is reduced due to some missing observations in the control variables, in particular in the number of primary school teachers.

[28] This point finds indirect support from two-stage least squares estimates in which we instrument population religious diversity in 1871 with (i) diversity of churches and (ii) diversity of preachers in 1816. The second stage coefficient for population religious diversity in 1871 is about three times larger than the correspondent OLS estimate (not shown but available upon request).

6.4 Migration as possible mechanism

So far we have shown that religious tolerance has a significant positive impact on innovative activity. We have also shown that this effect is persistent as we detect a robust and significant relationship when considering different measures for religious tolerance in 1816. These results are consistent with the notion that a culture of openness and tolerance fosters the creation and the adoption of new ideas (Mokyr, 1990, 2016). In this section we provide evidence for a possible mechanism.

Recent results from the literature stress the importance of migration for innovation. Akcigit, Grigsby and Nicholas (2017*a*,*b*) analyze the micro and macro-determinants of innovation in U.S. between 1880 and 1940. Among other findings, they show that inventors tended to migrate to places that were conducive to innovation. Serafinelli and Tabellini (2017), in the context of the Holy Roman Empire, show that the cities' institutional features that promoted creativity, i.e. being a *Commune*, are positively associated with the inflow of migrants. Consistent with this literature, we find that cities characterized by higher levels of religious tolerance have, *ceteris paribus*, a higher number of people born in another city. In fact, we find that differences in migration shares across cities explain to a large extent the relationship between religious tolerance and innovation.

The population census in 1871 reports for each city the number of resident people born in the municipality.[29] Therefore we construct the share of migrants and test, first, to what extent our measure for religious tolerance in 1871 can explain differences in migration shares. In column 1 of Table 6 we show estimates of this association conditional on our standard set of variables and fixed effects. We find that religious diversity is strongly positively associated with the share of resident people born in another city. A unit-change in religious diversity is associated with a 26 percentage points higher migrants share, which is equivalent to 62% of the mean.

In columns 2-3 we test whether differences in the share of migrants across cities within county in 1871 explain away our relationship of interest. In column 2 we run our baseline model on the 1,238 cities for which we have data on migrants. In column 3 we include the share of migrants. The estimates in column 3 show two important results. First, a large share of migrants is strongly positively related to valuable patents. The coefficient indicates that a change in the share of migrants by one standard deviation (0.12 percentage points) is associated with 14% more valuable patents per capita. Most importantly, we find that after accounting for the share of migrants the coefficient for religious diversity is about half the size with respect to the estimate in column 2 and is no longer statistically different from zero.

[29] This piece of information is missing for 40 cities so that the sample size is reduced to 1,238.

To further substantiate this result, we focus on the 152 cities that can be matched with the alternative indexes of religious tolerance in 1816.[30] As discussed in the previous section, these indexes are most likely less noisy measures of religious tolerance. Thus, in columns 4-5 we test to what extent the share of migrants observed in 1871 operates as a mechanism of the "reduced-form" relationship between religious tolerance in 1816 and innovation during the second industrial revolution including the same set of controls for 1816 as in columns 2 and 4 of Table 5.

Regarding religious tolerance measured through diversity of churches (column 4), the coefficient turns insignificant while the coefficient for the share of migrants is large and significant at the 10% level. As for tolerance measured through diversity of preachers (column 5), after the inclusion of the share of migrants the coefficient is 22% smaller compared to the estimates of Table 5 and it is only significant at the 10% level. The coefficient for the share of migrant is similar in size to the other estimates but is less precisely estimated.

In sum, the estimates for the sample of large cities in 1816 in columns 4 and 5 confirm the result that cities with higher levels of religious tolerance attracted over time a larger number of migrants who, in turn, significantly contributed to innovation.

7 County-level evidence

So far we have presented evidence on the effect of religious tolerance on innovation mainly based on variation across cities, within counties, conditional on a rich set of control variables. In this section we provide further evidence at a higher level of aggregation, namely the county level. This approach has several advantages. On the one side, it allows to exploit further variables which are only available at this level of observation. On the other side, it allows to account also for the rural environment.

In Table 7 we estimate our baseline model for 452 counties. In column 1 we only include fixed effects for the number of denominations in the county, whereas in column 2 we additionally include controls for literacy, landownership inequality, urbanization rate, population density, and an indicator for counties west of the river Elbe. We find a significant impact of religious tolerance on innovation also at the county level. The size of the coefficient for religious diversity in column 2 is about half the coefficient in column 3 of Table 1. This suggests that by looking at variation across counties (instead of within counties) we might underestimate the effect of religious diversity on innovative activity. This result makes sense as most of the innovation took place in large urban centers and the religious composition of the rural population probably played a negligible role. Estimates in columns 3 and 4 confirm our previous result of a non-linear effect of religious tolerance on innovation. The coefficients for the control variables also show the

[30] With respect to the sample of Table 5, column 2 and 4, we lose one additional observation because of missing information on the share of migrants.

expected signs: urbanization and counties west of the river Elbe tend to produce more innovation.

The availability of other dimensions of diversity at the county level allows us to show that, indeed, religious tolerance is the dimension which mattered for innovation during the second industrial revolution. In principle, diversity in the number of languages spoken could also be a proxy for the level of tolerance and openness of a society. However, in the last decades of the nineteenth century in Prussia, linguistic diversity was rather a source of economic and social conflicts between the German-speaking and (mainly) Polish-speaking part of the population. In the so-called "Germanization" process between the end of the nineteenth and beginning of the twentieth-century, German language and culture was imposed to the linguistic minorities creating social tensions.[31] Therefore, whereas religious tolerance was formally institutionalized, the use of languages other than German was less tolerated if not formally prohibited in schools and public offices.

In our setting we can thus use linguistic diversity as a sort of falsification test. If religious tolerance is the dimension which mattered for innovation, we should not expect linguistic diversity to have any positive impact on innovation. On the contrary, given the conflicting nature of the language policy in nineteenth century Prussia, we expect linguistic diversity to be negatively associated with innovation.[32]

The 1886 education census reports for each county the number of primary school students by language spoken at home. In particular, the 1886 census lists the following languages: German, Polish, Lithuanian, Wendish, Slavic, Danish, and a residual category. Therefore we construct an index of linguistic diversity based on the Herfindahl index.

In columns 5-7 of Table 7 we run our falsification test regressing the log number of valuable patents on linguistic diversity, conditional on the set of control variables as in the previous columns. In column 5 we include linguistic diversity linearly. As expected the point estimate is negative but the coefficient is imprecisely estimated. In column 6 we test for non-linearity by including linguistic diversity in quadratic form. The coefficients are again statistically insignificant. We obtain more insights when including a binary variable for counties with linguistic diversity in the top quartile.[33] The coefficient is negative and significant at the 10% level. The size of the coefficient indicates that, *ceteris paribus*, counties with higher linguistic diversity have about 10 percent lower levels of valuable patents. This result is consistent with the notion that linguistic diversity in nineteenth-century Prussia was a source of political and economic instability rather than a sign of tolerance and openness to diversity. Indirectly, this result further supports the notion

[31] The period of *Kulturkampf* that aimed at undermining the power of the Catholic church was more short termed (mainly in the 1880s) and did not succeed in its purpose.

[32] For example, Cinnirella and Schueler (2016) show that linguistic polarization caused a lower provision of public primary education in 1886.

[33] The distribution of linguistic diversity across counties is strongly right-skewed such that positive values of diversity start from the 75th percentile.

that religious tolerance, as proxied by diversity of religious denomination, was conducive to innovation.

7.1 Education by denomination

The analysis at the city level has shown that the effect of religious tolerance on innovation increases with the level of human capital measured in terms of literacy (see Figure 6). Recent research has stressed the importance of different types of human capital for economic growth. Squicciarini and Voigtländer (2015) finds that upper-tail knowledge, as opposed to average level of human capital, raised productivity in innovative industrial technology during the French industrial revolution. Cinnirella and Streb (2017) provide evidence on the positive impact of literacy on innovation activity of large-firms in frontier industrial sectors such as chemistry.

At the county level we can test whether the respective level of education of the different denominations affects our results. The population census of 1871 provides for each county the number of illiterate people older than 10 by religion. As expected, we find that Jews and Protestants had higher levels of literacy than Catholics. The average illiteracy rate is 5 percent for Jews, 7 percent for Protestant, and 11 percent for Catholics. In Table 8 we include separately each variable for illiteracy (columns 1-3) and then simultaneously (column 4).[34] The coefficients for religious tolerance remain unchanged across the different specifications.

Religious tolerance could be related to investments in higher education which make the county more attractive to potential inventors from other counties. In the city-level analysis we have already shown that having a university does not affect our main results. In column 5 of Table 8 we include as a control variable the per capita log spending on secondary education for the budget year 1883/84.[35] The coefficient for spending in secondary education is positive and significant. The coefficient for religious tolerance, if anything, increases in magnitude. In column 6 we include simultaneously all the controls for education and investments in human capital and the result on religious tolerance remains unchanged.[36]

In brief, the estimates of Table 8 indicate that the level of education specific to each denomination has no bearing on our results.

