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FLOW OF IDEAS: ECONOMIC SOCIETIES AND THE RISE OF USEFUL KNOWLEDGE*

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Economic societies emerged during the late eighteenth century. We argue that these institutions reduced the costs of accessing useful knowledge by adopting, producing and diffusing new ideas. Combining location information for the universe of 3,300 members across active economic societies in Germany with those of patent holders and World's Fair exhibitors, we show that regions with more members were more innovative in the late nineteenth century. This long-lasting effect of societies arguably arose through agglomeration economies and localised knowledge spillovers. To support this claim, we provide evidence suggesting an immediate increase in manufacturing, an earlier establishment of vocational schools and a higher density of highly skilled mechanical workers by the mid-nineteenth century in regions with more members. We also show that regions with members from the same society had higher similarity in industrial production and patenting, suggesting that societies facilitated spatial knowledge diffusion and, to some extent, shaped the direction of technological progress.

JEL codes: N33, O33, O31, O43

Technological progress is central to economic growth. Prior to modern growth, technological advances resulted from tinkering rather than directed research and were not informed by scientific methods. During the Industrial Revolution, inventors increasingly relied on the methods and ideas brought about by the Enlightenment and the Scientific Revolution.[1] The shift towards using scientific methods, e.g., measurement, replication and experimentation, arguably changed the way engineers and mechanics of the time improved technologies and invented new ones. Access to such useful knowledge became crucial to push the technological frontier. To what extent access

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[1] For details on the scientific knowledge of engineers and entrepreneurs during the Industrial Revolution and their (lack of) formal education, see, e.g., Allen (2009), Mokyr (2009), Meisenzahl and Mokyr (2012), Jacob (2014) and Ó Gráda (2016).

to new knowledge affected technological change during the Industrial Revolution is ultimately an empirical question that is hard to answer in the absence of systematic data.[2]

In this paper, we focus on economic societies, institutions committed to improving the local economy by adopting, producing and diffusing useful knowledge, and investigate how they created an environment conducive to innovation during the subsequent Industrial Revolution. Economic societies emerged during the eighteenth century all across Europe. They collected, systematised and promoted the diffusion of useful knowledge among their members, thereby arguably facilitating innovation and technological progress in the long run.[3] To do so, societies held regular meetings with debates and public lectures, held contests with prizes awarding innovations, published periodicals with articles discussing recent advances in useful knowledge and maintained substantial libraries providing members with access to recent scientific books. Several economic societies also established educational institutions instrumental to the training of mechanically skilled individuals. In addition, economic societies contributed to an increasing flow of ideas because their members formed a social network in which barriers to communication were low. In line with Mokyr (2005), we thus argue that economic societies reduced the costs of accessing new useful knowledge and created local conditions that subsequently facilitated the technological progress central to the Industrial Revolution.

This paper presents evidence on the impact of economic societies on industrialisation and innovation in the long run in Germany.[4] Despite their late adoption, Germany provides an ideal setting to study the impact of economic societies for two reasons. First, in contrast to other countries such as Britain and France, where the spatial location of societies concentrated on commercially active capital cities, the process was highly decentralised in Germany. Here, economic societies were created across polities of different sizes and with a considerable spatial distribution of membership. Second, most economic societies were established within a short time period in response to the Seven Years' War (1756–63). Facing significant deprivation and population losses, several local rulers issued decrees for the establishment and operation of economic societies to facilitate economic activity. Such initiatives closely aligned with the cameralist approach of the time, which advocated for state intervention. The highly decentralised formation process, in combination with the absence of comparable institutions prior to the Seven Years' War facilitates our econometric approach to identify the local impact of societies.

To quantify the contribution of economic societies to industrialisation and innovation, we use hand-collected information from membership registers across the universe of active economic societies established between 1764 and 1800 in Germany. We geo-referenced the location of more than 3,300 individual members organised in fifteen societies, which reflects variation in access to useful knowledge across space. To combine this information with geo-referenced measures of innovation, we aggregate our data to 2,698 grid cells of 15×15 km^2 size (equivalent to $0.1^\circ \times 0.1^\circ$ at the equator) encompassing Germany in its 1871 borders. To estimate the long-term impact of societies at the local level, we measure innovation in two ways, either by the

[2] Thus far, the literature has presented econometric evidence on innovative activities undertaken by individuals with formal training in occupations with useful knowledge (see, e.g., Maloney and Caicedo, 2022; Mokyr *et al.*, 2022) or the growth effects of individuals that had access to a specific body of useful knowledge, such as Diderot's Encyclopédie (see, e.g., Squicciarini and Voigtländer, 2015).

[3] For historian's perspectives on economic societies, see Lowood (1991), Stapelbroek and Marjanen (2012) or Howes (2020).

[4] For simplicity, we refer to the territory of interest in this paper as Germany, despite the fact that it changed its name and borders several times during the eighteenth and nineteenth centuries. In the quantitative analysis, we focus on the German Empire in its 1871 borders.

number of patents granted in Germany in the period 1877–1914 or by the number of German exhibitors at the 1873 World's Fair in Vienna.

Our analysis reveals a significant positive relationship between the local density of economic society members and innovation during the Second Industrial Revolution in Germany. Specifically, we find that doubling the local density of society members is associated with a 21% increase in the density of valuable patents. Furthermore, we observe a similar pattern when examining the density of exhibitors at the 1873 Vienna World's Fair. Doubling the local density of society members is associated with a 16% increase in the density of exhibitors at the fair. This suggests that the presence and interaction of society members contributed to a higher level of innovative activity in the region. Importantly, these results remain robust even after controlling for various factors, including polity fixed effects to account for reforms coinciding with the emergence of societies at the polity level and pre-existing levels of development. Additionally, we incorporate society fixed effects to account for any heterogeneity in membership acquisition, timing and activities across different societies. Results also hold in a sample of 191 cells that include a city with more than 5,000 inhabitants in 1750.

We address the concern that society members are not randomly distributed across space by exploiting exogenous variation in distance to the nearest society seat, the location where all society activities took place. Because the costs of participating in society activities, such as debates and official meetings, arguably increase in distance to the society seat, membership density is found to be lower in grid cells further away from the seat. Identification assumes that distance to the nearest society seat would be (conditionally) excludable from a regression of innovation on society members.[5] We provide both historical and econometric evidence in support of the exclusion restriction. In line with the existing historical literature (e.g., Bödeker, 2012), we argue that the seats of economic societies in Germany were not systematically selected based on their association with commercial or educational centres. We provide balancedness tests to support this claim, demonstrating that the distribution of society seats is not biased towards specific geographic locations with a concentration of economic or educational activities. Furthermore, we present evidence that, independent of their distance to the nearest society seat, regions were on similar trends with respect to the attraction and presence of upper-tail human capital prior to the emergence of societies. For this purpose, we exploit information from biographies of about 6,500 notable individuals listed in the *Deutsche Biographie* (Bayerische Akademie der Wissenschaften, 2021) in an event-study setup and show that our instrumental variable is unrelated to pre-existing trends in the attraction and presence of such individuals. When using distance to the nearest society seat as an instrumental variable, OLS findings are confirmed with elasticities increasing to 25%.

We undertake several exercises to investigate the channels linking the emergence of economic societies during the last third of the eighteenth century with innovation during the late nineteenth and early twentieth centuries. We start by providing evidence for the immediate effects of societies on economic activity. Using a list of new manufactories established in Saxony from the late sixteenth to early nineteenth century, we find significantly more of these proto-industrial establishments in regions with more members after 1764. This increase is largely borne by manufactories in textile production, a special focus of the Saxon society that offered several prize competitions for improvements in textile materials and production processes. We argue

[5] When interpreting the emergence of societies as a shock to useful knowledge that occurred after 1763, one would also need to assume that regions followed common trends, independent of their distance to the nearest society seat, in the absence of societies.

that the resulting investments in manufacturing led to agglomeration economies and geographic concentration that affected the spatial distribution of economic activity in the long run.

The historical narrative suggests that a lasting impact of economic societies may also result from the creation of vocational schools (Lowood, 1991). Consistent with this narrative, we argue that many economic societies established vocational schools that provided the necessary professional training to generate highly skilled mechanics who played a crucial role in supporting the implementation and maintenance of new technologies. Vocational schools thereby added to agglomeration effects and facilitated the local persistence of technological progress. To test these potential channels, we collected data on the founding years of vocational schools across Germany. Estimates from standard duration models (i.e., Cox proportional hazards models) show that, indeed, the presence of society members in a region accelerated the adoption of vocational schools. Furthermore, using a sample of Prussian cities for which we have detailed information on the occupational structure in 1849, we show that regions with a higher density of society members also have a higher density of highly skilled mechanics, but not of other artisans.

In addition, we present evidence in line with the hypothesis that societies played a pivotal role in the diffusion of ideas among their members. We argue that members collectively held a body of technical knowledge that was unique to their society, which guided their investment in specific industries and technologies promoted by this society. Consequently, from the eighteenth century onwards, regions with members belonging to the same society began to invest in similar industries, leading to a convergence in industrial development and innovation over the long run. To study this hypothesis, we inspect technological similarity in patents between grid-cell pairs ($n \approx 365{,}000$) based on an index proposed by Jaffe (1986) and refined by Bloom *et al.* (2013). When estimating a gravity-type model with grid-cell fixed effects, we find that, conditional on geographic distance, grid-cell pairs with members from the *same* society display a significantly higher technological similarity of their patented innovations. This pattern of similarity is absent in grid-cell pairs with members from *different* societies that likely did not possess a shared, specific body of useful knowledge. This finding suggests that initial differences in the focus of societies and knowledge of their members became path dependent through targeted investments and agglomeration effects. Our estimates suggest that a connection within the social network of a society had an impact on technological similarity equivalent in magnitude to a railroad connection.

To mitigate concerns about reverse causality and to further explore the relationship between society membership and technological similarity, we leverage the panel data on the establishment of new manufactories in Saxony. These data allow us to examine changes in industry similarity across pairs of counties with society members using a dyadic-dynamic difference-in-differences model. Our findings reveal that county pairs with joint membership in the Saxon society experienced a significant increase in the probability of establishing manufactories in the same textile industries following the opening of the society in 1764. Importantly, these changes are only observed after 1764 and not in the periods preceding the formation of the society. These results suggest that similarity increased due to the opening of the Saxon society and did not derive from a pre-existing network of like-minded individuals.

Our paper relates to the debate on the determinants of technical change during the Industrial Revolution. The most prominent contributions emphasise changes in the demand for new technologies driven by the incentives of inventors to mechanise and reduce labour costs (Allen, 2009) or changes in the supply of new technologies driven by the availability of scientific knowledge following the Enlightenment (Mokyr, 2009; 2016).[6] While our focus on Germany does not permit us to say anything about the origins of the British Industrial Revolution, we highlight the importance of low-cost access and diffusion of useful knowledge in the context of industrialisation.

The inventors of the British Industrial Revolution have largely been described as lacking formal education (Allen, 2009; Mokyr, 2009; Jacob, 2014) so that education was deemed irrelevant for the inventions of the early Industrial Revolution in England.[7] More recent scholarship adopts a broader definition of human capital. A new emphasis has been given to the upper tail of the skill distribution that constitutes 3%–5% of the labour force (Meisenzahl and Mokyr, 2012). Within this upper tail, the highly skilled mechanics, so-called ‘tweakers’, seem to have been essential for technological change during the British Industrial Revolution. A study by Mokyr *et al.* (2022) suggests that English millwrights and their engineering skills were particularly advantageous for technology adoption. Kelly *et al.* (2023) showed that mechanical skills were conducive to the industrialisation of British textiles and metallurgy.

In a related paper, Squicciarini and Voigtländer (2015) studied how French knowledge elites contributed to industrial activity and economic development. Similar to our study, the authors used a local measure of individuals interested in scientific advances, i.e., the subscriber density of Diderot’s famous *Encyclopédie* in 1777–9, and showed their positive relationship with various outcomes, including measures of innovation.[8] We build on Squicciarini and Voigtländer (2015) and emphasise the importance of reducing the cost of accessing new knowledge for long-term development. Moreover, we extend their perspective beyond viewing individuals as single entities leveraging their knowledge for innovation. Instead, we argue for the importance of knowledge sharing and transmission among individuals within a specific group, emphasising the flow of ideas as a critical factor. Other related studies provide evidence for the role of craftsmen skills in Prussian innovation (Cinnirella and Streb, 2017), the importance of engineers for US patenting (Maloney and Caicedo, 2022) or study the emergence of engineers in England (Hanlon, 2022). Focusing on higher education, Dittmar and Meisenzahl (2022) suggested that the probability that inventors were educated or employed at German universities increases after 1800.[9]

While much of the literature emphasises the importance of training for the formation of upper-tail human capital, we add that social interactions constitute an additional source for the formation of upper-tail human capital conducive to innovation during the Industrial Revolution.[10] Thus far, knowledge elites have predominantly been viewed as isolated individuals that combine and expand existing knowledge. It is however conceivable that the social network of knowledge

[6] A related literature debates whether technical change during the early Industrial Revolution was skilled-biased or unskilled-biased. Recent evidence supports the view that new technologies stimulated the formation of working skills in England (Feldman and Van der Beek, 2016; Zeev *et al.*, 2017; De Pleijt *et al.*, 2020) and advanced literacy and school enrolment in France (Franck and Galor, 2022).

[7] This resonates with earlier work by Mokyr (1992), Mitch (1993) and Allen (2003) arguing that formal education was irrelevant for the Industrial Revolution in England in general. Nevertheless, Becker *et al.* (2011) provided evidence that basic schooling was important for the catchup of the technological followers such as Prussia.

[8] Squicciarini and Voigtländer (2015) also used a measure of members in scientific societies that correlates with their subscriber density. Note that economic societies differ from scientific societies and academies of science in their emphasis of useful knowledge and focus on improving the local economy.

