Industrialization of the Alps[†]

(Preliminary Draft – please do not circulate)

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Abstract

We study factors that facilitate the diffusion of technology following the Industrial Revolution. Our novel dataset covers parts of Central Europe with high spatial resolution from 1782 to 1930. Leveraging instrumental variables and the staggered expansion of the railway network, we document that industrialization flourished particularly where transport infrastructure and resources coincided, highlighting strong complementarities between these endowments. We show that coal mining served as the predominant driver of this relationship. We find only limited support for the role of pre-existing artisanal skills in predicting growth. Finally, we demonstrate that electrification - though positively associated with growth - primarily reinforced existing patterns.

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1 Introduction

The transition from an agrarian to an industrial society represents the defining inflection point in long-run economic growth. This transformation, and the innovations that underpinned it, originated primarily in eighteenth-century Great Britain before diffusing across continental Europe and, eventually, the rest of the world. Technological progress, however, is not limited to the creation of new technologies at the frontier of human knowledge. Equally - and perhaps more importantly - it involves the adoption, adaptation, and effective implementation of technologies developed elsewhere. This paper examines how technologies emerging from the Industrial Revolution in England were introduced in remote regions of continental Europe and analyzes the factors that facilitated their diffusion and successful implementation.

We focus specifically on the interplay between railroad expansion and resource endowments. We center our analysis on Styria, a former Crownland of the Habsburg Empire situated in the south-eastern end of the Alps, encompassing parts of present-day southern Austria and northern Slovenia. Styria experienced a remarkable transformation during the late nineteenth century, evolving from a poor and remote agrarian region into one of the industrial centers of the Empire.[1] Between 1870 and 1910, manufacturing output more than tripled (Klein et al., 2017) and population increased by roughly 90% from 1812 to 1900. At the same time, the economic setting of nineteenth-century Styria, characterized by the concurrent expansion of the railway network and intensive mining activities, provides an ideal environment to test our main hypotheses: How transport infrastructure and mining affected industrialization and specifically whether the co-occurrence of both factors led to a significant acceleration in economic development. In addition, to provide a more comprehensive account of the industrialization process, we investigate the role of early modern skills (Mokyr 2005), which the literature identifies as a key facilitator for the adoption of new technologies as well as the roll-out of electricity.

To analyze this process, we digitize and transcribe a comprehensive set of historical sources covering the period from the late eighteenth to the early twentieth century. These include several population enumerations ("Seelenzählungen") from 1782,

[1] David Hume visited Styria in 1748. To illustrate its poor state of economic development, we quote his description of it in some length: "[...] as much as the country is agreeable in its wildness, as much are the inhabitants savage, and deformed, and monstrous in their appearance. Very many of them have ugly swelled throats; idiots and deaf people swarm in every village; and the general aspect of the people is the most shocking I ever saw. One would think, that as this was the great road, through which all the barbarous nations made their irruptions into the Roman empire, they always left here the refuse of their armies before they entered into the enemy's country, and that from thence the present inhabitants are descended. Their dress is scarce European, as their figure is scarce human." Hume (1820). Another literary description of the enormous economic transformation of this region during this period from an agricultural subsistence economy to an industrial region can be traced through the literary writings of Peter Rosegger (1993).

1812, and 1846; the extensive economic and topographic survey conducted by Georg Göth around 1840 under the direction of Archduke Johann; and a series of municipal gazetteers ("Gemeindelexika") from 1869, 1880, 1900, and 1930. Together, these sources provide a uniquely detailed view of the history Styria, that we do not exhaust in its usefulness in this research paper.

To identify the effects of railways and mining and to address potential endogeneity concerns we employ instrumental variable strategies developed in the economic literature. We exploit an incidental connection strategy to instrument for rail access, making use of the location of Styria between the cities of Vienna and Trieste, a key connection for the Habsburg empire. We use geological characteristics as proxy for mining potential, exogenous to human activity. In addition, we leverage the phased expansion of the 19th-century railway network to implement a staggered Difference-in-Differences specification. Our findings document a large and significant effect of both transport infrastructure and mining activity on the density of industrial establishments and population growth. Our results imply that industrialization took off specifically where railway access and extractive resource endowments coincided, highlighting strong complementarities between these drivers. Moreover, we disaggregated these effects by resource type - specifically coal and the iron industries. We demonstrate that while both sectors contributed to regional expansion, it was especially coal mining, which acted as the primary catalyst for industrialization and population growth.