7.2 Religious clustering of the workforce by sector

The results of section 6.4 show that cities characterized by higher levels of religious tolerance are positively correlated with a larger share of migrants who, in turn, could

[34] In these specifications we do not control for the overall literacy rate.

[35] Source: *Beiträge zur Finanzstatistik der Gemeinden in Preussen 1883/84, Königliches Statistisches Bureau in Berlin, 1884.*

[36] In column 6 the coefficients for illiteracy of Catholics and Jews become significant. However we refrain from any interpretation given the strong correlations among the variables for illiteracy.

have contributed to produce more innovative ideas. Yet, an important question about the mechanism is how the people, attracted by tolerance and openness of a society, contributed to more innovation. We argue that the *interaction* of people of different denominations and not the clustering of denominations in given industrial sectors can explain the higher number of valuable patents in more religiously tolerant environments. In particular, this section analyzes the relationship between the overall religious diversity and the religious diversity of the workforce employed in different industrial sectors in a county. A strong positive relationship would suggest no specialization of single denominations in given industrial sectors. On the contrary, a weak relationship in a given sector would indicate a denominationally "sticky" workforce which does not take full advantage of the diversity present at the population level.

The 1882 occupation census provides for each county the number of people employed in different economic sectors by denomination. Thus we know, for example, how many Protestants, Catholics, and Jews were employed in the metallurgy sector or in the chemical sector in county i. Thus, we construct indexes of religious diversity for 13 industrial sectors: mining, minerals, metallurgy, machine building, chemistry, fats and oils refining, textile, paper and leather, wood, food processing, clothing, construction, and printing. We construct also indexes of religious diversity for the financial sector and for the army which we expect to be relatively less diversified.

Each sector-specific diversity index is then regressed on the population index of diversity, conditional on our standard set of controls.[37] Importantly, we also include as control the share of people employed in the relative industrial sector to account for differences in the size of the industrial sector. In Figure 7 we display the added-value plots of the 15 OLS regressions.[38] To facilitate the comparison of the coefficients across sectors, we have standardized both the independent and the dependent variable of interest at zero mean and unitary standard deviation.

In general, we find a strong and significant positive conditional relationship between overall religious diversity and religious diversity of the workforce by industrial sector. For many industrial sectors the coefficient for the population religious diversity is close to one indicating that an increase in the population religious diversity translates almost one-to-one into the religious diversity of the workforce employed in the given sector. This is particularly true for sectors like metallurgy ($\beta = 0.94$), machine building ($\beta = 0.90$), clothing ($\beta = 0.96$), and construction ($\beta = 0.93$). Relatively low associations are found in the mining sector, in the production of fats and oils, and in the printing sector. We find a non-significant relationship between overall religious diversity and workforce religious diversity in the banking sector and a weak association in the army. These two sectors were relatively dominated, respectively, by Jews and Protestants.

[37] The controls are literacy rate, land inequality, urbanization rate, population density, and the indicator for west Elbe.

[38] The results in tabular forms are reported in Table A.6 in the appendix.

In sum, the pattern of the results displayed in Figure 7 indicates that denominations did not cluster in specific industrial productions. The level of diversity of the workforce by industrial sector reflects the overall level of diversity in the population. This result is consistent with the interpretation that religious tolerance and pluralism fostered the interaction of people of different denominations and did not generate a segmentation of the labor market by religious denomination.

7.3 Location of innovative industries

The distribution of valuable patents is strictly related to the geographic location of innovative industries. Crafts and Wolf (2014) show that the location of the UK cotton industry in 1838 is positively related to the availability of water power, ruggedness of terrain, and to proximity to ports. Gutberlet (2014) analyses the extent to which the dependence on natural resources such as water and coal affected the location of manufacturing in Germany at the end of the nineteenth century. Fernihough and O'Rourke (2014) underline the importance of access to coalfields for economic growth. In the U.S. context, Akcigit, Grigsby and Nicholas (2017*b*) finds that geographically-connected states were more innovative. In our case, large chemical firms settled at the banks of the rivers Rhine and Main, which were not only important navigable waterways, but were also used as a water source and to get rid of effluents. Firms engaged in the field of mechanical engineering were particularly concentrated in the neighborhood of iron and steel producers, namely in the Greater Ruhr area, and near textile manufacturers as in the Province of Saxony.

These geographic factors are accounted for in the city-level analysis as we exploit variation within counties and therefore control for time-invariant characteristics of the counties. However, given the amount of information available at the county level we can test whether the impact of religious tolerance on innovation survives once accounting for the presence of industrial sectors which, by the nature of their production process, have a higher propensity to patent. We account for the location of high-patenting industries by including in our model the share of people employed in metallurgy and chemistry, respectively. The results are reported in Table 9. As expected, the two industrial sectors are positively associated with patenting activity, especially the chemical sector. The coefficients for religious tolerance are slightly smaller but always highly significant.

In column 3 we include a control for the share of people employed in the banking and insurance sector. Innovating was an expensive endeavor. Investors had to finance R&D, pay patent fees and attorneys, and most importantly, invest in new production capacities. That is why the presence of a local financial sector might have helped to foster innovation and thereby also patenting.[39] In our case the financial sector is even more relevant as we are considering valuable patents, i.e. patents that were held for at least 10 years. Indeed,

[39]For the problem of financing innovation see Lehmann-Hasemeyer and Streb (2016).

the coefficient for employment in the financial sector is strongly related to patenting and is very large in magnitude.[40] The coefficient for religious tolerance remains similar in size.

Finally, in column 4 we include simultaneously all the controls variables. The coefficient for religious tolerance becomes smaller and is significant at 5% level. This set of results suggests a relationship between religious tolerance and the location of highly innovative industries and the development of the financial sector.

7.4 Religious tolerance and productivity

One could argue that the result of having more patents in religiously heterogenous counties is due to mistrust between denominations. Such an interpretation would go against some of the results presented so far, e.g. the complementarity between tolerance and human capital and the fact that religiously tolerant cities attract more migrants. Furthermore, if mistrust between two large polarized denominations were the cause, we would find a higher number of patents in cities with two denominations. The coefficients for the fixed effects of the number of denominations suggest, instead, that innovation increases with the number of denominations.

By means of data on income-tax revenues for the period 1899-1903, we can show that higher levels of religious tolerance are positively related to economic productivity.[41] Such a finding would be inconsistent with an interpretation of mistrust between denominations. In Table 10 we report specifications where we regress log income-tax revenues per capita for the period 1899-1903 on our measure for religious tolerance in 1871, conditional on our set of control variable and on fixed effects for the number of denominations. In column 1 we include religious diversity linearly. The coefficient is positive and significant at the 10% level. In the successive columns we test for non-linearity including religious diversity in quadratic form (column 2) and including indicators for quartiles (column 3). The estimates indicate a concave relationship between religious tolerance and log income-tax revenues. The non-parametric estimates in column 3 suggest that counties with religious diversity in the third quartile (mean diversity = 0.2) attain the highest level of tax revenues (the dummy for the first quartile is the reference group). Counties in the 4th quartile (mean diversity = 0.46) are associated with a relatively lower tax revenues, although the coefficients for the 3rd and 4th quartiles are not statistically different between each other. A possible interpretation of this result is that "too high" levels of religious diversity exert a negative impact on the economy due to coordination failures (Alesina and La Ferrara, 2005). However, this set of results is inconsistent with the interpretation that higher levels of religious diversity are associated with mistrust.

[40] Taken at face value, the estimates in column 3 indicate that a standard deviation increase in employment in the financial sector is associated with about 14 percent more valuable patents.

[41] For more details on the variable for income-tax revenues you are referred to Cinnirella and Streb (2017).

8 Conclusion

A culture of tolerance and openness to diversity is a crucial element for the adoption and generation of new ideas. Imperial Germany, at the end of the nineteenth century, experienced a rapid increase in technological progress and has been theatre of major innovations in several industrial sectors. We argue that the religious tolerance that developed from the Peace of Westphalia throughout the Age of Enlightenment created conditions important for the production of breakthrough inventions during the second industrial revolution.

By combining unique data on the exact religious composition of 1,278 cities and 452 counties in 1871 with data on valuable patents, we can study the impact of religious tolerance on innovation in Prussia at the end of the nineteenth century. We proxy religious tolerance with different measures such as population's religious diversity, diversity of churches, and diversity of preachers and religious teachers. Identification is based on local variation across cities, within county. Furthermore, we exploit variation in the relative size of religious groups in the population, conditional on the number of different denominations in the city. We address the issue of reverse causality by using alternative proxies for religious tolerance in 1816, a preindustrial period.