[9] Other studies that focus on the upper tail of the human capital distribution informed by higher education includes the literature on land-grant universities in the United States (see, e.g., Kantor and Whalley, 2019; Andrews, 2023b). Focusing on European universities, De la Croix *et al.* (2023) inspected the functioning of the academic market, analysing migration patterns of students 1000–1800, and Dittmar and Meisenzahl (2020) studied the effect of political changes induced by the Protestant Reformation on the accumulation of upper-tail human capital.

[10] Note that we will not be able to disentangle whether economic societies contribute to innovation because they facilitate human capital formation via training or social learning, or because they facilitate social capital formation.

elites contributes to their human capital formation. This is in line with Akcigit *et al.* (2018), who modelled and empirically confirmed that the interaction of researchers leads to knowledge diffusion that contributes to individual human capital formation and productivity, thereby feeding into innovation-based growth. In combination with models of localised knowledge spillovers and agglomeration economies (see, e.g., Krugman, 1991; Glaeser *et al.*, 1992; Ellison and Glaeser, 1997; Audretsch and Feldman, 2004), such a framework could explain the persistent effect of economic societies on innovation in Germany.

We thus connect to the literature emphasising the importance of social networks for invention and technological diffusion.[11] For example, Andrews (2023a) showed the consequences of limited social interactions for innovation when bars closed during the prohibition era, whereas Burlig and Stevens (2024) showed that mergers between social networks increased the rate of agricultural technology adoption among farmers in the United States.[12] We also contribute to a literature acknowledging that access to knowledge is costly and that the reduction of barriers to knowledge flows increases technological diffusion and adoption. For example, Iaria *et al.* (2018) inspected the collapse of international science as an event that increased the cost of accessing knowledge. Abramitzky and Sin (2014) analysed how the collapse of Communism in Eastern Europe affected the international flow of ideas via translations. Other studies rely on the idea that migration changes the supply of human capital and facilitates knowledge diffusion and innovation by lowering barriers to personal interaction (see, e.g., Hunt and Gauthier-Loiselle, 2010; Bloom *et al.*, 2019). A number of studies in this field rely on historical migration shocks such as the inflow of German Jewish scientists into the United States in the 1930s (Moser *et al.*, 2014), the inflow of Huguenots into Prussia (Hornung, 2014), the inflow of Danish migrants into the United States (Boberg-Fazlic and Sharp, 2024), the Age of Mass Migration into the United States (Sequeira *et al.*, 2020) or the Jesuits in China (Ma, 2021).

The remainder of this paper is organised as follows. In Section 1, we provide the historical background on economic societies, their activities, mission and members; Section 2 describes our main dataset; Section 3 presents our main results with respect to long-run innovation outcomes, including a discussion of identification issues; Section 4 presents results on the immediate impact focusing on the Saxon society; Section 5 provides evidence for potential channels through which economic societies affected innovation in the long run; Section 6 presents evidence for knowledge flows within societies; Section 7 concludes.

1. Historical Background on Economic Societies

The Enlightenment spawned a plethora of associations, clubs and salons. This way of formalising relationships between individuals with a common interest first caught on to elite circles, but eventually became a bourgeois phenomenon. Many of the resulting institutions, most notably secret societies such as *Freemasons* and *Illuminati* were very exclusive, catered only to elites and aimed at advancing the interests of their members. Others, while interested in promoting knowledge creation, were not interested in useful knowledge and its application. Hence, economic societies differed from all other Enlightenment institutions in their activities, which aimed at

[11] Another related literature emphasises the importance of physical infrastructure networks for innovation and technological diffusion. The role of transport infrastructure for the diffusion of ideas and culture have recently been analysed by Melander (2020) and Andersson *et al.* (2023) for Sweden, by Tsiachtsiras (2023) for France and by Flückiger *et al.* (2022) for ancient Rome.

[12] This also relates to a literature on social learning and diffusion of agricultural technologies in development economics (see, e.g., Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Conley and Udry, 2010).

the improvement of the common good and the application of useful knowledge, and in their membership, which was based on openness and equality. We discuss these two major distinctions in greater detail in Sections 1.2 and 1.4. Although we largely focus on German economic societies, the information presented below will often generalise to societies in other countries.

1.1. *Emergence and Diffusion in Europe and Germany*

Economic societies first emerged in early eighteenth century Great Britain and Ireland, specifically in Edinburgh (1723), Dublin (1731) and London (1754).[13] These were voluntary organisations with the aim to improve the economy for the common good, initially confined to agriculture, but soon extended to industry, commerce and society at large (see Stapelbroek and Marjanen, 2012). They promoted the sharing of new production techniques, new materials and new agricultural practices and aimed at expanding the existing knowledge using systematisation and experimentation, thereby reflecting the emerging culture of practical improvement (see Slack, 2014).

The economic society movement spread all across Europe, reaching as far as New York and St. Petersburg.[14] Many societies broadly emulated the societies in Dublin and London that also formed the blueprint for several economic societies in Germany.[15] In their names, several German societies featured the terms *gemeinnützig*, reflecting their service for the common good and *patriotic*, reflecting loyalty and love for their state or region that was typically associated with republican rather than royalist ideals (Engelhardt, 2007).[16] In Online Appendix A.1, we show that the emergence of economic societies coincides with a drastic shift towards expressing an interest in useful knowledge and improvement for the common good in the German historical literature, using German book titles within the Google *ngram* catalogue.

Economic societies in Germany emerged in the aftermath of the Seven Years' War. Some local rulers, motivated by economic deprivation and population losses due to the war, initiated economic societies to revive the local economy (Rübberdt, 1934, pp.51, 57; Braun, 1980, p.244). These initiatives were likely inspired by the principles of contemporary cameralism—a manifestation of economic enlightenment ideas through state intervention to boost local production.[17] Notably, many rulers, including several prince electors of the Holy Roman Empire, supported these societies by granting them charters and monopolies. Although these rulers played a crucial role in establishing societies, the societies operated independently rather than under coordinated state direction. Following an initial surge of society foundations in the late 1760s and early 1770s,

[13] The *Society of Improvers in the Knowledge of Agriculture* was founded in 1723 Edinburgh. Although only short lived until 1745, it gave rise to the *Dublin Society for improving Husbandry, Manufactures and Other Useful Arts* established in 1731, as well as the *Society for the Encouragement of Arts, Manufactures and Commerce* in London established in 1751. For the Scottish Society, see Bonnyman (2012) and Smout (2012), for the Dublin Society, see Livesey (2012), and for the Society of Arts, see Howes (2020).

[14] The estimated number of societies in the world ranges from 233 in Engelhardt (2007) to 562 in Stapelbroek and Marjanen (2012).

[15] Braun (1980, p.245) described how shortly after the foundation of the economic society in Leipzig, the society started to correspond with the society in London, asking for its catalogue of prize competitions, as well as for its statutes. The economic society in Leipzig further profited from having a correspondent in London who informed the society in Leipzig of the activities of the Society of Arts (Braun, 1980, pp.245, 251). The society in Celle also drew on the statutes of the Society of Arts for their own statutes (Königliche Landwirthschafts-Gesellschaft zu Celle, 1864).

[16] Note that eighteenth-century patriotism reflects pre-national sentiments of identity that span across ethnicities and even nationalities.

[17] Evidence of rulers initiating economic societies can be found in Am Ende (1884, p.6) for Leipzig, Rübberdt (1934, p.57) for Celle, Popplow (2010, p.181) for Rübberdt (1934, p.80) for the Prussian societies in Silesia.

a second wave took place in the late 1780s and early 1790s. However, the period of French occupation saw the dissolution of many societies, with only a few being re-established post-1812. The nineteenth century did not witness new foundations, marking a shift towards trade associations.[18]

In contrast to Britain, where societies were initiated by merchants, artisans and inventors, the literature describes the process of society foundation in Germany as top down. Sometimes the impetus for their creation was given by cameralist rulers who commissioned government officials with the organisational issues. In some cases, these officials established society seats in their home towns (see Online Appendix A.2 for an example). In the eighteenth century, the origin of noble state officials reflected the old feudal order rather than the location of new commercial classes. Thus, the historical literature agrees that societies were not created in centres of commerce and education (see Schlögl, 1993, p.68; Bödeker, 2012, p.183; Tosch, 2012, p.310).

1.2. *Mission and Activities*

Whereas universities, academies and other learned societies were interested in advancing scientific knowledge for its own sake, the activities of economic societies explicitly aimed at generating and applying useful knowledge at the local level. According to Lowood (1991, p.3) no ‘other set of organizations in Germany, even the much touted universities, better exemplified the scientific, economic, and technological interests of active citizens in the Spätaufklärung [*late Enlightenment* (ca. 1789 bis 1804)]’. Economic societies typically had the explicit statutory mission to improve the local economy for the common good. To accomplish this, economic societies aimed to provide their members with access to useful knowledge. For example, the economic society in Hamburg aimed ‘[...] to apply every useful result of human knowledge, discovery, and invention to practical and civic life’ (translation by Lowood, 1991, p.22).[19] Online Appendix Table A.1 provides an overview of mission statements for all societies in our dataset.

The core activities of economic societies included promoting new ideas by granting prizes and rewards, and diffusing new ideas through debates, lectures, collections and journals. Most activities took place in the operational centre, the society seat. Here, members met on a regular basis for debates and public lectures, often organised by sections assigned to specific fields (such as history, geography, philosophy, physics, economics, philology). Societies also kept large libraries, filled with recent advances in many fields, and permanent collections displaying curious instruments and machines, accessible for all society members. Societies also published journals to which members submitted articles. Often, there was a core set of active members with a long publication record, ranging from translations of foreign scholarly work into German to reports on their own experiments. To extend access to useful knowledge to non-members, some societies published cheaper versions of their journals for the general public.[20] Well-endowed societies frequently held competitions and awarded prizes toward solving specific known problems in

[18] Throughout the nineteenth century, economic societies gradually gave way to trade associations like the Prussian *Verein zur Beförderung des Gewerbefleißes in Preußen*, though a few, such as Hamburg’s *Patriotische Gesellschaft*, remain active to this day.

[19] Hubrig (1957, p.49) listed the following achievements of the Hamburg society during the first twenty years of its existence: introduction of the lightning rod in Hamburg (first appearance in Europe), improvement of street lighting (1767–71), establishment of a drawing school for twelve students (1767), introduction of vocational schooling, supply of improved fire pumps for the fire station (1769), improvement of street paving (1782) and the erection of wind mills to drain tidal wetlands.

[20] For example, the society in Potsdam published a monthly non-member journal (*Gemeinnütziges Volksblatt*) that was meant to be displayed in every parish and city (see Schultze, 1964; Tosch, 2010).

various disciplines. For experimentation and application of new methods, some societies operated demonstration factories and farms.

Societies especially emphasised the verification and falsification of new practices through tests and experiments. Several societies sent out instructions for new practices in agriculture and the trades to their members, asking them to try these practices and to report on their success in questionnaires. The economic society in Burghausen even included a rule in their statute that required each member to do either one experiment, one communication entry or one empirical observation per year (Lowood, 1991, p.48). Often, questionnaires were combined with prize competitions for solving a question or producing a certain good.[21]

Despite their focus on applied practices, economic societies also provided access to state-of-the-art scientific knowledge. Online Appendix Table A.4 lists all journal subscriptions held by the society in Breslau in 1806, including many international publications, such as the *Philosophical Transactions* of the Royal Society of London, *Nicholson's Journal of Natural Philosophy, Chemistry, etc.*, *the Annales de Chemie* and the *Annales des Arts, Manufactures, etc*. In 1828, the society in Potsdam held a total of 1,072 books, notable for their practical focus on, e.g., agriculture, mineralogy and engineering (Königlich Märkische Ökonomische Gesellschaft, 1828).

1.3. *Establishment of Vocational Schools*

Next to the above activities, societies advanced the diffusion of useful knowledge through the establishment and administration of schools, especially for vocational training. Among a list of 502 society projects compiled by Lowood (1991, p.88), there are twenty-one schools founded between 1765 and 1810. Since such schools were place-based institutions that continued to exist beyond the life of the society and its members, they arguably constitute potential mechanisms through which societies had a long-lasting effect on the diffusion of knowledge and innovation. We provide qualitative evidence in line with this argument before exploring this mechanism quantitatively in Section 5.1 below.

The historical literature highlights that education was a topic of particular interest for the societies, with significant contributions to the establishment of vocational schools. Hubrig (1957, pp.111–17) listed several examples of the successful creation of schools, noting that economic societies did pioneering work by financing and managing experimental and model schools that were later taken over by the state. Economic societies particularly established drawing schools to train 'prospective artisans' in essential skills such as freehand and construction drawing, arithmetic, mechanics and practical engineering (Bödeker, 2012, p.200). These drawing schools were precursors of the vocational and trade schools that emerged in the nineteenth century and Lowood (1991, p.355) suggested that 'the societies paved the way for the polytechnical movement of the nineteenth century in Germany'.

For instance, Lowood (1991, pp.354–61) described the establishment and funding of a school for fine arts and drawing by the Hamburg society in 1767. Its focus was initially on training local workers who had been banished by the guilds. The initiative saw notable success post-1790 when

[21] For example, in 1792, the economic society in Potsdam awarded ten Prussian gold coins towards the invention of a plough that could be built by any commoner. Online Appendix Table A.2 provides an overview of the prizes that were offered by the Leipzig society between 1764 and 1790. It illustrates that most prize questions were aimed at concrete practices of the trades and agriculture. Online Appendix Table A.3 lists all 'natural and artificial products', including both new raw materials and finished goods, presented to the society from 1764 to 1767.

the society introduced two-year courses for artisans and manufacturers.[22] These courses, which included free public lectures and private consultations, attracted an average of 225 students over the first four semesters. In 1792, the enrolment list, which predominantly featured carpenters (112) among its 222 students, also included highly skilled mechanics like masons (eight), clockmakers (six), locksmiths (six) and coopers (five). The main instructor combined aspects of a mechanics' institute with elements of apprenticeship and a cameralist curriculum. The school was taken over by the state in 1864 (Eulen, 1967) and has evolved into the University of Fine Arts of Hamburg.