We also test whether early modern skill endowments - proxied by the share of craftsmen in 1830 - hindered or fostered subsequent growth. We show that while these endowments correlate with economic success, the relationship is not robust across specifications. Furthermore, we find a negative relationship for the interaction between skill endowments and railway access regarding population growth; however, this result is not robust to our staggered DiD design. This stands in contrast to the documented importance of the presence of skill to growth in Britain (Mokyr 2005).

We also analyze the impact of early 20th-century electrification. Although reduced-form evidence suggests that electricity networks spurred population growth, the relationship is only partially supported by our IV analysis, where we exploit geographic variation in hydropower potential and coal accessibility. In contrast, our results show that the spatial distribution of the power grid was highly path-dependent. Both initial industrial activity, growing population and existing transport infrastructure (railways) strongly predicted the deployment of voltage lines. This evidence suggests a regional "Matthew Effect": rather than acting as a leveling force, the adoption of new technology was clustered in already advanced municipalities, further concentrating economic activity.

The research is embedded within a broad body of literature across economics and the social sciences. First, it relates to the substantial literature documenting that new or improved transport infrastructure typically exerts a large, positive effect on population

and GDP growth in better-connected areas. Key examples include Baum-Snow et al. (2020), Faber (2014), and Michaels (2008) on highways; Donaldson (2018) and Donaldson and Hornbeck (2016) on railways; and Maurer and Rauch (2022) and Bakker et al. (2021) focusing on sea transportation. Recent studies also emphasize unintended consequences, such as González et al. (2025) on the relationship between road networks and state repression, and Calamunci and Lonsky (2024) on the impact of U.S. highways on crime. Similarly, Neubert and Nikolic (2026) demonstrate that for the case of Habsburg that in the imperial periphery (i.e. Bosnia), direct connectivity to the railway network - and the subsequent exposure to interregional competition - precipitated a decline in non-agricultural activity. The role of natural endowments in economic development has also received considerable attention, though findings are more mixed. Fernihough and O'Rourke (2021) show that cities near coal mines grew faster during the Industrial Revolution, suggesting that resource proximity fostered industrial growth. In contrast, other studies emphasize potential "Dutch Disease" effects, where resource booms depress other sectors (Harding, Stefanski, and Toews, 2020; Mien and Goujon, 2021). What remains less explored is the interaction between natural resources and infrastructure, particularly in the context of early industrialization. Theoretical work by Neary and van Wijnbergen (1986) links Dutch Disease dynamics to trade patterns, while recent evidence highlights the complementarity of infrastructure investments. Moneke (2020) shows for the case of Ethopia that access to both electricity and roads yields substantially higher growth than either alone, a finding further supported by Abassi et al. (2022) for Sub-Saharan-Africa. However, similar analyses regarding the onset of industrialization are currently lacking.

Beyond economics, this research also contributes to the broader fields of history and the social sciences. In recent years, the Habsburg Empire has once again attracted growing academic interest (Harmat, 2025; Romberg et al., 2023; Winkelbauer, 2022; Judson, 2016). At the same time, there has been a broader shift toward regional histories that emphasize the heterogeneous nature of economic development within Europe (Rosés and Wolf, 2019; O'Rourke and Williamson, 2017). While most of these studies adopt an inter-regional perspective (e.g., Schulz, 2018; Klein et al., 2017), our dataset enables an intra-regional analysis, allowing for a more detailed examination of how industrialization unfolded within a single region. It also contributes to the economic history of Styria, a topic that has recently attracted renewed attention in economic research (Ochsner, 2023). In addition, the digitized survey of Georg Göth consiting of over 40000 pages of detailed qualitative description of the social life in 1840 will be of significant interest for other scholars especially in the field of humanities. Furthermore, the project is methodologically embedded in a growing body of economic research that leverages machine learning techniques to recover historical data (e.g., Gorin et al. 2021; Heblich et al. 2021).

Our main research contributions include the following: We construct and provide a novel historical dataset on economic conditions in the South-Eastern Alps at a high spatial resolution. This dataset will be made available online, alongside the digitized primary records and full transcriptions of the extensive historical survey. Moreover, we analyze the factors that contributed to local growth in the region. Our findings stand in interesting contrast to results reported elsewhere, particularly the low importance of existing skills and electricity, and the great importance of the complementarity of rail and mining. Studying the spread of ideas is not only of historic interest, but holds important lessons for the economic development of countries that are technologically catching up. In particular, the importance of the interaction of resources and transportation suggests that technological transfer is not a linear process, but the complex result of multiple investments that need to come together to be particularly impactful.
The remainder of the preliminary draft is organized as follows. Section 1 provides a historical overview on the importance of railways and mining during the Industrial revolution and core economic developments of 19th-century Styria. Section 2 details the construction of our dataset and presents descriptive statistics. Section 3 outlines our empirical strategy with section 4 presenting our main empirical results, Section 5 concludes.