We consistently find that higher levels of religious tolerance are strongly positively associated with innovation. Quadratic and non-parametric estimates indicate a non-linear effect with decreasing marginal returns to religious tolerance. We find that the effect is independent from the type of religious majority in the city. We also unveil important complementarity between religious tolerance and human capital, the latter proxied by literacy rates.

As for the mechanism, we provide evidence consistent with the hypothesis that more tolerant cities attracted a higher share of migrants. Furthermore, results using detailed information on the religious composition of the workforce by industrial sector suggest that people of different denominations might have interacted, thus, rejecting the notion of religious clustering by industrial sector.

In general, the findings of this paper contribute to our understanding of the innovation process. Our results indicate that a culture of tolerance and openness to diversity is key to attract human capital which, in turn, fosters innovation and technological progress.

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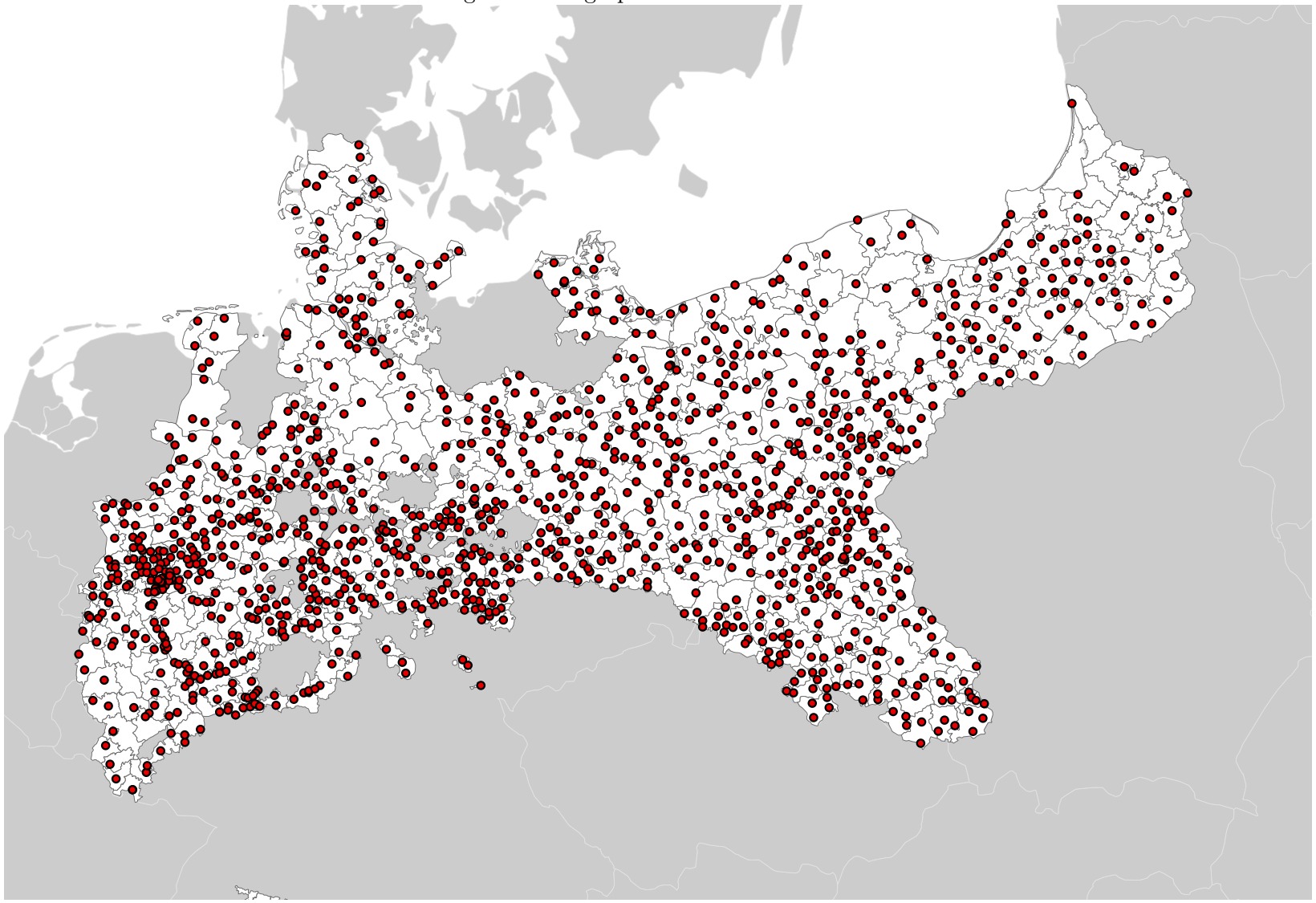
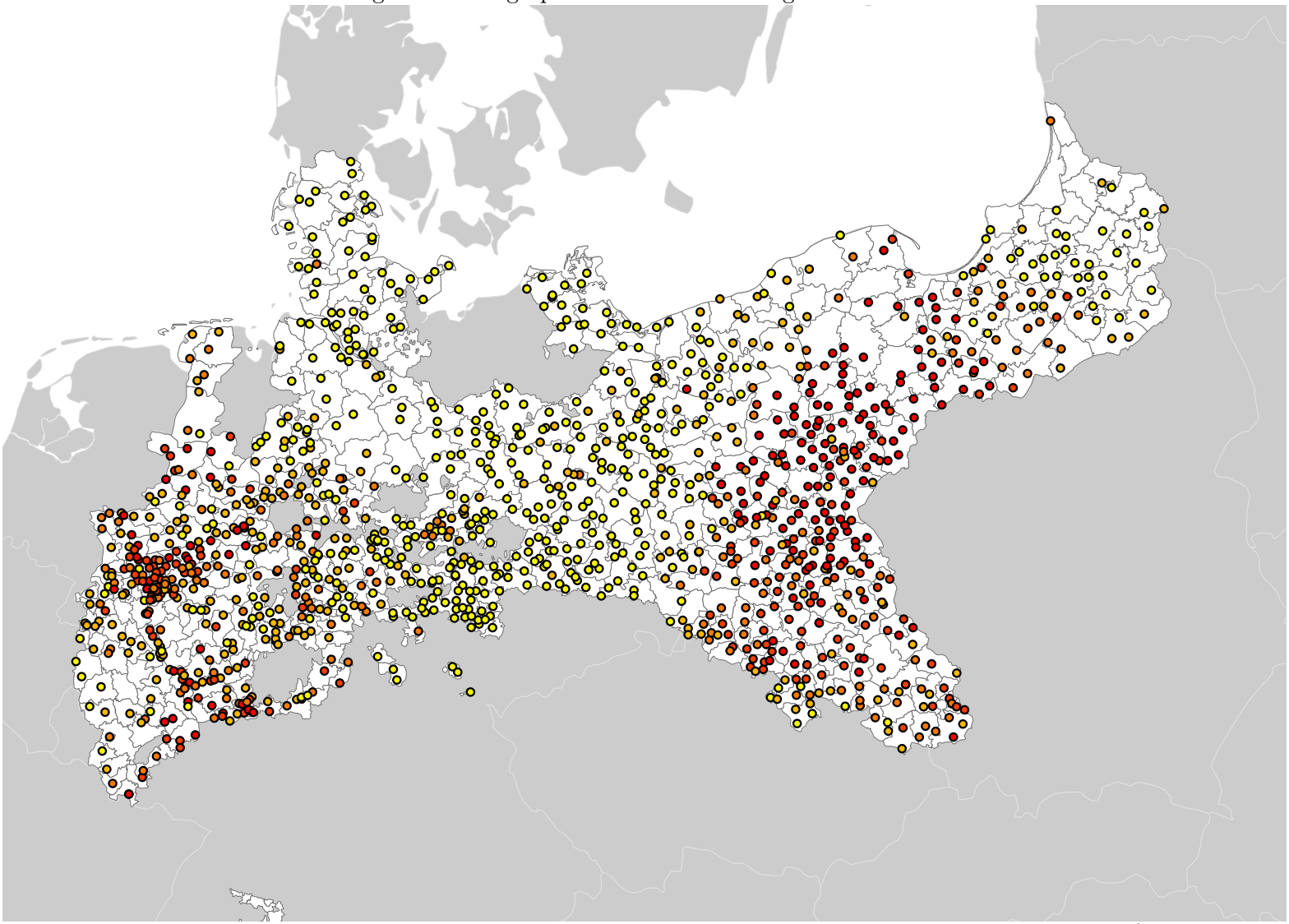
Figure 1: Geographic distribution of cities