Inspired by Hamburg's example, the society in Lübeck established a similar school in 1795, where three members of the society had trained more than a 1,000 journeymen and apprentices free of charge until 1836 (Hubrig, 1957, p.189). Exceptionally talented students were awarded medals and travel bursaries to further their education. The school was taken over by the city in 1875 and eventually became part of the Technical University of Applied Sciences Lübeck. In Saxony, a school for fine arts and drawing was founded in 1764 by Adam Friedrich Oeser, a member of the Saxony society. Oeser initially operated the school from his private home in Leipzig, teaching twenty-three students (Blume, 1996). It was also attended by students from the University of Leipzig, including Johann Wolfgang Goethe. The school was taken over by the state in 1876 and has evolved into the Academy of Fine Arts Leipzig.

Beyond these examples of vocational schools that trained students to become highly skilled, societies were involved in the establishment of various schools for different target audiences. For instance, the Nürnberg society pioneered girls' industrial education, opening a school in 1793. This initiative inspired similar establishments by the Rostock (date not specified) and Lübeck societies (1799), with the latter reporting enrolment numbers of 388 students in 1824 and 612 in 1836 in their industrial school (Hubrig, 1957, p.113). The Hamburg society established a navigation school in 1785, a mechanics school in 1792 and a Sunday school for construction workers in 1795. Likewise, the Lübeck society established a Sunday school for children working in factories in 1795 and a navigation school in 1808. The Rostock society opened several Sunday schools for children working in factories after 1798. In 1802, the Celle society, under the stewardship of agronomist and member Albrecht Thaer, inaugurated the first German Agricultural Training Institute (Lowood, 1991, p.346). Furthermore, the society in Lautern gained recognition for establishing the High Cameral School in 1774, aimed at training administrative officials (Popplow, 2010, pp.215–35). This school was later moved to Heidelberg in 1784, becoming part of the University of Heidelberg. The initiatives of the Potsdam society were significantly influenced by its chairman and founding member, Friedrich Eberhard von Rochow, who was a prominent educator and reformer.[23] He was a vocal advocate for universal primary education, industrial schools for the poor and authored a primary school textbook. Rochow also founded a model school that employed his innovative didactic teaching methods, thereby setting new benchmarks in educational practices in Prussia (Tosch, 2010).[24]

[22] These were created in response to the insight that 'sustaining the flow of new products and inventions proved difficult, though it sharpened the society's awareness of the need for improving the level of education and training among instrument makers and others in the mechanical trades' (Lowood, 1991, p.125).

[23] Similarly, Peter Graf von Hohenthal, the co-founder of the Leipzig society, was a known advocate of school reforms.

[24] Engelhardt (2007, p.211) mentioned that Danish economic societies 'established elementary schools and peasant libraries, they held reading circles and distributed publications aimed at increasing productivity and improving the morals of the peasants'.

1.4. *Membership and Organisation*

In contrast to other Enlightenment associations, economic societies generally did not impose restrictions on membership and did not aim at exclusivity (Lowood, 1991, p.24). They were private institutions whose statutes typically granted admission to any individual who applied for it.[25] If formal requirements for membership were established, they requested, e.g., the submission of written scientific work.

The organisation of economic societies was based on egalitarian principles. Because of the fact that societies were influenced by republican ideals, statutes determined that all members had equal rights and could participate equally in decision making (Im Hof, 1990). Remarkable for the eighteenth century, economic societies mixed noble and non-noble members and thereby broke with social traditions. Nevertheless, many societies imposed membership fees, thereby effectively excluding the lower classes from joining. Thus, despite their official claim to be open for everyone, members predominantly came from the upper-middle class, including government officials, physicians, academics, priests, merchants and craftsmen. Among these, government officials stand out as the largest group across German societies. Online Appendix Figure A.2 shows the distribution of occupations across society members included in our analysis. Information on the occupation of members is missing for about 28% of the sample.

Most societies had three types of members: ordinary, corresponding and honorary.[26] Ordinary members built the core of the society and were residents at the society seat; corresponding members resided elsewhere and were invited to attend the meetings and submit articles to the society journal.[27] In contrast, honorary membership was often granted by invitation to high-ranking members of the administration or affluent patrons who usually did not participate in the society activities (Schlögl, 1993, p.75). In other cases, honorary members were well-known scholars that were expected to actively contribute to the publishing activities of the society. Hierarchies between different types of members were nevertheless flat and they interacted on equal footing.

New members joined societies either because they had social ties to other members or because they learned about the society from newspapers. Societies actively advertised their formation in advance and reported on their activities to acquire as many potential members as possible. Typically, a core set of founding members would try to enlist accomplished people from various fields.[28]

2. Data

Substantial effort was devoted to collecting information on the members of economic societies. We further collected data that measure local innovative activity and human capital from various sources that we describe in detail below. All of these data were geo-located and subsequently

[25] The economic society of Silesia provides a vivid example for such open-access ideals. According to Lowood (1991, p.25): 'Members should not expect their society to become an "imitation of learned academies on a small scale". It is more important that they remain open to every good citizen, especially the "patriot and the businessman", and never close into a circle of scholars who work for personal reputation or livelihood, rather than the welfare of their fellow man.' The Saxonian society in Leipzig invited anyone to join: 'every farmer of whatever class, even peasants, artisans, craftsmen, foresters, gardeners' (Lowood, 1991, p.34). Members of the economic society of Schleswig-Holstein at Kiel vowed that 'no rank and no title means anything to us' (Lowood, 1991, p.37).

[26] Societies in free imperial cities (Hamburg, Lübeck, Nürnberg) did not have corresponding members, only residents.

[27] Statutes that stipulated the privileges of these members widely differ across societies.

[28] Graf (1993) confirmed that social ties were crucial in the recruitment of new members for the society in Burghausen.

Table 1. *Economic Societies and their Members.*

City	Incorporation	Register	Total members	Geo-located members
Bad Homburg	1775	1777	135	132
Breslau	1771/2	1806	245	233
Burghausen	1765	1765–79	231	196
Celle	1764	1764–71	265	209
Hamburg	1765	1790	424	424
Jauer/Schweidnitz	1772	1821	154	143
Kassel	1765	1773	72	59
Kiel	1786	1787	154	141
Lautern/Mannheim	1769/70	1769–80	127	97
Leipzig	1764	1764–89	643	468
Lübeck	1789	1819	238	238
Mohrungen	1791	1796–800	120	118
Nürnberg	1792	1817	138	135
Potsdam	1791	1791–815	332	316
Rostock	1798	1827	417	393
Sum			3,695	3,302

Notes: The table lists the fifteen economic societies active in Germany before 1800 by their society seat(s). Since two societies switched their seat during the period of investigation (Jauer/Schweidnitz and Lautern/Mannheim), the resulting number of seats is seventeen. Membership registers from Burghausen, Celle, Mannheim/Lautern, Leipzig and Potsdam cover all members joining over the period specified, whereas registers from all other societies represent a cross section of membership in the specified year.

aggregated to the respective level of observation, typically grid cells of 15×15 km^2 (equivalent to $0.1^\circ \times 0.1^\circ$ at the equator) size.[29] Summary statistics are presented in Online Appendix Table B.2.

2.1. *Economic Society Members*

The literature disagrees on the number of societies that existed, not least because many of them were short lived or did not engage in substantial activities. Reasonable accounts by van Dülmen (1986) and Bödeker (2012) conjecture that about sixty societies with between 4,000–5,000 members existed in the German language area, thirty-five of which had their society seat located within the borders of the German Empire (see Online Appendix B.3 for the full list). While a number of societies actively engaged in publishing journals, thereby leaving a testimony of their existence, others were discontinued shortly after their establishment and left few traceable marks.

Combining the list in van Dülmen (1986) with information from Rübberdt (1934) and our own investigation, we identify fifteen societies that match our criteria for an active economic society. In particular, we include societies and their members in our dataset if (*i*) their seat was located within the borders of the German Empire of 1871, (*ii*) the society had the explicit aim to engage in the advancement of the local economy according to their statutes, (*iii*) the society addressed more than one field of the local economy,[30] (*iv*) the society actively engaged in publishing or funding of projects for more than one year, (*v*) the society was established before 1800. We report information on the fifteen societies that match our criteria in Table 1. Because two societies changed their seats before 1800, the list encompasses seventeen different seats.

[29] Results are robust to using grid cells of 45×45 km^2 size (see Online Appendix Table D.9) and to moving the grid in steps of 1.5 km ten times in each cardinal direction (see Online Appendix Table D.10).

[30] This criterion aims to exclude societies that exclusively focused on beekeeping or hunting.

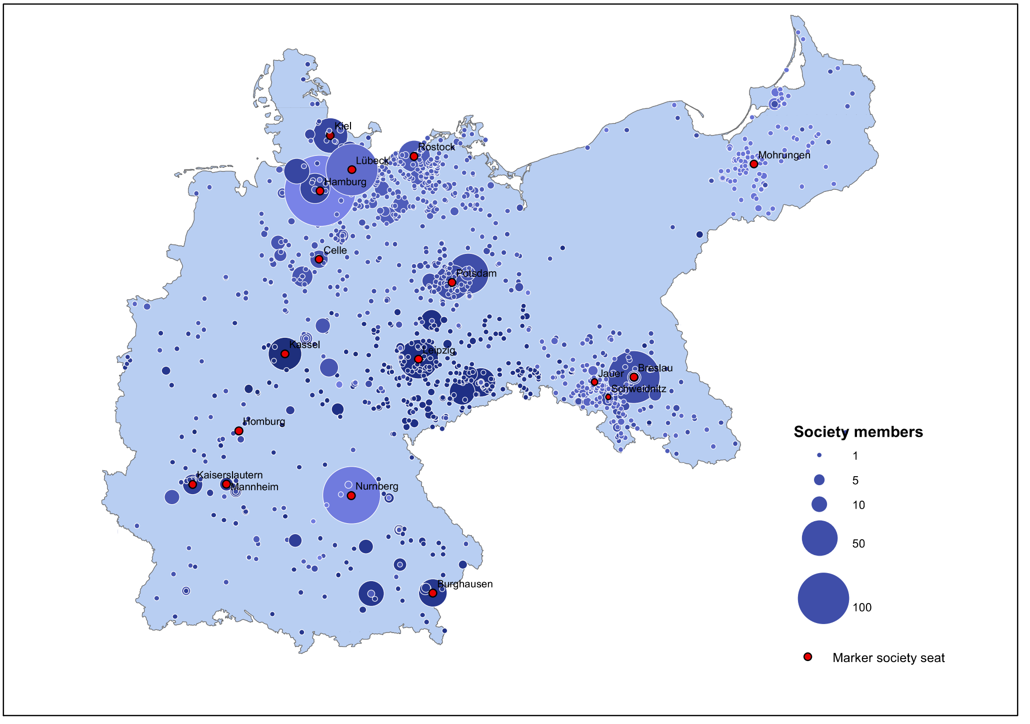


Fig. 1. *Spatial Distribution of Members in Economic Societies.*

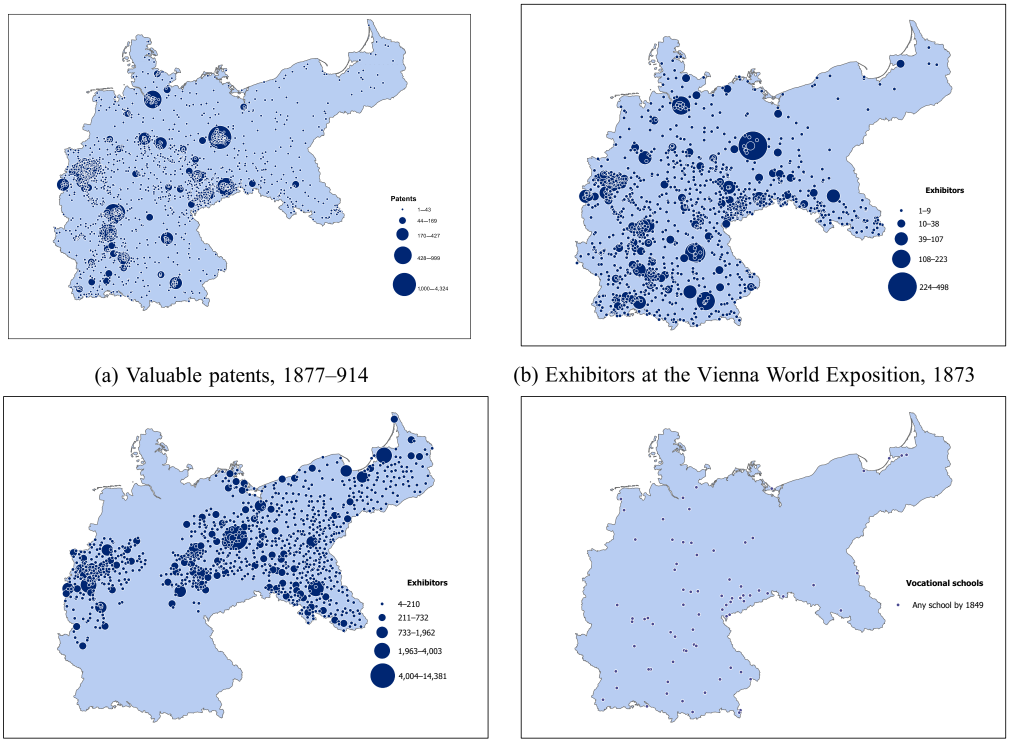
In contrast to secret societies, economic societies prided themselves on their members and frequently published registers in society journals. For each of these societies, we thoroughly searched their publications for membership lists and included all members from the earliest available membership register in our dataset.[31] Our quantitative results are robust to including society fixed effects that, e.g., account for differences in the timing of lists.

We digitised these lists including members' names, social status, occupation and location. In total, we collected and geo-located the residence of 3,302 patriotic economic society members. Failure to locate a member arises when registers did not list their residence or when the listed residence could not be assigned to a unique location.[32] Figure 1 shows the geographical distribution of members where the size of a circle indicates the number of members from any society in a given location.[33] The map shows that there is substantial heterogeneity in the spatial distribution of individuals interested in advancing the diffusion of useful knowledge during the late eighteenth century. For the purpose of our analysis, geo-located members are aggregated to the grid-cell level.