2 Historical Context

The pivotal role of transportation during the Industrial Revolution is well established. While Fogel (1964), Donaldson and Hornbeck (2016), and Maurer and Rauch (2019) provide robust quantitative evidence for these historical dynamics - alongside modern empirical studies by Faber (2014) and Baum-Snow et al. (2020) - these findings are complemented by a vast historical literature on Europe (i.e., Szostak 1991; Aldcroft 1979; Fremdling 1977; Landes 1969) and the Habsburg Empire (Treml 1969; Matis 1972): This body of work identifies several key mechanisms through which infrastructure catalyzed industrialization: first, expanded market access enabled regional specialization and fostered the move toward large-scale, standardized production. Beyond these demand-side shifts, enhanced reliability incentivized a transition from decentralized domestic systems to efficient, centralized workshops. Crucially, lower transit costs and year-round availability prevented capital from being "sunk" in idle inventories, allowing for direct reinvestment into machinery and factory expansion (Landes, 154). This structural change was further reinforced by the accelerated flow of information through these networks, which acted as a critical driver of innovation. This positive effect of infrastructure and especially railroads is also described with regard to the Habsburg Empire, where from 1837 to 1900 railway lines extended from 74km to 19270km. Hereby, Tremel (1969, p. 370) writes that "the railway constructions fundamentally changed transport and had an impact on the settlement and economy of the valleys they traversed, as well as those valleys they avoided, which now became desolate, while new places flourished because they were situated on the railway".[2] Whereas Kaser and Stocker (1987, p. 12), for example, attributes the underdevelopment of the eastern part of Styria largely to a lack of infrastructure hindering the export of goods and spread of ideas to this region writing: "This isolation prevented or slowed down external influences. As very few people ever ventured into Eastern Styria, there was little contact with the outside world, and people knew very little of what was happening elsewhere". [3] Beyond these quantitative and descriptive accounts of historical infrastructure, numerous studies provide robust empirical evidence of its impact.
However, beyond its standalone importance, the critical interplay between transportation and complementary factors, specifically mining and natural resources, remains a central focus of the historical literature. Already, Rostow (1962, p. 302) writes, that "perhaps most important for the take-off itself, the development of railways has led on

[2]Die Bahnbauten veränderten den Verkehr grundlegenden und wirkten sich auf die Siedlung und Wirtschaft der Täler aus, die sie durchzogen, ebenso aus wie jene Täler, de se mieden und die nun verödeten und neue Orte blühten auf, weil sie an der Bahn lagen [...]

[3]Die Abgeschlossenheit verhinderte beziehungsweise verlangsamte von außen kommende Impulse. Da sich nur sehr wenige Menschen in die Oststeiermark verirrten, fehlte der Kontakt nach außen, man erfuhr nur sehr wenig von dem, was sich in der Welt tat[...]