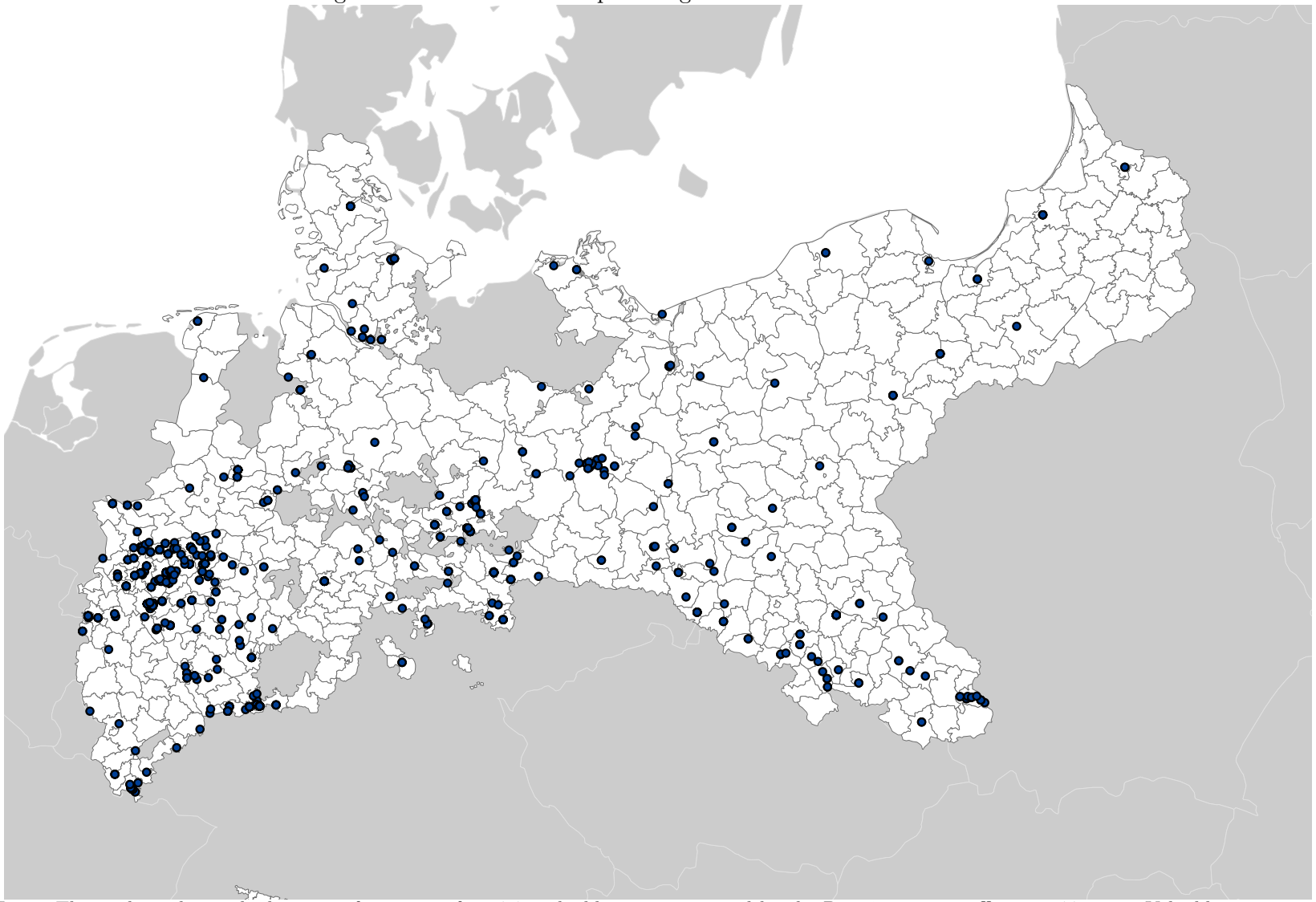
Notes: The sample consists of 1,278 cities from the 1871 Prussian population census. The map displays also county borders as in 1871.

Figure 2: Geographic distribution of religious tolerance



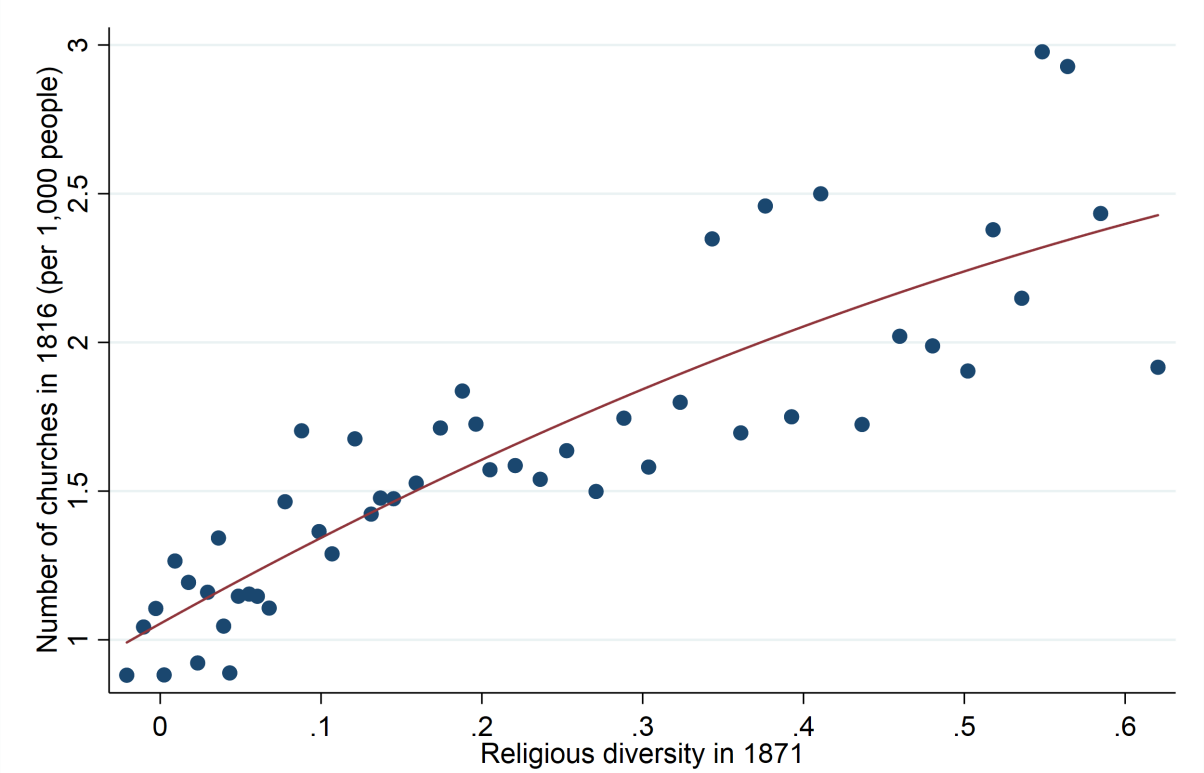
Notes: 1,278 cities from the 1871 Prussian population census. Religious tolerance is measured through the fractionalization index (1−Herfindahl index). The scale goes from light yellow (low diversity) to dark red (high diversity). The denominations reported in the 1871 population census are: Protestant, Catholic, other Christian religion, Jewish, other religion.

Figure 3: Stock of valuable patents granted in Prussia in 1877-1890



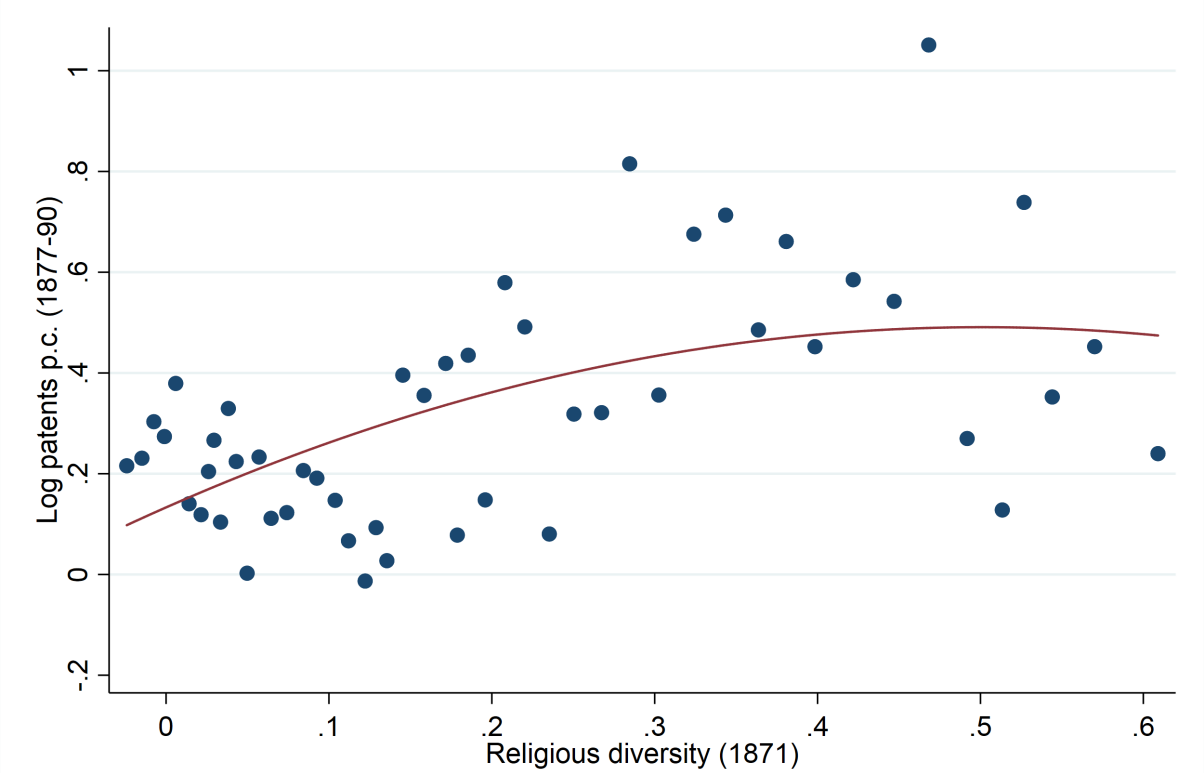
Notes: The circles indicate the location of patentees for 1,740 valuable patents granted by the Prussian patent office in 1877-1890. Valuable patents are patents which have been renewed for at least 10 years.