[31] In four cases, we were not able to find a register of members before 1800. This may raise worries that the spatial variation of members from such societies deviates from pre-1800 registers. We thus inspected the spatial correlation between early membership lists for societies from which we found several lists. For the society in Breslau, the correlation coefficient of membership frequency across cells between registers from 1806 and 1820 is $p \approx .62$. Comparing registers of the society in Leipzig from 1764–89 and 1811, the spatial correlation is $p \approx .65$.

[32] In cases when the residence was missing, but the name of the member referred to an estate, we used the location of the estate. In cases when multiple estates were listed, we used the main estate of the family.

[33] Online Appendix Figure B.1 shows fifteen separate maps, one for each society.



(a) Valuable patents, 1877–914

(b) Exhibitors at the Vienna World Exposition, 1873

(c) Highly skilled mechanics 1849 (Prussia)

(d) Any vocational school by 1849

Fig. 2. *Spatial Distribution of Main Dependent Variables and Mechanisms.*
Notes: The sizes of the circles reflect quintiles in the number of (a) valuable patents (1877–1914), (b) exhibitors at Vienna (1873) and (c) highly skilled mechanics in Prussia (1849). Circles in (d) indicate the presence of at least one vocational school by 1849.

2.2. *Measures of Innovation and Human Capital*

In our cross-sectional analysis, we rely on the following outcome measures to assess the impact of society members on the local production of innovation and prevalence of skills.

Patents. We measure the local intensity of innovation by the stock of valuable patents registered in Germany in the period 1877–1914 in a grid cell (see Streb *et al.*, 2006; Cinnirella and Streb, 2017). Valuable patents are those that have been patented for at least ten consecutive years. In a context of increasing registration fees over time, this is a valid proxy for innovations with a significant economic value. The patent data list the name of the inventor, the location, the year of the patent and the technological class of the invention. In Figure 2(a) we report the spatial distribution of the stock of valuable patents.

Exhibitors. Patents, although a good proxy for innovation, might provide a biased picture of local innovation if not all innovations are patented, if patenting varies across technological classes, or if secrecy constitutes a valid alternative to patenting. To overcome such issues, we use data on German exhibitors at the 1873 Vienna World's Fair as an alternative measure for the local intensity of innovation. More than 5,000 of the 26,000 individual exhibitors came from the German Empire and presented their novel products at Vienna. Using the exact location as reported in the official catalogue of the Vienna World's Fair, we show the spatial distribution of exhibitors in Figure 2(b). The spatial correlation with the stock of valuable patents is high ($p \approx .85$).

Highly skilled mechanics. To capture the upper tail of the useful knowledge distribution, we rely on Feldman and Van der Beek (2016) and De Pleijt *et al.* (2020) to classify occupations into skill groups. The resulting measure of highly skilled mechanics broadly follows Meisenzahl and Mokyr (2012), who labelled artisans that operate at the cutting edge of contemporary technology as 'tweakers'. To calculate the local density of highly skilled mechanics, we rely on the Prussian occupation census of 1849 that reports the number of artisans across approximately ninety occupations at the city level.[34] This measure is only available in cities in the German Empire that were part of Prussia in 1849, as depicted in Figure 2(c). We categorise other occupations either as other artisans or as factory workers and use these in placebo tests.

Vocational schools. To capture local investment in vocational schooling, institutions that arguably trained highly skilled mechanics, we digitised and geo-referenced the universe of vocational schools in the German Empire. Pache (1896–1905) listed all vocational schools including technical colleges (*Fachschulen*) and continuation schools (*Fortbildungsschulen*).[35] These schools provided technical training for children above mandatory schooling age. We focus exclusively on technical colleges, including those for crafts, commerce, mining and agriculture because they provided applied training for students with some prior work experience, usually from the age of sixteen. Besides the location of vocational schools, we collected information on their year of establishment.[36] This information is available for 912 out of 1,466 technical colleges.[37] Figure 2(d) shows locations that had at least one such school by 1849.

2.3. *Control Variables*

Geographical. To account for spatial heterogeneity in geographical endowments that may simultaneously affect incentives for innovation and human capital formation, but also the propensity to join a society, our baseline specification includes controls for temperature, precipitation, altitude, ruggedness, soil suitability for cereal production and for potato cultivation, and distance to navigable rivers, to sea ports and to coal fields.

Population. In the absence of data for population density at the grid-cell level, we capture pre-existing agglomeration effects through several measures, including the aggregate population of all cities with more than 5,000 inhabitants in 1750 in a grid cell from Bairoch (1988), the growth of this population between 1700 and 1750, a count of cities with city status in a grid cell based on Keyser (1939–74) and a measure of market access based on the distance-weighted

[34] The data include (but are not limited to) all of the occupations mentioned by Meisenzahl and Mokyr (2012): scientific instrument makers, clockmakers, musical instrument makers, gold and silversmiths, jewellers and locksmiths.

[35] Since education was organised at the state level throughout the nineteenth century, there may be systematic differences between types of vocational schools across states. In the analysis we account for such differences by including polity fixed effects. Nevertheless, school finance was typically the responsibility of municipalities. In several cases, however, vocational schools were funded by private associations.

[36] We supplement the original dating by Pache (1896–1905) using information from Glasser (1893), Lexis (1904) and Keyser (1939–74). In case the sources reported different years of establishment, we used the earliest year.

[37] We did not find a systematic pattern of omission of the establishment year. For example, missing information occurs in all states of the German Empire.

population size of all cities in 1750.[38] Furthermore, the set of population controls includes an indicator that becomes one if a cell belonged to a Protestant polity. When focusing on grid cells that were part of Prussia in 1849, we include the aggregate population of cities in 1816, the city growth between 1802 and 1816, a count of these cities, a measure of market access based on the 1816 population and the urban share of Protestants in 1849.[39]

Polity fixed effects. To capture institutional, cultural and other time-invariant unobserved heterogeneity across German territories, our preferred specifications will condition on polity fixed effects. These fixed effects are designed to account for local policies, including any reform that might have been introduced concurrently with the emergence of societies, provided these reforms align with the boundaries of the polities.[40] To generate polity dummies, we rely on the political borders of the Holy Roman Empire as they were defined in 1789.[41] Following the methodology of Dittmar and Meisenzahl (2020), we aggregate polities represented by fewer than five grid cells into a single fixed effect to mitigate multicollinearity concerns. This approach results in a total of sixty-five polity dummies.[42]

3. Empirical Analysis

3.1. *Access to Useful Knowledge and Innovation*

Our main hypothesis is that societies reduced the cost of accessing useful knowledge, thereby facilitating industrialisation and technological change that continue to generate higher levels of innovation in the long run. Empirically, we test this hypothesis by inspecting whether a higher density of society members is associated with more innovative activity. Below, we introduce our econometric model, discuss potential endogeneity concerns and threats to identification, introduce an instrumental variable approach to address these issues and present our main results. Throughout, we estimate versions of the following model through OLS:

$$Y_{ip} = \beta\, \text{Members}_{ip} + \mathbf{X}'_{ip}\gamma + \delta_p + \varepsilon_{ip}. \quad (1)$$

Here, the dependent variable Y_{ip} reflects various measures of innovation and human capital, such as the number of valuable patents granted to patent holders in grid cell i ($n \approx 2{,}700$) in polity p ($n = 65$), the number of exhibitors at the 1873 Vienna World's Fair from a given grid cell or the number of highly skilled mechanics from cities in a grid cell. Variable Members_{ip} counts members of any economic society residing in grid cell i and polity p; vector $\mathbf{X}_{ip}$ includes geographical and population controls; δ_p indicates polity fixed effects. SEs are clustered at the polity level.

Because Y_{ip} and Members_{ip} are count variables with a skewed distribution and a substantial number of observations that are zeros, we transform them using the inverse hyperbolic sine

[38] We define market access of a grid cell i as $M_i = \sum_{i=1}^{N} pop_j/dist_{ij}$, where pop_j is the population of town $j \neq i$, and $dist_{ij}$ is the geographic distance, between town i and town j.

[39] To appreciate the quality of the city size data reported by Bairoch (1988), we estimate the spatial correlation with city sizes reported in the Prussian census. The correlation coefficient is $p \approx .97$.

[40] Note that between 1764 and 1800, Germany enjoyed a relatively stable period with minimal border changes, facilitating the effectiveness of these fixed effects.

[41] We rely on a political map by Wolff (1877) that was recently geo-referenced by Huning and Wahl (2023) and kindly provided to us by the authors. Since this map depicts the Holy Roman Empire's borders in 1789, it excludes territories in Eastern Prussia and Alsace-Lorraine. For our analysis, grid cells within these omitted regions are assigned to the respective political entity they were part of.

[42] The main results are robust to adding fixed effects for polities that cover less than five grid cells.

(arcsinh). This transformation is superior to the logarithmic transformation because it is defined at zero, but still allows the estimated coefficients to be interpreted as elasticity.[43] Our results are robust to using the natural logarithm or estimating Poisson regression and negative binomial regressions instead (see Online Appendix Tables D.1–D.2).

3.2. *Mitigating Endogeneity*

The location of society members is not randomly assigned. Membership and willingness to acquire useful knowledge may be related to local economic activity and potential for innovation. Furthermore, the network of members may capture pre-existing ties between individuals with common interests in a particular field or technology. As a consequence, regions with a higher member density could have been more innovative even in the absence of a society.

There is no systematic and centralised process that determines the distribution of members across Germany because each society had its own idiosyncratic history and way to acquire members. Nevertheless, we argue that membership density can be partly explained by the cost of participating in society activities. Attending meetings and lectures, and using the library and collections at the society seat are important benefits of membership that come at the cost of travelling. To acquire useful knowledge, members thus had to travel to the society seat and local member density is expected to decline in distance to the society seat.

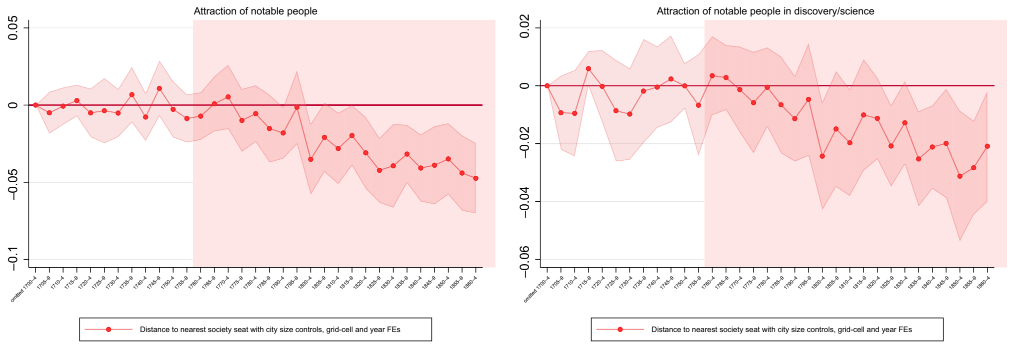
Following this logic, we use the geographic distance between the centroid of each grid cell and the nearest society seat as an instrumental variable for the number of society members in a grid cell. In what follows, we inspect the validity of this instrument in two ways. First, we inspect potential violations of the exclusion restriction by showing that distance to the nearest society seat is unrelated to pre-existing trends in human capital. Second, we inspect the potential drivers of location choices for society seats and execute tests using distances to randomly distributed placebo society seats.

3.2.1. *Inspecting the exclusion restriction*

A crucial concern regarding the validity of our instrument is that distance to the nearest society seat might be correlated with the pre-existing density of upper-tail human capital. To address this concern, we use panel regressions that allow us to inspect differential trends in the presence of upper-tail human capital prior to the emergence of societies between cells of varying distance to society seats. To approximate the local density of upper-tail human capital, we draw on a cross-verified database of notable individuals from Laouenan *et al.* (2022).[44] To understand whether regions in closer proximity to a society seat already attracted higher numbers of notable individuals prior to the emergence of societies, we follow Dittmar and Meisenzahl (2020) and construct a measure of attraction of upper-tail human capital from information on the place of birth and death included in the database. Laouenan *et al.* (2022) claimed that their database explicitly allowed them to study the attractiveness of locations for notable individuals in general and scientists in particular. Individuals are classified into broad occupational categories, allowing

[43] For a discussion of the advantages and drawbacks of using the inverse hyperbolic sine transformation, see Bellemare and Wichman (2020).

[44] Laouenan *et al.* (2022) matched the entries of Wikipedia editions for different languages and entries in Wikidata to cross-verify entries of notable people. Only entries that could be cross-referenced multiple times are included in the final dataset of notable people. The full dataset includes 2.29 million notable people between 3500 BC and AD 2018.



(a) Notable individuals (all) (b) Notable individuals (science/discovery)

Fig. 3. *Attraction of Notable Individuals and Distance to the Society Seat.*
Notes: The figure plots β_τ coefficients estimated from (2) with 95% confidence intervals. The omitted period is 1700–04. Dependent variable, main explanatory variable and city size controls are transformed using the inverse hyperbolic sine (arcsinh). SEs are clustered at the grid-cell level.

us to focus on individuals in the category 'science and discovery'.[45] We estimate the model

$$\text{People}_{it} = \zeta_i + \eta_t + \sum_{\tau=1700\text{–}4}^{1860\text{–}4} \beta_\tau \cdot \text{Distance to Society}_i \times \eta_t + \gamma \cdot \text{Pop}_{it} + \varepsilon_{it}, \qquad (2)$$

where People_{it} is the number of notable individuals that died in grid cell i during a five-year period t (i.e., 1700–4, 1710–14, ..., 1860–4). We only consider individuals that migrated after birth, i.e., who were born in a grid cell $j \neq i$.[46] The estimated coefficients β_τ reflect differences in the number of notable individuals that were attracted to grid cells of varying distance to a society seat in a given period t compared to the omitted period (1700–04). Here, $\text{Distance to Society}_i$ is a continuous measure of geographic distance to the nearest society seat; ζ_i and η_t are grid-cell and time-period fixed effects, respectively. Our main specification includes a time-varying measure of urban population size (Pop_{it}).[47] The main explanatory variable and the dependent variables are transformed using the inverse hyperbolic sine (arcsinh).

Figure 3(a) plots the coefficients of interest β_τ, estimated from (2) using an event-study design. The graph depicts changes in the relationship between our instrument—distance to the nearest society seat—and upper-tail human capital over time. Figure 3(b) shows that this finding holds when restricting the sample to individuals in the category 'science and discovery'. Relative to the omitted period, regions closer to a society seat did not differ from other regions with respect to their attraction of notable individuals in general and notable scientists in particular, prior to the emergence of economic societies. This means that locations that later had a higher density of society members did not attract a larger number of notable individuals before 1760. This mitigates concerns about individuals interested in scientific advances, optimising the location of society seats to minimise the cost of travelling to the seat.

[45] The category science and discovery includes occupations such as research, historian, physician, scientist, academic, engineer, explorer, inventor, sailor, pioneer, etc.
[46] Online Appendix C.2 shows that we obtain similar results when not constraining the sample to migrants, i.e., considering the location of death for all notable individuals.
[47] We use urban population data from Pfister (2020) instead of Bairoch (1988) due to its higher frequency.

Instead, we observe an increase in the migration of notable individuals (all and science/discovery) to regions closer to a society seat from about 1800. Because our dependent variable reflects the year of death, it is conceivable that individuals migrated to these locations earlier. It seems reasonable to assume that the majority of migration spells of individuals who died in the period 1800–4 occurred after 1764, given that life expectancy of scholars at age thirty in Germany was sixty-four years (Stelter *et al.*, 2021). Thus, we cautiously interpret the pattern of our results to be consistent with the notion that, if anything, notable individuals were attracted to locations closer to a society seat only after these became active and not before. In sum, this evidence mollifies concerns regarding a violation of the exclusion restriction and supports our instrumental variable approach.

***Robustness*:** We show robustness of these results in Online Appendix C. Results are robust to the inclusion of polity fixed effects interacted with time-period fixed effects to account for potentially confounding institutional change at the polity level. They are also robust to including all notable individuals with a known place of death and to restricting the analysis to grid cells containing cities.[48]

Furthermore, we show that results are similar when using data from the *Deutsche Biographie*, an online compendium of notable individuals in German history, as an alternative outcome. This proxy for historical upper-tail human capital was pioneered by Dittmar and Meisenzahl (2020) and provides a sample of historically notable people within the German-speaking lands that is argued to be representative across space, religion and fields of activity.[49]

3.2.2. *The location of society seats*

***Balancedness*:** A remaining concern may be that the society seats themselves were not chosen at random and that the instrument picks up variation in distance to non-arbitrarily chosen places. As argued in Section 1 and Online Appendix A.2, the choice of society seats reflected individual idiosyncratic decisions rather than a systematic pattern. In Online Appendix Table C.3, we explore the determinants of society seat location more formally.[50] Using a linear probability model in column 1, we regress an indicator that assumes the value one if a grid cell was the location of a society seat on our set of geographical and population controls, as well as polity fixed effects and a set of long-run controls described in Section 3.4 below. These long-run controls measure commercial and educational activity prior to the emergence of societies and are included here to test whether society seats were created in cities that were important commercial and educational centres. Similarly, in column 2, we inspect balancedness with respect to the instrumental variable ‘distance to a society seat’.

[48] We also obtain qualitatively similar results when using the location of birth as a proxy for the production of upper-tail human capital (not shown). However, we believe that birth years are not informative for our purposes because it is impossible to establish exactly *when* individuals can be considered as ‘treated’ by a society.

[49] Individuals included in the *Deutsche Biographie* were, not only selected due to their historical fame, but also due to the importance of their intellectual, cultural or technical contributions (see Hockerts, 2008). The online version of the *Deutsche Biographie* contains 48,000 entries of notable individuals originally published in the *Allgemeine Deutsche Biographie* between 1875 and 1912 and in the *Neue Deutsche Biographie* published since 1952.

[50] Less formally, we show a list of the forty largest cities in Germany in 1750 according to Bairoch (1988) in Online Appendix Table C.2. Among these largest cities, eight have a society seat, whereas thirteen have a university. Only four cities have both a university by 1760 and a society seat. We also augment the list with the nine society seats that were created in minor cities with less than 10,000 inhabitants, among them four that are too small to have been recorded by Bairoch (1988).

We find that only distance to rivers, distance to sea ports and the indicator for an Imperial/free city significantly raise the probability of being selected as a society seat in column 1. We further find that distance to coal, distance to a river, city size in 1750, market access in 1750 and the indicator for belonging to a Protestant polity are significantly correlated with our instrumental variable in column 2. While especially market access might be mechanically correlated with all types of distance measures, we alleviate concerns of unobserved heterogeneity by including all of these measures in our preferred specification that conditions on a large set of geographical and population controls. Furthermore, our results are robust to including distance to the seventeen largest cities, distance to universities or distance to other enlightened societies (see Section 3.4 below).

***Placebo seats*:** Next to inspecting the determinants of society seats, in Online Appendix C.5, we present evidence that our main results cannot be replicated using distance to nearest *placebo* society seats, where the placebo society seat locations are derived from 10,000 random draws of seventeen grid cells.[51] We conduct this randomisation exercise to understand whether placebo distances generally generate reduced-form results that resemble those on distance to the nearest actual society seat.

We use distance to the nearest of seventeen randomly drawn grid cells to estimate 10,000 β coefficients for the reduced-form effect on innovation, conditional on our baseline set of controls. We first draw placebo seats from a uniform distribution. Online Appendix Figure C.4 shows the distribution of estimated coefficients using patents and exhibitors as outcomes. As expected, coefficients are normally distributed and centred around zero. The coefficient for distance to the nearest actual society seat falls within the highest percentile of estimated coefficients from placebo distances for both patents and exhibitors. In a second approach, we reduce the sample of grid cells from which we randomly draw placebo seats to cells that include a city with at least 5,000 inhabitants, i.e., to only 191 grid cells minus those thirteen cells that include such a city that was an actual society seat. The distribution of coefficients estimated from 10,000 random draws is presented in Online Appendix Figure C.5. Again, the estimated coefficients are normally distributed and centred around zero and the coefficient for distance to the nearest actual society seat falls into the highest percentile of estimated coefficients for both exhibitors and patents.

Finally, we account for the possibility that the location of society seats might be spatially correlated. Therefore, we first estimate the parameters of a Kelly (2021) spatial noise distribution based on the real location of society seats.[52] Next, we use distance to seventeen grid cells drawn from this spatial noise distribution to estimate 10,000 β coefficients from the previous model. Online Appendix Figure C.6 shows the results. As before, the estimated coefficients are centred around zero and the coefficient for distance to the nearest actual society seat falls into the highest percentile of estimated coefficients for both exhibitors and patents.

We interpret these findings to indicate that there is indeed something relevant about the distance to grid cells with society seats that facilitates innovation and cannot be replicated with combinations of distances to randomly drawn locations, even when these are drawn from a selected sample of cells with large cities. Furthermore, we may interpret the mean effect of the displayed random draws as indicative of potential biases from a confounding distance effect.

[51] We exclude grid cells with actual society seats from the draws.

[52] Following Kelly (2021), we estimate the spatial parameters of society seats after orthogonalising society seats for the explanatory variables in (1). Then, we estimate the underlying spatial parameters of orthogonalised society seats using a kriging procedure with a Matérn function as a kernel.

Table 2. *Society Members and Innovative Activity.*

	(1) Geography	(2) Population	(3) Polity FEs	(4) Society FEs	(5) Prussia	(6) IV
Panel A. Dependent variable: patents (1877–914)						
Society members	0.581***	0.219***	0.274***	0.136*	0.336***	0.329**
	(0.096)	(0.048)	(0.040)	(0.080)	(0.061)	(0.132)
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Population controls	No	Yes	Yes	Yes	Yes	Yes
Polity fixed effects	No	No	Yes	Yes	Yes	Yes
Society dummies	No	No	No	Yes	No	No
Observations	2,698	2,698	2,698	2,698	721	2,698
R^2	0.20	0.46	0.52	0.52	0.56	
Kleibergen–Paap F-statistic						80.31
Panel B. Dependent variable: exhibitors (1873)						
Society members	0.447***	0.195***	0.224***	0.123**	0.215***	0.295***
	(0.062)	(0.034)	(0.037)	(0.060)	(0.036)	(0.063)
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Population controls	No	Yes	Yes	Yes	Yes	Yes
Polity fixed effects	No	No	Yes	Yes	Yes	Yes
Society dummies	No	No	No	Yes	No	No
Observations	2,698	2,698	2,698	2,698	721	2,698
R^2	0.21	0.46	0.49	0.51	0.50	
Kleibergen–Paap F-statistic						80.31

Notes: The table shows results from estimating (1). The unit of observation is a grid cell. Dependent variables, main explanatory variable, city size and city growth are transformed using the inverse hyperbolic sine (arcsinh). Column (1) controls for geographical endowments (temperature, precipitation, altitude, soil suitability (cereals), soil suitability (potatoes), ruggedness, distance to a navigable river, distance to a sea port, distance to coal); column (2) adds population controls (Bairoch city population 1750, Bairoch city growth 1700–50, No. Keyser cities, Berlin dummy, Protestant dummy); column (3) adds polity fixed effects; column (4) adds society dummies; column (5) estimates in a sample of Prussian grid cells and uses 1816 city population, 1802–16 city growth and Protestant share as controls; column (6) estimates the specification in column (3) using distance to the society seat as an instrument for the number of society members. SEs clustered at the 1789 polity level are reported in parentheses. ***, **, * Statistical significance at the 1%, 5% and 10% levels.

We find the largest mean value of 0.033 in our simulation of distance to the nearest placebo society seat for the sample of large cities with patents as the dependent variable. We find the smallest value of 0.001 in our of simulation of distance to the nearest placebo society seat for the full sample with exhibitors as the dependent variable. Based on these values we conclude that potential downwards bias ranges between 28% and 0.01% (0.033/−0.118 and 0.001/−1.05). Note that throughout all simulations we only find evidence of downwards bias, i.e., the mean of all simulated coefficient has the opposite sign to the coefficient of actual society seats.

3.3. *Society Members and Innovative Activity*

In this section, we present our main results regarding the long-run impact of economic societies on innovative activity. Table 2 presents OLS estimates from (1) across the circa 2,700 grid cells in the German Empire. Panel A shows results using valuable patents as the dependent variable, whereas panel B shows results using exhibitors at the 1873 Vienna World's Fair as the dependent variable.

When conditioning only on the set of geographic controls in column (1) of panel A, we find a large and significant positive relationship between the local density of society members and patenting activity. In column (2), we additionally condition on urban population size and thereby account for the fact that social activity, but also innovation may be driven by pre-existing agglomeration effects. Indeed, the estimated coefficient for society members is smaller in size, consistent with the notion that society members are located in more urban environments. However, the positive relationship remains statistically significant and economically relevant.

In our preferred specification in column (3), we add sixty-five polity fixed effects, reflecting the political borders of the Holy Roman Empire as of 1789. By including such fixed effects, we account for time-invariant unobserved heterogeneity, e.g., the institutional and cultural framework under which societies and their members acted. The resulting coefficient in column (3), when interpreted at the mean (mean of 1.2 members, SD of 10.7), indicates that an increase in member density by 100% is associated with an increase in the number of valuable patents by 21% (mean of 9.6 patents, SD of 111.5).[53]

We add fifteen society fixed effects in column (4). Each dummy takes the value of one if a cell is inhabited by a member of a given society and zero otherwise.[54] This specification accounts for variation across cells populated by members of the same society (the extensive margin) and the coefficient on society members presented in the table thus measures the effect of having more members (the intensive margin) within the same society. By adding such fixed effects we also aim to account for heterogeneity in the characteristics of societies, such as their activities, their way of acquiring members or the timing of publication of membership registers. Given that this specification accounts for differences across societies with varying levels of activity in promoting knowledge diffusion, it is not surprising that the coefficient presented in column (4) is smaller and less precisely estimated than in column (3).

In column (5), we focus on a sample of grid cells containing at least one Prussian city in 1816 ($n = 721$). In this sample, we can add more precise controls for urban population size, city growth and the Protestant population share from Prussian censuses data. The estimated coefficient remains highly significant and large.

In column (6), we report results from estimating the second stage of a 2SLS approach, using distance to the nearest society seat as an instrumental variable for the number of society members, as proposed in Section 3.2. The first-stage estimates, presented in Online Appendix Table C.7, reveal that our instrument is relevant and powerful with a first-stage F-statistic of 80. The IV coefficient is larger than the corresponding OLS estimate in column (3). At face value, the IV estimate suggests that doubling the number of society members in a cell is associated with an increase of valuable patents by 25%.

One potential concern may be that our data do not track whether society members changed their location after we observe them in our membership registers, particularly because innovation outcomes are measured several decades later. If the society's knowledge were confined exclusively to its members and not embedded in local institutions, like vocational schools or industries, this would lead to a less accurate measurement of the geographical distribution of knowledge. Such measurement error may explain why the estimated IV coefficients are slightly larger than those derived from OLS analyses.

Many inventions, even the most successful ones, were not patented. To address this concern, the literature (see, e.g., Moser, 2005; 2012) has relied on other proxies, such as exhibitors at world

[53] For the correct way to calculate the elasticity when both variables are arcsinh transformed, see Bellemare and Wichman (2020).