Figure 4: Religious diversity in 1871 and number of churches in 1816



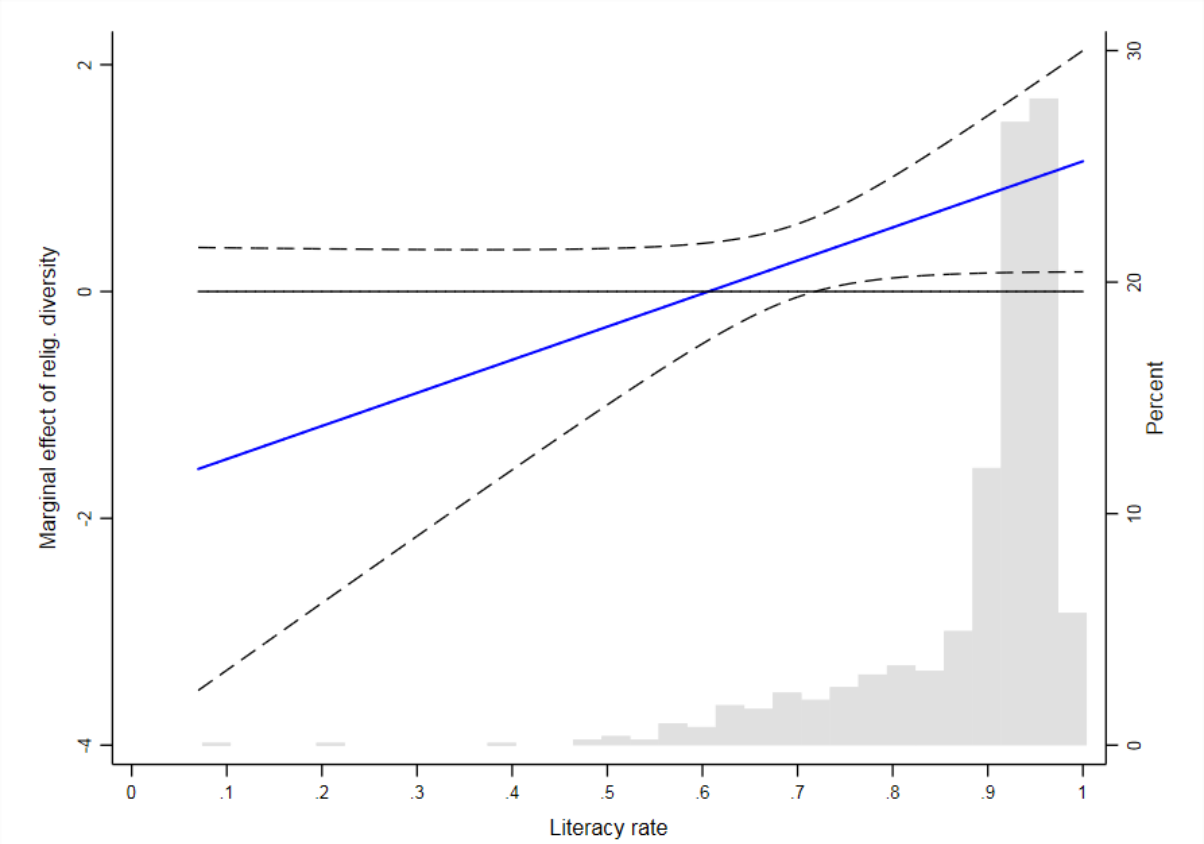
Notes: Binned scatterplot with quadratic fit based on 50 equally-sized bins controlling for the number of denominations (fixed effects) and cities west of the river Elbe. The sample consists of 946 cities.

Figure 5: Religious diversity in 1871 and log patents p.c. in 1877-90



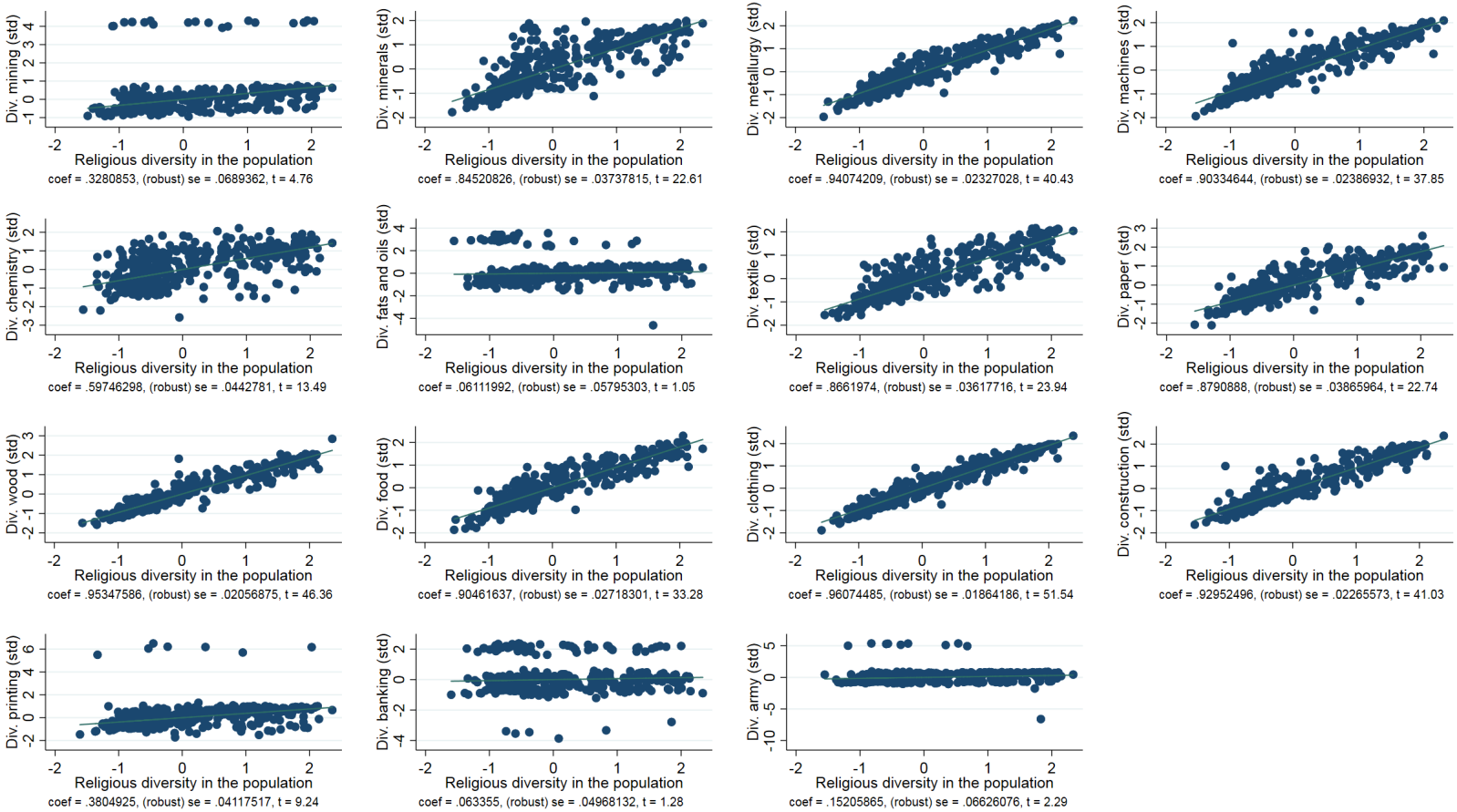
Notes: Binned scatterplot with quadratic fit based on 50 equally-sized bins controlling for the number of denominations (fixed effects) and cities west of the river Elbe. The sample consists of 1,278 cities.