[54] Note that there are members from more than one society in 118 of the 2,698 grid cells. In such cases multiple dummies assume the value one for the same cell.

fairs, to measure spatial variation in innovation. In panel B of Table 2, we replicate the results from panel A using the local number of German exhibitors at the 1873 Vienna World's Fair as the dependent variable. Again, we find a robust positive relationship between member density and innovation across specifications. The coefficient is smaller once measures for urban population size are included in column (2), but remains stable when adding polity and society fixed effects (columns (3) and (4)). We obtain similar results when using the sample of Prussian grid cells with more comprehensive information on city size (column (5)). Finally, in column (6) we again present 2SLS results using distance to the nearest society seat as an instrumental variable. The coefficient is comparable in size to the IV coefficient in panel A and suggests that doubling the member density at the mean is associated with approximately 25% more exhibitors.

3.4. *Robustness Checks*

Alternative controls. Online Appendix Table D.3 addresses possible concerns regarding the way our main control variables are designed. Because of the absence of precise data on population density at the grid-cell level, we resort to presenting a number of results from second-best alternatives. Columns 2–5 show that results are robust to replacing our baseline population control derived from urban population size reported by Bairoch (1988) with urban population size reported by Pfister (2020), or with measures of overall population size, urban population size and urbanisation rates derived from the HYDE dataset of Klein Goldewijk *et al.* (2017). In column 6, we add to our specification polity fixed effects based on 1820 borders. In this way, we account for interim border changes and might be able to better capture differences in institutions governing innovation and patenting (see, e.g., Donges and Selgert, 2022). We find that our results are robust to changing the definitions of our control variables.

Long-run controls. Online Appendix Table D.4 presents estimates that aim to exclude the fact that pre-existing differences in development confound our results. In particular, we add indicators for Hanseatic League membership, Bishop seat in 1500, printing press in 1500, free and Imperial city status, market charter by 1760, primary school before 1760, Huguenot settlement, as well as the number of notable constructions in 1760. The coefficient on member density remains positive and significant even when we include all variables simultaneously.

Human capital controls. Online Appendix Table D.5 presents estimates conditioning on the pre-existing stock of notable individuals for different periods. While we show that there is no evidence of pre-existing differential *trends* in the attraction of upper-tail human capital to regions closer to society seats in Section 3.2.1, this does not constitute evidence for the absence of pre-existing differences in *levels* of upper-tail human capital density in the cross section. The estimated coefficients on society member density remain largely unaffected by the inclusion of such controls, independent of the respective period during which the stock of notable individuals accumulated.

Distance controls. In Online Appendix Table D.6, we show that our instrument does not capture other potentially confounding distances. In particular, we add several distance measures to our baseline IV specification, including distance to (*i*) the nearest university operating in 1760, 1800 or 1820 (columns 2–4), (*ii*) the seventeen largest cities in 1750,[55] (*iii*) literary society seats and (*iv*) reading society seats. Several of these distances are positively related to successive innovative activity. However, the negligible changes in the coefficient of interest indicate that

[55] The number 17 mimics the number of society seats.

the economic society effect is largely orthogonal to other distances. Similar results are found when we drop grid cells that are located in closer proximity to universities, as presented in Online Appendix Table D.7.

Sample splits. We further corroborate our findings by applying various sample restrictions presented in Online Appendix Table D.8. Specifically, we exclude grid cells that host a society seat (column 2), focus on grid cells containing at least one city as defined by Bairoch (1988) (column 3), exclude such grid cells from our analysis (column 4), focus on grid cells within polities hosting a society (column 5) and divide the sample based on grid cells located either east or west of the River Elbe (columns 6 and 7). None of these sample variations changes the results qualitatively.

Grid-cell size. In Online Appendix Table D.9, we show that our results are robust to increasing the size of grid cells from 15×15 to 45×45 km^2. Using larger cells allows us to capture local spillovers, especially because of more accurate matches between cities and their catchment area. However, assignment to polities is less accurate. Estimated elasticities are slightly larger than when using smaller cells.

Grid-net shift. In Online Appendix Table D.10, we show that coefficient estimates are robust to shifting the grid net ten times by 1.5 km in each cardinal direction, showing that results do not hinge on the starting point of the net.

Spatial correlation. Cross-sectional studies of persistence have recently been put under scrutiny due to spatial correlation issues (see, e.g., Kelly, 2021). To account for arbitrary spatial correlation, we adjust our SEs using the correction introduced by Conley (1999). Online Appendix Table D.11 shows that our results on valuable patents and exhibitors are robust to distance cutoffs of 50, 100 and 200 km. In addition, Online Appendix D.1 performs a robustness check testing whether 10,000 random draws from a simulated spatial noise distribution can predict the innovation outcomes. When regressing spatial noise on our patent (exhibitor) outcome, we find that none (0.02%) of the *t-statistics* for the spatial noise variable is larger than the *t-statistics* of the coefficient for society members.

Spatial trends. Studies of historical Germany are often subject to concerns regarding spatial trends such as the strong East-West divide. To address such concerns, we show that results are robust to adding various polynomials of longitude and latitude in Online Appendix Tables D.12–D.13.

Instrument validity. In Online Appendix Table D.14, we present further evidence to corroborate the validity of our instrument. Here, we split the sample between grid cells with a positive member density and grid cells with zero members to estimate separate reduced-form effects of distance to a society seat on innovative activity. Columns 1 and 2 show that the instrumental variable only affects innovation in the presence of society members. In the absence of the proposed channel, i.e., differences in the propensity to join a society, distance to a society seat has no discernible impact on innovation. This adds further support to our instrumental variable approach.

In sum, our analysis confirms that there is a robust positive effect of society membership on innovative activity during the Industrial Revolution. The extensive set of robustness checks lends credibility to the main results and the validity of the instrumental variable approach.

4. Immediate Impact for the Local Economy

Since one of their main goals was to improve the local economy, this section inspects whether societies had an immediate impact. Specifically, we analyse the case of the Saxonian economic society seated in Leipzig.[56] As presented in Online Appendix Tables A.2–A.3, their prize competitions and inspected products indicate substantial activity directed at improving the local manufacturing sector, especially in textile production. Of the twenty-three prize competitions, eleven targeted improvements in textiles. We thus expect new enterprises in manufacturing, especially in textiles, to emerge in response to the improved access to new knowledge about materials and production techniques provided by the society.

Using a geo-referenced list on the timing of manufactory establishment in Saxony from Forberger (1958), we test whether regions with more society members saw an increase in manufactory foundations after the inception of the Saxonian society. The list of manufactories includes 253 firms and covers a period between the sixteenth century and 1845 (for details, see Online Appendix E).[57] By focusing on manufactories, we capture a highly progressive sector during the phase of 'proto-industrialisation' in Germany (Ogilvie, 1996).

The list can be organised as panel data that we use to estimate the difference-in-difference model

$$\text{Manufactories}_{it} = \alpha_i + \delta_t + \beta\, \text{Members}_i \times \text{Post society foundation}_t + \mathbf{X}'_{it}\,\gamma + \varepsilon_{ip}, \qquad (3)$$

where $\text{Manufactories}_{it}$ is the number of manufactories created in a county (*Amt*) i during a period t. Time periods are defined as years before and after the foundation of the society in Leipzig in 1764, restricted to the period 1700–1800. Thus, there are ninety-five counties and two time periods. During this period 192 firms were created, 133 of which in textiles. As in the main specifications, the explanatory variable of interest, Members_i, counts the number of society members residing in a county. Conditional on county and time fixed effects α_i and δ_t, coefficient β captures differential changes in manufactory creation between counties with varying numbers of members after the emergence of the society. Vector $\mathbf{X}'_{it}$ includes controls for the census populations in 1755 and 1792 to capture (potentially endogenous) population growth following the foundation of the society. It further includes our measure of the local attraction of upper-tail human capital derived from the migration of notable individuals mentioned in the *Deutsche Biographie*. All continuous variables are transformed using the inverse hyperbolic sine (arcsinh).

In Table 3, we present the results from the difference-in-differences model in (3). Our baseline specification in column (1) only conditions on county fixed effects capturing unobserved time-invariant heterogeneity, whereas column (2) adds controls for population size and the immigration of notable individuals. Both columns consistently show that counties with more members saw an increase in manufactory establishment after the Saxonian society was formed. The coefficient in column (2) indicates the fact that doubling the society members in a county is associated with a 20% increase in manufactory foundations, when interpreted at the mean (mean of 0.98 members, SD of 3.185).[58]

In columns (3) and (4), we distinguish between manufactories associated with textile production and manufactories in all other sectors. In line with the notion that the Saxonian society

[56] The decision to focus on Saxony is predominantly driven by data availability. However, as one of the earliest regions in the German lands to industrialise, Saxony is clearly of special interest.

[57] This list is derived from official documents and constitutes the most comprehensive source on early Saxonian manufacturing. Because of the necessity to operate a firm with the ruler's official permission, this list is likely to reflect the universe of established firms. We check robustness of the results when only using firms with precise establishment years in Online Appendix Tables E.2–E.3.

[58] Online Appendix E shows that results are robust to using the entire list spanning the sixteenth century until 1845 and to excluding manufactories for which only the year of first mention instead of the foundation year is known.

Table 3. *Society Members and Manufactory Establishment.*

	Number of new manufactories			
	(1) All	(2) All	(3) Textiles	(4) Other
Society members × post 1764	0.159***	0.148**	0.174***	0.00356
	(0.0571)	(0.0617)	(0.0646)	(0.0788)
Census population 1755/92		−0.0290	0.0611	−0.142
		(0.186)	(0.164)	(0.160)
Attraction of upper-tail human capital, 1700–800		−0.136	−0.148	−0.0712
		(0.189)	(0.216)	(0.217)
County fixed effects	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes
Observations	190	190	190	190
R^2	0.85	0.85	0.85	0.77

Notes: The table shows results from estimating (3). The unit of observation is the county × time period (1700–63, 1764–1800). Dependent variables, main explanatory variable, population and attraction of upper-tail human capital are transformed using the inverse hyperbolic sine (arcsinh). Column (1) estimates the difference-in-difference model with county fixed effects; column (2) adds control variables; column (3) uses only textile firms for the dependent variable; column (4) uses all non-textile firms. SEs clustered at the county level are reported in parentheses. ***, ** Statistical significance at the 1% and 5% levels.

especially focused on improving the local textile industry, as indicated by their large number of prize competitions in this sector, we find that the overall effect is borne by increases in textile manufactories.

We interpret these results as evidence for the immediate impact of societies, that is, the local economy already benefited from improved access to useful knowledge during the pre-industrialisation period. Potentially, the local increase in manufacturing might have led to agglomeration effects. This could partly explain the observed higher levels of innovation in the long run.

5. Channels of Transmission in the Long Run

How can we explain the link between society membership in the late eighteenth century and innovation in the late nineteenth century? As laid out in Section 1, economic societies facilitated human capital formation, promoted certain industries and created information networks. These aspects likely continued to influence the local economy even when societies ceased to exist by creating localised knowledge spillovers and agglomeration economies, resulting in persistently higher innovation. In this section, we provide evidence on the immediate improvement of the local economy through the formation of human capital. Section 6 below explores the long-run effect of information networks through which certain industries were promoted.

5.1. *Societies and the Provision of Vocational Schooling*

Economic societies were particularly interested in advancing technical training and they actively contributed to the opening of vocational schools. We provide evidence consistent with this historical narrative, showing that regions with more society members adopted vocational schools earlier. We argue that, by establishing vocational schools, societies created the prerequisites for the training of highly skilled mechanics, a group of individuals that played a key role in triggering innovation and technical change in the early phase of the industrialisation process

(Meisenzahl and Mokyr, 2012; Mokyr *et al.*, 2022). Therefore, we argue that the provision of vocational schooling constitutes one potential channel of transmission linking society members with innovative activity during the Second Industrial Revolution.

To test whether economic societies fostered the *early* adoption of vocational schooling, we estimate duration models of the time to establish the first vocational school. Using the terminology of duration analysis, in this case a 'failure event' is the opening of the first vocational school in a grid cell.[59] The time at risk for opening a vocational school (of any type) in a grid cell begins in 1764, with the emergence of the first societies. Grid cells that did not have a vocational school by 1899 are treated as censored spells with 1900 as the censoring date.

Online Appendix Figure F.1 shows Kaplan–Meier survival estimates for two groups: grid cells with at least one society member and grid cells without any society member. In comparison to grid cells without any member, grid cells with members experience a considerable increase in the adoption rate starting in the 1820s, with an even higher difference in growth rates after the 1860s. In other words, the probability of not having a vocational school ('surviving') in a given grid cell is systematically higher in cells without any society member from 1820 onward.

To model the opening of vocational schools, we estimate a standard Cox proportional hazards model (Cox, 1972), specified as

$$\lambda_{ip}(t) = \lambda_0(t) \exp(\beta \, \mathrm{Members}_{ip} + \mathbf{X}'_{ip} + \gamma \delta_p). \tag{4}$$

The term $\lambda_0(t)$ is the unknown baseline hazard function, where t is time measured in years; the term $\exp(\cdot)$ represents the covariate-specific relative risk; $\mathrm{Members}_{ip}$ is either an indicator variable that assumes the value one if we recorded at least one member of a given society in a grid cell i within polity p or a variable that counts the number of members of economic societies in a given grid cell; vector $\mathbf{X}$ includes geographical and population controls; δ_p reflects polity fixed effects. SEs are clustered at the polity level.[60]

In Table 4 we present results from the Cox proportional hazards model. The reported coefficients are hazard ratios, i.e., a coefficient larger than one indicates that a variable increases the hazard rate of establishing a vocational school. Across columns, we expand the model by controlling for geographical factors (column (1)), population-related factors (column (2)), polity fixed effects (column (3)) and society fixed effects (column (4)). The coefficient associated with the dummy variable for having at least one society member is always larger than one and highly significant across specifications, except for column (4). This indicates that grid cells with one or more society members adopt vocational schools earlier compared to grid cells without any society member (and that one member might be sufficient).

In column (5) we inspect the intensive margin, using the number of members in a grid cell as the variable of interest. We find that a higher number of society members is also associated with the earlier adoption of vocational schools. Finally, in column (6) we include both margins simultaneously and find that, while the coefficient on the extensive margin remains above one,

[59] As discussed in Section 2, information on the year of establishment is missing for approximately 40% of schools. Furthermore, we observe only schools that were still open by 1899, thus ignoring schools that opened and closed before 1899. Accordingly, results could also be interpreted to indicate that grid cells with society members adopted more successful vocational schools early on.

[60] The Cox proportional hazards model assumes that the hazard ratio is constant over time. To test the proportionality assumption, i.e., whether the log hazard ratio function is constant over time, we inspect the Schoenfeld residuals for our preferred specification that conditions on polity fixed effects (column (3)). The lack of a systematic pattern over time indicates that the proportionality assumption cannot be rejected.

Table 4. *Society Members and the Adoption of Vocational Schooling.*

Dependent variable:	Year vocational school established					
	(1) Geography	(2) Population	(3) Polity FEs	(4) Society FEs	(5) Intensive margin	(6) Both
≥ 1 society member	2.798***	1.535***	1.633***	1.292		1.163
	(0.306)	(0.147)	(0.151)	(0.248)		(0.241)
Society members					1.347***	1.258**
					(0.128)	(0.142)
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Population controls	No	Yes	Yes	Yes	Yes	Yes
Polity fixed effects	No	No	Yes	Yes	Yes	Yes
Society dummies	No	No	No	Yes	Yes	Yes
Observations	2,698	2,698	2,698	2,698	2,698	2,698

Notes: The table shows results from estimating Cox proportional hazards models via (4) conditional on time-invariant control variables. Hazard ratios reported. Here, *Year vocational school established* is the earliest year of foundation of a vocational school in a grid cell after 1764, before 1900; ≥ 1 *society member* is a dummy variable equal to one if records show at least one member of any society in a grid cell; *Society members* is a continuous variable, transformed using the inverse hyperbolic sine (arcsinh), counting all society members in a grid cell. Column (1) controls for geographical endowments (temperature, precipitation, altitude, soil suitability (cereals), soil suitability (potatoes), ruggedness, distance to a navigable river, distance to a sea port, distance to coal); column (2) adds population controls (Bairoch city population 1750, Bairoch city growth 1700–50, No. Keyser cities, Berlin dummy, Protestant dummy); column (3) adds polity fixed effects; column (4) adds society dummies. SEs clustered at the 1789 polity level are reported in parentheses. ***, ** Statistical significance at the 1% and 5% levels.

only the intensive margin is significantly associated with the earlier adoption of vocational schools.

5.2. *Societies and Skilled Mechanics*

After having adopted comparatively earlier vocational schools for technical training, regions with more society members may have gained a head start in training workers that turned out to be crucial for subsequent industrialisation and innovation. Thus, we expect regions with a larger number of society members to also have a higher density of highly skilled mechanics, potentially trained in vocational schools. To test this hypothesis, we use the earliest available full-scale occupational census undertaken in Prussia in 1849 to approximate the local distribution of skills. This comes at the cost of reducing the sample to the 721 grid cells that were part of Prussia in 1849.

Table 5 presents OLS estimates of (1) using the number of highly skilled mechanics as the dependent variable (column (1)).[61] In falsification tests (columns (2)–(3)), we use dependent variables that group the remaining occupations into 'other artisans' and 'factory workers'. In columns (4)–(6) we report the corresponding second-stage estimates using distance to the nearest society seat as an instrumental variable. For consistency, all dependent variables are subject to the inverse hyperbolic sine transformation.

The estimates in column (1) show a strong positive relationship between society members and the number of highly skilled mechanics. Column (2) shows that there is also a positive and significant correlation with other artisans. The relationship with factory workers (column (3)), a

[61] We follow Feldman and Van der Beek (2016) and De Pleijt *et al.* (2020) in their definition of highly skilled mechanical occupations. These are cabinet makers, carpenters and ship builders, instrument makers, wrights, plumbers, printers, copper engravers, craftsmen in lithographic institutions, bell founders, tin moulders, coppersmiths, locksmiths, blacksmiths, coopers and turners. Within the categories listed above we include both masters and assistants, as well as self-employed craftsmen.

Table 5. *Society Members and Highly Skilled Mechanics.*

	OLS			IV		
Dependent variable:	(1) Highly skilled mechanics	(2) Other artisans	(3) Factory workers	(4) Highly skilled mechanics	(5) Other artisans	(6) Factory workers
Society members	0.064***	0.057***	0.011	0.094*	0.072	−0.325**
	(0.014)	(0.016)	(0.078)	(0.048)	(0.059)	(0.154)
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Population controls	Yes	Yes	Yes	Yes	Yes	Yes
Polity fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	721	721	721	721	721	721
R^2	0.86	0.87	0.67			
Kleibergen–Paap F-statistic				59.3	59.3	59.3

Notes: The table shows results from estimating (1) via OLS (columns (1)–(3)) and 2SLS, using distance to a society seat as an instrumental variable for the number of society members (columns (4)–(6)). The unit of observation is a grid cell, limited to a sample of 721 Prussian grid cells. Dependent variables, the main explanatory variable, city size, city growth and the instrumental variable are transformed using the inverse hyperbolic sine (arcsinh). Geographical controls: temperature, precipitation, altitude, soil suitability (cereals), soil suitability (potatoes), ruggedness, distance to a navigable river, distance to a sea port, distance to coal. Population controls: Prussian city population 1816, Prussian city growth 1802–16, number of Prussian cities, Berlin dummy, Protestant share. SEs clustered at the 1789 polity level are reported in parentheses. ***, **, * Statistical significance at the 1%, 5% and 10% levels.

broad measure of industrialisation, is insignificant, although the point estimate is similar to the estimate in column (2).

When estimating the same three specifications exploiting arguably exogenous variation in distance to the nearest society seat, the relationship between society members and highly skilled mechanics remains significant (column (4)). The relationship between members and other artisans (column (5)) turns insignificant and the relationship between members and factory workers (column (6)) becomes significant with a negative sign, a result for which we are currently unable to offer a plausible explanation. The instrumental variable results are therefore consistent with our claim that economic societies either attracted or contributed to the training of highly skilled mechanics who became key in the Industrial Revolution and in pushing technological innovation.

5.3. *Societies, Vocational Schooling, Skilled Mechanics and Innovation*

In this section, we inspect whether the impact of society membership on innovation indeed works through the local establishment of vocational schooling and the training or attraction of skilled mechanics. For this purpose, in Table 6, we present results consecutively adding these mediating factors to our preferred specification. Because of the fact that skilled mechanics are only available for the subset of Prussian grid cells, we restrict our analysis to this sample, and reproduce column (5) of Table 1 here. If the two mediating variables constitute relevant channels through which the main explanatory variable affects innovation, they should reduce the coefficient on society members, as well as this variable's contribution to the R^2.

Upon consecutively adding an indicator for whether or not a cell had adopted vocational schooling by 1849 and the number of highly skilled mechanics in 1849, the coefficient on society members is eventually reduced by approximately 15% for patents and 16% for exhibitors. At the same time, its partial R^2 declines by approximately 26% for patents and 30% for exhibitors. We interpret these findings as supportive to the idea that societies affected innovation in the long run, inter alia, through the establishment of vocational schools and the training of comparatively

Table 6. *Mediation Analysis.*

Dependent variable:	Patents (1877–914)			Exhibits (1873)		
	(1) Baseline	(2) Voc. school	(3) Skilled mechanics	(4) Baseline	(5) Voc. school	(6) Skilled mechanics
Society members	0.336***	0.327***	0.284***	0.215***	0.205***	0.185***
	(0.061)	(0.059)	(0.069)	(0.036)	(0.035)	(0.040)
Voc. school 1849		0.455**	0.474**		0.527***	0.536***
		(0.166)	(0.188)		(0.155)	(0.167)
Skilled mechanics 1849			0.653***			0.307***
			(0.144)			(0.097)
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Population controls	Yes	Yes	Yes	Yes	Yes	Yes
Polity fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	721	721	721	721	721	721
Adjusted R^2	0.525	0.526	0.548	0.461	0.464	0.475
Partial R^2 of members	0.039	0.037	0.029	0.031	0.028	0.023
Partial R^2 of schools		0.003	0.003		0.007	0.008
Partial R^2 of mechanics			0.048			0.020

Notes: The table shows results from estimating (1) via OLS, adding an indicator for vocational school establishment until 1849 and the number of skilled mechanics as mediating factors. The unit of observation is a grid cell, limited to a sample of 721 Prussian grid cells. Dependent variables, the main explanatory variable, city size, city growth, and the instrumental variable are transformed using the inverse hyperbolic sine (arcsinh). Geographical controls: temperature, precipitation, altitude, soil suitability (cereals), soil suitability (potatoes), ruggedness, distance to a navigable river, distance to a sea port, distance to coal. Population controls: Prussian city population 1816, Prussian city growth 1802–16, number of Prussian cities, Berlin dummy, Protestant share. SEs clustered at the 1789 polity level are reported in parentheses. ***, ** Statistical significance at the 1% and 5% levels.

more highly skilled mechanics. This may have contributed to innovation because highly skilled mechanics are more innovative themselves or because this determined the location of more innovative industries (see Mokyr *et al.*, 2022). However, after including these mediators, the coefficient on society members remains significantly correlated with both innovation outcomes. Hence, we conclude that there may be additional channels through which society members affected innovation in the long run.

6. Diffusion of Useful Knowledge

6.1. *Long-Run Impact*

In the last part of our analysis, we argue that societies played a pivotal role in the diffusion of ideas among their members, with important consequences for the geographical distribution of industries and innovations in the long run. In particular, we argue that members of the same society, even when based in disparate locations, accessed a common pool of useful knowledge that was unique to their society, prompting them to innovate, invest and specialise in similar technologies and industries. This shared knowledge, established in the late eighteenth century, potentially played a relevant role in shaping the economic geography of innovation into the late nineteenth century. The initial investments in certain industries, promoted by the societies, arguably triggered sustained technological advancement in those fields, thereby shaping the development and specialisation of regional industries over time.

Empirically, we test whether common membership in a given society across cell pairs increases similarity in the technological classes of innovation during the Second Industrial Revolution. Figure 4 illustrates two examples of networks created by common membership in the societies

Fig. 4. *Illustration of Society Networks across Locations with Common Membership.*
Notes: Spatial networks of members in the economic societies of (a) Burghausen and (b) Rostock. Each member of a given society is connected with a line to every other member.

in Burghausen and Rostock.[62] We test our hypothesis by estimating the gravity-type equation

$$T_{ij} = \alpha_i + \alpha_j + \beta M_{ij} + \delta D_{ij} + \lambda P_{ij} + \mathbf{X}'_{ij}\theta + \varepsilon_{ij}, \tag{5}$$

where T_{ij} is the level of technological similarity between grid cells i and j based on Jaffe (1986). The logic behind this index is that each cell is a series of vectors in a multidimensional technology space defined by the technological classes, which are eighty-six in our case. The index measures the degree of overlap across technological classes between cell pairs and is defined between zero and one. If two grid cells have patents in the exact same technological class, the index will be one; if two grid cells have no overlap in the technological classes of their patents, the index will be zero. Grid-cell-i and grid-cell-j fixed effects are captured by α_i and α_j. The inclusion of these fixed effects captures local heterogeneity in geography, economic activity and cultural attitudes in both cells. The variable of interest M_{ij} is an indicator that takes the value one if grid-cell pair i, j has at least one member from the same society in both cells i and j.[63]

Consistent with the standard assumption in gravity-type models, we expect geographically more proximate pairs to be more technologically integrated. Thus, we condition on geographic distance D_{ij} between grid cells i and j to capture effects arising from geographic proximity. Indicator P_{ij} takes the value one if grid-cell pair i, j belongs to the same polity in 1789. This is expected to capture border effects and a home bias in similarity. Finally, in an extended versions of the model, we add vector $\mathbf{X}_{ij}$ that includes factors that are likely to facilitate the flow of information between cells due to better connectivity via transport infrastructure such as joint access to roads, railroads and navigable rivers. SEs are two-way clustered at grid cells i and j.

The unit of observation in this regression framework is a grid-cell pair i, j. Our sample consists of approximately 365,000 grid-cell pairs with positive patenting activity in both cells, since similarity between i and j can only be calculated with positive patenting activity in both cells. Furthermore, each grid-cell pair is included only once because we do not assume any direction to information flows.

[62] Online Appendix Figure G.1 provides figures for the networks of all other societies.
[63] Note that a grid-cell pair can have common members in several societies.

Table 7. *Shared Knowledge and Technological Similarity.*

Dependent variable: technological similarity	Same society		Different societies		Horse race
	(1)	(2) W/o society seat	(3)	(4) W/o society seat	(5) W/o society seat
Members from the same society	0.015***	0.013***			0.013***
	(0.003)	(0.003)			(0.003)
Members from different societies			0.002	0.000	0.001
			(0.002)	(0.002)	(0.002)
Geographic distance	−0.002***	−0.002***	−0.002***	−0.002***	−0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Same polity	0.003	0.003	0.005**	0.004**	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Grid-cell-*i* and grid-cell-*j* fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	365,938	354,901	365,938	354,901	354,901
R^2	0.13	0.13	0.13	0.13	0.13

Notes: The table shows results from estimating (5) via OLS. The unit of observation is a grid-cell pair, limited to a sample of cells with positive patenting activity. Here, *Technological similarity* is an index based on Jaffe (1986) capturing the level of technological similarity in patents across grid-cell pairs; *Members from the same society* is an indicator that takes the value one if both cells in a pair are home to at least one member of the same economic society; *Members from different societies* is an indicator that takes the value one if both cells in a pair are home to members from different economic societies. Geographic distance is reported per 100 km. *Same polity* is equal to one if a grid-cell pair belongs to the same polity as in 1789. SEs, two-way clustered at grid cells i and j, are reported in parentheses. ***, ** Statistical significance at the 1% and 5% levels.