Figure 6: Marginal effects of religious diversity interacted with the literacy rate



Notes: The figure plots the marginal effects of the interaction of religious diversity with the literacy rate against the literacy rate. The marginal effects are based on the estimates in Table 2, column 5. Dashed lines represents 95% confidence intervals. The underlying histogram shows the distribution of literacy across cities.

Figure 7: Population religious diversity and religious diversity of the workforce employed in selected industrial and service sectors



Notes: Added variable plots based on OLS regressions at county level (Table A.6 in the appendix). The dependent variable is the religious diversity of the workforce employed in the given industrial or service sector in 1882. The variable of interest is religious diversity of the county population in 1871. Unit of observations are 452 counties. The industrial sectors considered are: mining, minerals, metallurgy, machine building, chemistry, fats and oils refining, textile, paper and leather, wood, food processing, clothing, construction, and printing. The service sectors are banking and military. Control variables (measured in 1871) used in the regressions are: the share of people employed in the relative sector, literacy rate, land inequality, urbanization rate, population density, dummy for counties west of the river Elbe, and fixed effects for the number of religious groups in the county.

Table 1: Religious tolerance and innovation — Evidence across cities, within county

Dep. var.: Log patents p.c. (1877-90)				Non-linearity	
	(1)	(2)	(3)	(4)	(5)
Relig. diversity	1.062***	0.804***	0.680**	1.977***	
	(0.183)	(0.286)	(0.278)	(0.648)	
Relig. diversity sq.				-2.038**	
				(0.856)	
Relig. diversity (2nd quartile)					0.037
					(0.069)
Relig. diversity (3rd quartile)					0.274***
					(0.101)
Relig. diversity (4th quartile)					0.372***
					(0.134)
Literacy rate	1.630***	0.814*	0.707	0.719	0.750
	(0.245)	(0.446)	(0.470)	(0.481)	(0.488)
West Elbe	0.341***				
	(0.059)				
1 denomination			-0.253	-0.212	-0.262
			(0.285)	(0.290)	(0.288)
2 denominations			0.070	0.090	0.065
			(0.109)	(0.109)	(0.110)
4 denominations			0.167***	0.158***	0.164***
			(0.052)	(0.052)	(0.053)
5 denominations			0.210	0.196	0.181
			(0.129)	(0.126)	(0.128)
County FE	No	Yes	Yes	Yes	Yes
Observations	1278	1278	1278	1278	1278
R-squared	0.12	0.02	0.03	0.04	0.04
R-squared (within)		0.02	0.03	0.04	0.04

Notes: OLS estimates with county fixed effects (columns 2-5). The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table 2: Religious tolerance and innovation — Sample split by religious majority

Dep. var.: Log patents p.c. (1877-90)	Protestant majority		Catholic majority		Complementarity with literacy
	(1)	(2)	(3)	(4)	(5)
Relig. diversity	1.244**	1.128**	0.732**	0.661**	0.823**
	(0.538)	(0.532)	(0.314)	(0.317)	(0.338)
Literacy rate	2.434***	2.184***	-0.243	-0.315	-0.326
	(0.420)	(0.482)	(0.300)	(0.308)	(0.729)
Relig. diversity x Literacy rate					2.918*
					(1.562)
Number of denominations FE	No	Yes	No	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes
Observations	904	904	373	373	1278
R-squared (within)	0.04	0.05	0.02	0.03	0.04
Number of patents	2.23	2.23	1.66	1.66	
Mean diversity	0.17	0.17	0.30	0.30	

Notes: OLS estimates with county fixed effects. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table 3: Religious tolerance and innovation — Accounting for preindustrial conditions

Dep. var.: Log patents p.c. (1877-90)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Relig. diversity	0.678**	0.674**	0.677**	0.919***	0.666**	0.689**	0.916**
	(0.278)	(0.278)	(0.278)	(0.353)	(0.281)	(0.281)	(0.360)
Imperial city (dummy)	0.081						-0.003
	(0.239)						(0.251)
Hanseatic city (dummy)		0.073					0.054
		(0.090)					(0.091)
University (1700-1830)			0.253				0.205
			(0.385)				(0.379)
Share Jews				-1.475**			-1.493**
				(0.608)			(0.616)
Jews persecution (dummy)					0.094		0.096
					(0.100)		(0.103)
Huguenots colony (dummy)						-0.070	-0.133
						(0.150)	(0.143)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of denominations FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1278	1278	1278	1278	1278	1278	1278
R-squared (within)	0.03	0.04	0.04	0.04	0.04	0.04	0.04

Notes: OLS estimates with county fixed effects and fixed effects for the number of denominations. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Controls are: the literacy rate and an indicator variable for cities west of the river Elbe. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table 4: Religious denomination of students in secondary schools

Dep. var.: Log patents p.c. (1877-90)	(1)	(2)	(3)	(4)
Relig. diversity	0.612**	0.620**	0.691**	
	(0.252)	(0.246)	(0.286)	
Relig. diversity (2nd quartile)				0.146
				(0.117)
Relig. diversity (3rd quartile)				0.265**
				(0.130)
Relig. diversity (4th quartile)				0.309**
				(0.151)
West Elbe	0.434***	0.452***	0.158	0.137
	(0.096)	(0.091)	(0.121)	(0.126)
Number of secondary schools		0.155***	0.137***	0.133***
		(0.047)	(0.051)	(0.051)
Share students in secondary education		0.305	0.349	0.333
		(0.856)	(0.834)	(0.822)
Distance to nearest river			-0.003*	-0.003**
			(0.002)	(0.002)
Distance to nearest medieval route			-0.001**	-0.001***
			(0.001)	(0.001)
Distance to nearest Imperial city			-0.001**	-0.001*
			(0.000)	(0.000)
Distance to nearest university			-0.001*	-0.001*
			(0.000)	(0.000)
Observations	307	307	307	307
R-squared	0.08	0.14	0.18	0.17
Number of patents	5.3	5.3	5.3	5.3

Notes: OLS estimates. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index), computed at the school level and averaged at the city level. Religious diversity refers to the students enrolled in secondary schools in the winter semester 1873/74. The three denominations are: Protestant, Catholic, and Jewish. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table 5: Religious tolerance and innovation — Evidence from large towns in 1816

Dep. var.: Log patents p.c. (1877-90)	Large towns 1816		Large towns 1816		Large & small towns 1816	
	(1)	(2)	(3)	(4)	(5)	(6)
Diversity of churches	0.598**	0.484*				
	(0.232)	(0.263)				
Diversity of preachers			0.851***	0.763***		
			(0.279)	(0.277)		
Relig. diversity					0.340**	0.199*
					(0.132)	(0.112)
West Elbe	0.683***	0.592***	0.666***	0.578***	0.538***	0.322***
	(0.126)	(0.130)	(0.120)	(0.126)	(0.071)	(0.062)
Share Catholics	-0.105	-0.154	-0.020	-0.079		
	(0.186)	(0.186)	(0.178)	(0.180)		
Share Jews	-1.400***	-0.732**	-1.273***	-0.666*		
	(0.302)	(0.337)	(0.298)	(0.345)		
Teachers per 100 children (0-14)		0.524***		0.503**		0.991***
		(0.200)		(0.208)		(0.224)
Factories p.c.		0.016*		0.014		0.024**
		(0.009)		(0.009)		(0.011)
Share merchants		-0.143***		-0.149***		-0.111**
		(0.055)		(0.053)		(0.049)
Share craftsmen		-0.053		-0.056		0.020
		(0.058)		(0.054)		(0.027)
Looms p.c.		-0.001		-0.002		0.001
		(0.003)		(0.003)		(0.003)
Observations	166	153	166	153	929	868
R-squared	0.23	0.27	0.24	0.29	0.12	0.17

Notes: OLS estimates. The dependent variable is the log number of valuable patents p.c. +1 granted by the Prussian patent office in 1877-1890. Diversity of churches in columns 1 and 2 is based on the number of Lutheran churches, Calvinist churches, Catholic churches, and Jewish synagogues. Diversity of preachers in columns 3 and 4 is based on the number of preachers and religious teachers of the following denominations: Lutheran, Calvinist, and Catholic. Religious diversity of the population in columns 5 and 6 is based on the denomination of the 1816 population divided in Lutheran, Calvinist, Catholic, and Jewish. All diversity indexes are measured through the fractionalization index (1−Herfindahl index). Robust standard errors in parenthesis are clustered by county. Significance at * 10, ** 5, *** 1 percent.