Descriptive statistics of the grid-cell pairs used in this analysis are reported in Online Appendix Table G.1. The mean value of the Jaffe index for technological similarity is 0.06. The relatively low value is due to the large number of zeros ($\approx$ 73%), that is, the number of grid-cell pairs with no technological similarity. The share of grid-cell pairs with members from the same society is 3%. We also report descriptive statistics for membership in different societies, an indicator that will be used in a falsification test: 12% of grid-cell pairs have members belonging to different societies.

Estimates of (5) are reported in Table 7. The results in column (1) show that grid-cell pairs with members from the same society have significantly higher technological similarity, i.e., they tend to patent in similar technological classes towards the end of the nineteenth century. The size of the coefficient is substantial: having members from the same society increases the technological similarity of a grid-cell pair by 1.5 points, which is an increase of 35% at the mean. As expected, larger geographic distance is associated with lower technological similarity, whereas belonging to the same polity tends to increase similarity, although the coefficient is insignificant.

In column (2), we drop pairs in which at least one cell is the seat of a society. In this way, we test whether the diffusion of technological knowledge worked exclusively through the main hub constituted by the seat of the society. The coefficient for the variable of interest in column (2) is of similar size and highly significant, indicating that society seats are not the main drivers of our results.

In columns (3) and (4), we perform a falsification test estimating the impact of membership in *different* societies on technological similarity. If a given society network only provides access to a specific set of technological knowledge, we expect to find a zero effect when inspecting grid-cell pairs with members belonging to different societies. Indeed, this is what we find: the coefficient for members from different societies in column (3) is small and not significantly different from zero. This result is confirmed when dropping cells with societies seats (column (4)). The coefficient for same-polity affiliation increases in size and significance compared to columns (1) and (2),

Table 8. *Shared Knowledge and Technological Similarity—Robustness Check.*

Dependent variable: technological similarity	(1)	(2)	(3)	(4)	(5)
Members from the same society	0.015***	0.014***	0.015***	0.015***	0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Both access to road	0.007**				0.006*
	(0.003)				(0.003)
Both access to railroad		0.011***			0.011***
		(0.004)			(0.004)
Both access to river			0.005**		0.005**
			(0.002)		(0.002)
Both urban				0.004**	0.003**
				(0.002)	(0.002)
Geographic distance	−0.002***	−0.002***	−0.002***	−0.002***	−0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Same polity	0.003	0.003	0.003	0.003	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Grid-cell-i and grid-cell-j fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	365,938	365,938	365,938	365,938	365,938
R^2	0.13	0.13	0.13	0.13	0.13

Notes: The table shows results from estimating (5) via OLS. The unit of observation is a grid-cell pair, limited to a sample of cells with positive patenting activity. Here, *Technological similarity* is an index based on Jaffe (1986) capturing the level of technological similarity in patents across grid-cell pairs; *Members from the same society* is an indicator that takes the value one if both cells in a pair are home to at least one member of the same economic society. Geographic distance is reported per 100 km. Access to road refers to 1848; access to railroad to 1875; access to river to 1874. *Same polity* is equal to one if a grid-cell pair belongs to the same polity as in 1789. SEs, two-way clustered at grid cells i and j, are reported in parentheses. ***, **, * Statistical significance at the 1%, 5% and 10% levels.

suggesting that joint membership in the same society absorbs some of the home-bias effect. In columns (5) and (6) we run a 'horse race' between joint membership in the same versus in different societies. Both coefficients remain largely unchanged from the previous specifications, confirming that they are conditionally unrelated.

In Table 8 we estimate specifications testing the robustness of our findings to ensure that the networks of society members do not overlap with physical networks and other means of communication. During the nineteenth century, new means of transportation such as railroads became important vectors of knowledge diffusion (see, e.g., Melander, 2020) and could therefore affect the technological similarity within a cell pair. Nevertheless, since railroads and roads (to the extent that they have been constructed after the establishment of societies) are likely endogenous to existing social networks, controlling for them potentially captures mechanisms rather than confounders. We add dummy variables indicating whether both cells i and j had access to a paved road in 1848 (column (1)), to a railroad in 1875 (column (2)) and to a navigable river in 1874 (column (3)).[64] We also include a dummy variable accounting for the fact that both cells are urban, i.e., have at least one town with city rights according to Keyser (1939–74) (column (4)).

Our results indicate that all three means of communication are significantly related to the technological similarity of a grid-cell pair. The coefficient for having members of the same society remains unchanged. It also remains unchanged when all control variables are added at the same time in column (5). While the index of technological similarity is not straightforward to interpret, these results allow us to assess some magnitudes. By comparing the estimated coefficients, we can conclude that the effect of common society membership is roughly similar in

[64] Note that these variables measure if cells i and j both have access to the infrastructure, but do not necessarily imply that these cells are directly linked by the given mean of communication.

size to common access to railroads. This finding indicates that, in the eighteenth century, access to social networks was as crucial for the diffusion of information as access to physical infrastructure was in the nineteenth century. Furthermore, these results imply that, by substantially lowering the costs of accessing a specific body of useful knowledge during the Enlightenment, economic societies had lasting consequences for the direction of technical change and thereby shaped the economic geography of innovation in Imperial Germany.

6.2. *Short-Run Impact*

After having provided evidence for the long-run impact of economic societies on the direction of technological change, two questions still require attention. First, were members of the same society connected for other reasons prior to joining, potentially leading to our results capturing pre-existing networks? Second, what are the mechanisms through which economic societies influenced the direction of technological change in the long run?

To address these questions, this section revisits the case of the Saxonian economic society introduced in Section 4. Using the Saxonian data on manufactory establishments from Forberger (1958), we test whether pairs of counties that had members from the Saxonian society established manufactories in the same industry after the society's opening in 1764. Since we know the establishment dates, we can also investigate whether there was pre-existing similarity across county pairs before the society was established.

We test whether the establishment of the Saxonian society led to a change in the establishment of manufactories in similar industries, by estimating the dyadic difference-in-differences model

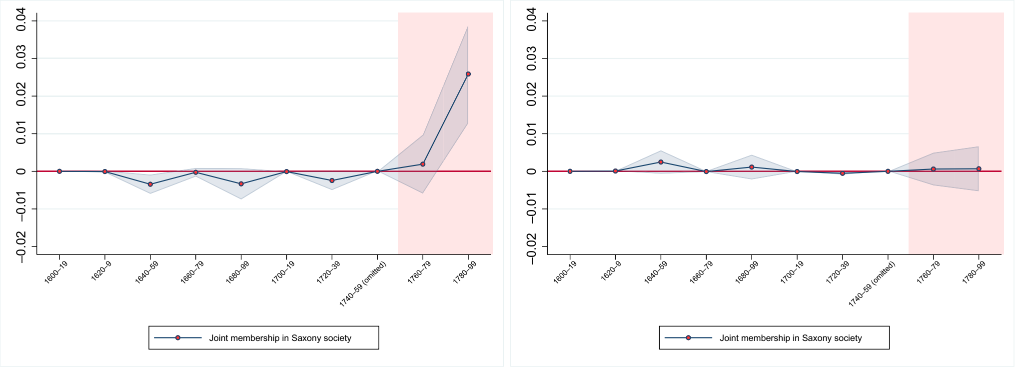
$$T_{ijt} = \alpha_{ij} + \alpha_t + \sum_{\tau=1600\text{–}19}^{1780\text{–}99} \beta_\tau (M_{ij} \cdot \alpha_t) + \theta F_{ijt} + \zeta N_{jit} + \varepsilon_{ij}, \quad (6)$$

where T_{ijt} is an indicator variable that takes the value one if counties i and j both established a manufactory in the same industry during a twenty-year period (i.e., 1600–19, 1620–39,..., 1780–99) indexed by t. We classify the 214 manufactories established in the period 1600–1799 into nine industries based on their output.[65] The establishment of a manufactory reflects organisational innovation and the adoption of new technologies that is potentially facilitated by the diffusion of useful knowledge through the social network of the society.

The variable of interest M_{ij} is an indicator of joint membership in the Saxonian society for county pairs. Because we want to study the dynamic effects of joint membership, this variable is interacted with time-period dummies α_t for each twenty-year interval. To avoid concerns of reverse causality, we only measure membership in the Saxonian economic society in the year of its inception in 1764.

To account for time-invariant heterogeneity at the county-pair level, such as geographic distance, size and other geographical factors, we incorporate dyadic fixed effects α_{ij}. Period fixed effects α_t are included to capture shocks that affect all county pairs uniformly. We further include the indicator F_{ijt} that takes the value one if both counties in a pair established a manufactory of any type during a given period. This allows us to capture broader trends in manufactory establishment within pairs. Additionally, the model includes controls for the sum of manufactories established in both i and j, denoted N_{ijt}. This variable captures the tendency for manufactories

[65] The nine industries are food and tobacco, ceramics, dyeing, fire weapons, instruments, metals and glass, textile printing, weaving and spinning.



(a) Textiles (b) Non-textiles

Fig. 5. *Shared Knowledge and Industry Similarity.*
Notes: The figure plots β coefficients from estimating (6). The dependent variable in panel (a) is an indicator that takes the value one if both counties in a county pair established a manufactory in the same textile industry (dyeing, printing, spinning and weaving) during a period, whereas in panel (b) it takes the value one if both counties in a county pair established a manufactory in the same non-textile industry (food and tobacco, ceramics, fire weapons, instruments, metals and glass). The main explanatory variable is joint membership in the Saxonian economic society in 1764. SEs are clustered at the county-pair level.

to be established in the same industry when there is a higher overall number of manufactories established in a given period. The omitted reference period is 1740–59, the period just before the opening of the Saxonian society. SEs are clustered at the county-pair level.

Our sample consists of 4,305 county pairs observed ten times in twenty-year periods. To avoid imposing assumptions on the direction of information flows, each county pair is included only once in the analysis. Descriptive statistics of the grid-cell pairs used in this analysis can be found in Online Appendix Table G.2.

Based on the findings presented in the previous section, we expect that county pairs with joint membership in the Saxonian society establish manufactories in the same industry following the society's opening. Considering the society's specific emphasis on advancements in textiles, as discussed in Section 4, we expect a particularly notable effect in these sectors.

Figure 5 presents the results obtained from estimating the dynamic-dyadic difference-in-differences model presented in (6), separately for textile industries (a) and non-textile industries (b). Panel (a) shows an immediate increase in the probability that both counties in a pair establish a textile manufactory if they share membership in the Saxonian society after its inception. Joint membership leads to an increase of approximately one percentage point in the probability during the period of 1760–79 and three percentage points in 1780–99. These percentages correspond to a relative increase of 13% and 50%, respectively. Importantly, no discernible trends in manufactory similarity are observed before 1764, addressing concerns regarding pre-existing networks influencing the results. Furthermore, no differential trends are observed in industries where the Saxonian society did not possess significant expertise, both prior to and after 1764 (panel (b)).

These results demonstrate the transformative power of knowledge diffusion through the society and its members, as it can shape the economic structure of a region. It is plausible to conclude that the early establishment of new industries and investments into production techniques determined the path for regional industrial development in the following decades. This finding helps to explain the long-term effects on innovation discussed in the previous subsection. The dynamic difference-in-differences framework employed in this section also provides evidence that gaining membership and thereby access to industry-specific useful knowledge was not driven by pre-existing trends in this industry. This supports our assertion that we have identified a causal effect of knowledge diffusion through society membership that is independent of pre-existing knowledge networks.

7. Conclusion

In this paper, we provide evidence for the important role that economic societies played for innovation and technical change during Germany's Industrial Revolution. At the end of the eighteenth century, the newly established economic societies substantially lowered the cost of accessing new useful knowledge. Using unique data from membership registers of all active German economic societies, we document that regions with higher membership density during the late eighteenth century display higher levels of innovative activity during the Second Industrial Revolution. Our results suggest that doubling the member density is associated with a 25% increase in patents granted between 1877–1914 and a 25% higher number of exhibitors at the 1873 Vienna World's Fair. To rule out that membership density reflects underlying trends in economic development, we adopt an instrumental variable strategy that exploits plausibly exogenous variation in the distance to the nearest society seat. We present extensive evidence that regions closer to these seats did not experience different trends in upper-tail human capital attraction prior to the emergence of societies using a difference-in-differences approach.

We argue that economic societies have a lasting impact on innovation through the presence of agglomeration economies and localised knowledge spillovers. When specifically examining the Saxonian economic society, a difference-in-differences analysis reveals an increase in the establishment of new manufactories in regions with a higher number of society members following its inception. This effect is primarily driven by the textile industry, which received significant promotion from the society through numerous prize competitions. We argue that the shift to industrial production, especially in textiles, created the geographic concentration of novel industries that is still reflected in innovative activity during the Second Industrial Revolution. Furthermore, our analysis indicates that regions with members from economic societies adopted vocational schools at an earlier stage and had a greater number of highly skilled mechanics. The co-location of these activities leads to Marshallian externalities (Marshall, 1890), including technological spillovers, that may explain the persistent effects of society membership.

In addition to our primary findings, we extend our analysis to explore the impact of economic societies on the direction of technological progress. By delving into this new dimension of research focused on upper-tail human capital, we aim to deepen our understanding of how the diffusion of knowledge within the network of the society influences the direction of innovation. We hypothesise that individuals belonging to the same society had access to a distinct body of technological information that was shared more extensively within the society's network. We provide two pieces of evidence for this conjecture. Firstly, we show that pairs of regions with members from the Saxonian society started establishing manufactories in the same industry immediately after its inception in 1764. Secondly, we show that region pairs with members from the same, but not from different societies innovate in similar technological classes a hundred years later during the Second Industrial Revolution. This suggests that the economic societies served as platforms for the transmission of knowledge and facilitated the flow of ideas, transcending geographical boundaries. This had long-lasting effects, working through local investments, thereby contributing to path dependence in technological progress. Our findings highlight the importance of reducing barriers to the diffusion of knowledge for fostering innovation and emphasise the role of idea flows in shaping the direction of technological change.

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Additional Supporting Information may be found in the online version of this article:

Online Appendix
Replication Package

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