Table 6: Religious tolerance and innovation — The role of migration

Dependent variable:	Sh. migrants	Log patents p.c. (1877-90)		Log patents p.c. (1877-90)	
	(1)	(2)	(3)	(4)	(5)
Relig. diversity (1871)	0.308***	0.700**	0.326		
	(0.031)	(0.287)	(0.268)		
Diversity of churches (1816)				0.343	
				(0.277)	
Diversity of preachers (1816)					0.600**
					(0.302)
Share of migrants (1871)			1.214***	1.274*	1.036
			(0.347)	(0.718)	(0.720)
Controls	Yes	Yes	Yes	No	No
Number of denominations FE	Yes	Yes	Yes	No	No
County FE	Yes	Yes	Yes	No	No
Controls 1816	No	No	No	Yes	Yes
Observations	1238	1238	1238	152	152
R-squared	0.23	0.03	0.06	0.28	0.29
R-squared (within)	0.23	0.03	0.06		

Notes: OLS estimates with county fixed effects and fixed effects for the number of denominations. The dependent variable in column 1 is the share of people in 1871 born outside the municipality. The dependent variable in columns 2-5 is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity in columns 1-3 is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Diversity of churches in column 4 is based on the number of Lutheran churches, Calvinist churches, Catholic churches, and Jewish synagogues. Diversity of preachers in column 5 is based on the number of preachers and religious teachers of the following denominations: Lutheran, Calvinist, and Catholic. Controls are: the literacy rate and an indicator variable for cities west of the river Elbe. Controls for 1816 in columns 4 and 5 are: the number of factories, mills, and warehouses per 1,000 people; the share of traders and merchants in the population; the share of craftsmen in the population; the number of textile looms per 1,000 people. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table 7: Religious tolerance and innovation — County level estimates

Dep. var.: Log patents p.c. (1877-90)	Religious diversity				Linguistic diversity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Relig. diversity	0.410***	0.307***	1.154***				
	(0.115)	(0.100)	(0.387)				
Relig. diversity sq.			-1.654**				
			(0.783)				
Relig. diversity (2nd quartile)				0.089**			
				(0.036)			
Relig. diversity (3rd quartile)				0.160***			
				(0.041)			
Relig. diversity (4th quartile)				0.171***			
				(0.047)			
Ling. diversity					-0.087	-0.289	
					(0.120)	(0.407)	
Ling. diversity sq.						0.416	
						(0.686)	
Ling. diversity (4th quartile)							-0.103**
							(0.046)
Literacy rate		-0.064	-0.009	-0.017	-0.373*	-0.415*	-0.586***
		(0.160)	(0.156)	(0.159)	(0.213)	(0.252)	(0.212)
Land inequality		-0.015	-0.003	-0.001	-0.025	-0.026	-0.030
		(0.024)	(0.023)	(0.024)	(0.024)	(0.025)	(0.024)
Urbanization rate		0.009***	0.009***	0.009***	0.010***	0.010***	0.010***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Population density		0.001	0.001	0.001	0.002	0.002	0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
West Elbe		0.182***	0.196***	0.197***	0.177***	0.175***	0.165***
		(0.048)	(0.049)	(0.048)	(0.048)	(0.049)	(0.048)
Number of denominations FE	No	Yes	Yes	Yes	No	No	No
Observations	453	452	452	452	452	452	452
R-squared	0.08	0.39	0.40	0.40	0.37	0.37	0.38

Notes: OLS estimates. Unit of observation is the county. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index) and is based on the following denominations: Protestant, Catholic, other Christian religion, Jewish, other religion. Linguistic diversity is measured through the fractionalization index (1−Herfindahl index) and is based on the following languages: German, Polish, Lithuanian, Wendish, Slavic, Danish, and a residual category. Standard errors are clustered by district (*Regierungsbezirk*). Significance at * 10, ** 5, *** 1 percent.

Table 8: Religious tolerance and innovation — Literacy by denomination

Dep. var.: Log patents p.c. (1877-90)	(1)	(2)	(3)	(4)	(5)	(6)
Relig. diversity	0.324***	0.312***	0.340***	0.330***	0.453***	0.483***
	(0.093)	(0.095)	(0.097)	(0.098)	(0.131)	(0.139)
Share Protestants illiterate	-0.151			-0.306		-0.399
	(0.229)			(0.398)		(0.617)
Share Catholics illiterate		0.033		0.256		0.434*
		(0.101)		(0.174)		(0.244)
Share Jews illiterate			-0.287	-0.429		-1.026*
			(0.243)	(0.338)		(0.566)
Log spending secondary educ.					0.040**	0.036*
					(0.018)	(0.019)
Land inequality	-0.010	-0.014	-0.008	-0.005	-0.015	-0.004
	(0.024)	(0.023)	(0.023)	(0.025)	(0.033)	(0.037)
Urbanization rate	0.009***	0.009***	0.009***	0.009***	0.008***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Population density	0.001	0.001	0.001	0.001	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
West Elbe	0.170***	0.181***	0.174***	0.183***	0.222***	0.234***
	(0.048)	(0.049)	(0.046)	(0.050)	(0.066)	(0.070)
Number of denominations FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	452	452	452	452	296	296
R-squared	0.39	0.39	0.39	0.40	0.41	0.41

Notes: OLS estimates. Unit of observation is the county. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index) and is based on the following denominations: Protestant, Catholic, other Christian religion, Jewish, other religion. Standard errors are clustered by district (*Regierungsbezirk*). Significance at * 10, ** 5, *** 1 percent.

Table 9: Accounting for employment in high-patenting sectors

Dep. var.: Log patents p.c. (1877-90)	(1)	(2)	(3)	(4)
Relig. diversity	0.278***	0.282***	0.237***	0.181**
	(0.099)	(0.100)	(0.087)	(0.084)
Perc. working in metallurgy (1882)	0.064**			0.066**
	(0.028)			(0.026)
Perc. working in chemistry (1882)		0.540***		0.541***
		(0.133)		(0.125)
Perc. working in bank and insurance (1882)			2.018***	2.095***
			(0.479)	(0.451)
Controls	Yes	Yes	Yes	Yes
Number of denominations FE	Yes	Yes	Yes	Yes
Observations	452	452	452	452
R-squared	0.42	0.43	0.47	0.53

Notes: OLS estimates. Unit of observation is the county. The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index) and is based on the following denominations: Protestant, Catholic, other Christian religion, Jewish, other religion. Controls are the literacy rate, land inequality, urbanization rate, population density, and an indicator for counties west of the river Elbe. Standard errors are clustered by district (*Regierungsbezirk*). Significance at * 10, ** 5, *** 1 percent.

Table 10: Religious tolerance and income-tax revenues

Dependent variable:	Log income tax revenues p.c. (1899-1903)		
	(1)	(2)	(3)
Relig. diversity	0.229*	1.511***	
	(0.120)	(0.374)	
Relig. diversity sq.		-2.503***	
		(0.764)	
Relig. diversity (2nd quartile)			0.110**
			(0.045)
Relig. diversity (3rd quartile)			0.214***
			(0.045)
Relig. diversity (4th quartile)			0.152***
			(0.056)
Controls	Yes	Yes	Yes
Number of denominations FE	Yes	Yes	Yes
Observations	452	452	452
R-squared	0.66	0.67	0.67

Notes: OLS estimates. Unit of observation is the county. The dependent variable is the log of average income-tax revenues for the years 1899-1903. Religious diversity is measured through the fractionalization index (1−Herfindahl index) and is based on the following denominations: Protestant, Catholic, other Christian religion, Jewish, other religion. Controls are the literacy rate, land inequality, urbanization rate, population density, and an indicator for counties west of the river Elbe. Standard errors are clustered by district (*Regierungsbezirk*). Significance at * 10, ** 5, *** 1 percent.

Appendix A Summary statistics and supplementary results

Table A.1: Descriptive statistics

City level variables (1871)	Obs.	Mean	Std. dev.	Min.	Max.
Number of patents	1278	2.06	15.34	0.00	461.00
Religious diversity	1278	0.21	0.19	0.00	0.67
Share Protestants	1278	0.67	0.36	0.00	1.00
Share Catholics	1278	0.29	0.35	0.00	1.00
Share other Christians	1278	0.00	0.00	0.00	0.05
Share Jews	1278	0.04	0.05	0.00	0.41
Share non religious	1278	0.00	0.00	0.00	0.00
Jews persecutions (dummy)	1278	0.06	0.24	0.00	1.00
Population size	1278	6,223	25,671	251	825975
Literacy rate	1278	0.89	0.10	0.07	1.00
Share of migrants	1238	0.42	0.12	0.08	0.86
West Elbe (dummy)	1278	0.45	0.50	0.00	1.00
Hanseatic League (dummy)	1278	0.12	0.32	0.00	1.00
Free Imperial city (dummy)	1278	0.01	0.11	0.00	1.00
University 1700-1830 (dummy)	1278	0.01	0.12	0.00	1.00
County level variables (1871)					
Number of patents	452	3.84	23.99	0.00	464.00
Religious diversity	452	0.19	0.18	0.00	0.59
Share Protestants	452	0.64	0.38	0.00	1.00
Share of Catholics	452	0.34	0.38	0.00	1.00
Share other Christian	452	0.00	0.01	0.00	0.09
Share Jews	452	0.01	0.01	0.00	0.13
Share other religion	452	0.00	0.00	0.00	0.00
Linguistic diversity	452	0.07	0.15	0.00	0.60
Literacy rate	452	0.65	0.11	0.26	0.82
Population size	452	54,424	42,079	11,609	826,341
Population density	452	3.36	14.33	0.21	167.84
Urbanization rate	452	0.28	0.22	0.00	1.00
Landownership concentration (standardized)	452	−0.00	1.00	−0.91	6.64
Share employed in manufacturing	452	0.28	0.13	0.06	0.72
Share employed in services	452	0.03	0.02	0.01	0.12
Log income-tax revenues p.c. (1901)	452	0.94	0.61	−0.51	3.19
Log spending higher education p.c. (1883)	296	−1.71	1.50	−7.80	2.11

Table A.2: Religious tolerance and innovation — Patents assigned within 2 km radius

Dep. var.: Log patents p.c. (1877-90)	(1)	(2)	(3)	(4)	(5)
Relig. diversity	0.726***	0.635***	0.508**	1.201**	
	(0.131)	(0.203)	(0.202)	(0.493)	
Relig. diversity sq.				-1.089	
				(0.705)	
Relig. diversity (2nd quartile)					0.008
					(0.055)
Relig. diversity (3rd quartile)					0.072
					(0.077)
Relig. diversity (4th quartile)					0.235**
					(0.097)
Literacy rate	1.190***	0.985***	0.885***	0.892***	0.902***
	(0.191)	(0.319)	(0.323)	(0.328)	(0.331)
West Elbe	0.143***				
	(0.040)				
Number of denominations FE	No	No	Yes	Yes	Yes
County FE	No	Yes	Yes	Yes	Yes
Observations	1278	1278	1278	1278	1278
R-squared	0.08	0.03	0.04	0.05	0.05
R-squared (within)		0.03	0.04	0.05	0.05
Max	1.27				

Notes: OLS estimates with county fixed effects (columns 2-5). The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table A.3: Religious tolerance and innovation — Dependent variable without log

Dep. var.: Patents p.c. (1877-90)				Non-linearity	
	(1)	(2)	(3)	(4)	(5)
Relig. diversity	5.841***	4.606*	4.353*	9.793**	
	(1.423)	(2.420)	(2.395)	(4.333)	
Relig. diversity sq.				-8.551	
				(5.377)	
Relig. diversity (2nd quartile)					0.112
					(0.391)
Relig. diversity (3rd quartile)					1.027
					(0.891)
Relig. diversity (4th quartile)					2.000
					(1.309)
Literacy rate	7.759***	4.502*	4.322	4.377	4.565
	(1.847)	(2.466)	(2.752)	(2.790)	(2.798)
West Elbe	2.270***				
	(0.399)				
1 denomination			-0.817	-0.644	-0.928
			(1.260)	(1.287)	(1.262)
2 denominations			1.004	1.089	0.949
			(0.811)	(0.817)	(0.811)
4 denominations			0.905**	0.865**	0.916**
			(0.395)	(0.396)	(0.419)
5 denominations			-2.842	-2.899	-2.957
			(2.248)	(2.245)	(2.212)
County FE	No	Yes	Yes	Yes	Yes
Observations	1276	1276	1276	1276	1276
R-squared	0.06	0.01	0.02	0.02	0.02
R-squared (within)		0.01	0.02	0.02	0.02

Notes: OLS estimates with county fixed effects (columns 2-5). The dependent variable is the absolute number of patents p.c. +1 granted by the Prussian patent office in 1877-1890. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. The cities of Hoechst am Main and Hundsfeld with, respectively, 201 and 293 patents per 1,000 people have been dropped as outliers. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table A.4: Religious tolerance and innovation — Stock of patents 1877-1900

Dep. var.: Log patents p.c. (1877-1900)				Non-linearity	
	(1)	(2)	(3)	(4)	(5)
Relig. diversity	1.387***	1.259***	1.012***	3.248***	
	(0.240)	(0.350)	(0.338)	(0.897)	
Relig. diversity sq.				-3.513***	
				(1.186)	
Relig. diversity (2nd quartile)					0.115
					(0.095)
Relig. diversity (3rd quartile)					0.499***
					(0.139)
Relig. diversity (4th quartile)					0.614***
					(0.173)
Literacy rate	2.177***	0.395	0.186	0.208	0.254
	(0.431)	(0.959)	(0.978)	(0.994)	(1.011)
West Elbe	0.470***				
	(0.081)				
1 denomination			-0.224	-0.153	-0.219
			(0.340)	(0.348)	(0.345)
2 denominations			0.073	0.108	0.073
			(0.145)	(0.145)	(0.147)
4 denominations			0.317***	0.301***	0.307***
			(0.071)	(0.071)	(0.072)
5 denominations			0.384**	0.360*	0.335*
			(0.192)	(0.187)	(0.191)
County FE	No	Yes	Yes	Yes	Yes
Observations	1278	1278	1278	1278	1278
R-squared	0.13	0.02	0.05	0.06	0.06
R-squared (within)		0.02	0.05	0.06	0.06
Average number of patents	5.44				

Notes: OLS estimates with county fixed effects (columns 2-5). The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1900. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table A.5: Religious tolerance and innovation — Stock of patents 1877-1914

Dep. var.: Log patents p.c. (1877-1914)				Non-linearity	
	(1)	(2)	(3)	(4)	(5)
Relig. diversity	1.883***	1.743***	1.408***	4.761***	
	(0.321)	(0.473)	(0.462)	(1.358)	
Relig. diversity sq.				-5.267***	
				(1.830)	
Relig. diversity (2nd quartile)					0.125
					(0.152)
Relig. diversity (3rd quartile)					0.741***
					(0.215)
Relig. diversity (4th quartile)					0.852***
					(0.249)
Literacy rate	3.055***	0.470	0.183	0.215	0.286
	(0.545)	(0.994)	(1.024)	(1.044)	(1.072)
West Elbe	0.786***				
	(0.114)				
1 denomination			0.054	0.161	0.055
			(0.671)	(0.690)	(0.683)
2 denominations			0.130	0.182	0.128
			(0.176)	(0.177)	(0.177)
4 denominations			0.453***	0.428***	0.439***
			(0.095)	(0.095)	(0.096)
5 denominations			0.502**	0.467**	0.430**
			(0.206)	(0.198)	(0.204)
County FE	No	Yes	Yes	Yes	Yes
Observations	1278	1278	1278	1278	1278
R-squared	0.16	0.02	0.06	0.07	0.07
R-squared (within)		0.02	0.06	0.07	0.07
Average number of patents	17.92				

Notes: OLS estimates with county fixed effects (columns 2-5). The dependent variable is the log number of patents p.c. +1 granted by the Prussian patent office in 1877-1914. Religious diversity is measured through the fractionalization index (1−Herfindahl index). The five religious denominations are: Protestant, Catholic, other Christian religion, Jewish, other religion. Robust standard errors in parenthesis. Significance at * 10, ** 5, *** 1 percent.

Table A.6: Overall religious diversity and religious diversity of workforce by sector

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Relig. div. (std)	0.328***	0.845***	0.941***	0.903***	0.597***	0.061	0.866***	0.879***	0.953***	0.905***	0.961***	0.930***	0.380***	0.063	0.152**
	(0.069)	(0.037)	(0.023)	(0.024)	(0.044)	(0.058)	(0.036)	(0.039)	(0.021)	(0.027)	(0.019)	(0.023)	(0.041)	(0.050)	(0.066)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. denom. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	452	452	452	452	452	452	452	452	452	452	452	452	452	452	452
R-squared	0.11	0.70	0.92	0.88	0.44	0.11	0.81	0.80	0.93	0.88	0.95	0.91	0.17	0.04	0.05

Notes: OLS estimates. Unit of observation is the county. The dependent variable is the index of religious diversity of the workforce in the respective sector. The sectors are: (1) mining, (2) minerals, (3) metallurgy, (4) machine building, (5) chemistry, (6) fats and oils refining, (7) textile, (8) paper and leather, (9) wood, (10) food processing, (11) clothing, (12) construction, (13) printing, (14) financial sector, (15) and army. The independent variable is the population religious diversity measured through the fractionalization index (1−Herfindahl index) and based on the following denominations: Protestant, Catholic, other Christian religion, Jewish, other religion. Population religious diversity is standardized at zero mean and unit standard deviation. Controls are: the share of people employed in the relative sector, the literacy rate, land inequality, urbanization rate, population density, and the indicator for counties west of the river Elbe. Standard errors are clustered by district (*Regierungsbezirk*). Significance at * 10, ** 5, *** 1 percent.