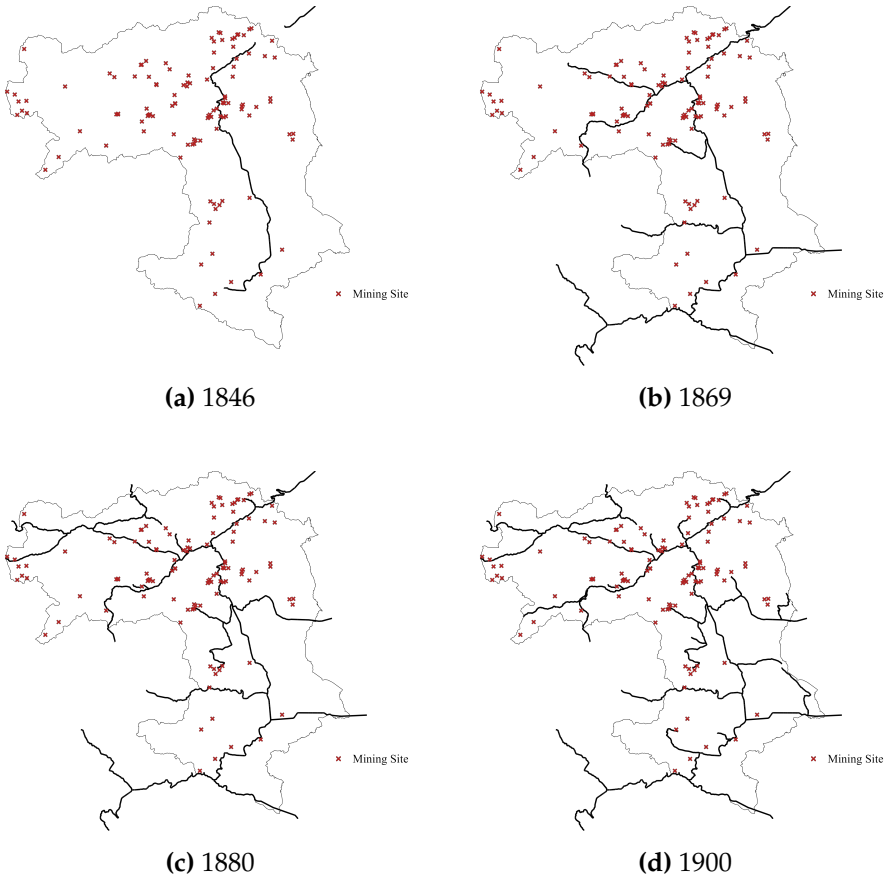
to the development of modern coal, iron, and engineering industries" (Rostow 1962, p. 302) underpinning this central interaction of mining and railways. Similarly, Weber (1961) identifies the synergy between coal, metal, and railways as the decisive catalyst for the first phase of Habsburg industrialization.

This complementarity operates through several distinct channels, which can be categorized into backward linkages, where transport innovations drive demand in sectors providing essential inputs, and forward linkages, which enhance the distribution and market reach of the selling sectors. The metal and coal industries were particularly sensitive to the backward linkages generated by the railway sector. The iron industry benefited directly from the railroad boom through the manufacturing of locomotives and rails; Fremdling (1977), for instance, demonstrates the transformative importance of this demand for the German iron sector. Beyond sheer volume, this pressure catalyzed technological innovation, particularly in the ability to smelt, mold, and manipulate unprecedented masses of metal. Similarly, the coal industry experienced a dual demand shock: coal served both as a critical metallurgical input for the iron industry and as the primary energy source for steam propulsion. As Mathias (1983) shows for Britain, this interaction formed a self-reinforcing triad between coal, iron, and railways: rail construction generated sustained demand for iron products, the iron industry in turn relied on coal as both fuel and input, and the expanding rail network reduced coal's transport costs - amplifying mining viability and deepening industrial interdependence.

In addition, the general positive forward linkages, i.e., increased market access or safer transportation, applied to these mining industries. For the coal industry, the reliability and physical security of rail transit were particularly important: the smooth movement of rail prevented fragile charcoal or coke from crumbling under its own weight or being pulverized by constant jolting. This shift ensured that the fuel reached its destination with the porosity and structural rigidity necessary to withstand the heavy charge of a modern blast furnace. Furthermore, the railway's ability to provide the energy-intensive iron industry with consistent access to coal - combined with the simultaneous integration of regional markets - likely generated a powerful amplifying effect on the pace of industrialization.

Yet, despite its historical significance, this interdependence has received relatively little attention within quantitative economic research. To investigate both the standalone impact of railroads and the specific interaction between railways and mining, the Crownland of Styria provides an ideal historical setting: On the one hand, Styria served as a mining hub within the Austrian Empire, characterized by the dense proximity of massive iron ore deposits - most notably the Erzberg – together with extensive coal fields. This unique geography makes it possible to disentangle the effects for the metal and the coal industries and to examine these complementarities. On the other hand, during the 19th century Styria heavily extended its railway network. As

the pre-existing road network was poor due to the alpine terrain, and the region's rivers were largely unsuitable for heavy industrial navigation, railways were especially transformative for this region. The most central project was the Südbahn connecting Vienna and Trieste, which serves as a prime example of our incidental connection argument. Originally, the railway was planned to run through the flatter terrain of Burgenland (region east of Styria). However, due to the Empire's strategic desire to avoid placing critical infrastructure within the Hungarian region at that time, the route was diverted through Styria. This shift turned Styria from an isolated region to being connected to a central corridor of the Empire's railway strategy. In the following decades, the network underwent significant expansion, aimed not only at integrating Styria with neighboring Crownlands - such as Salzburg and Carinthia - but also at interconnecting major internal urban hubs. Figure 1 illustrates this staggered adoption of the railway network across the 19th century, whereby the railway lines are clustered according to the availability of our population census data.



(a) 1846 **(b)** 1869

(c) 1880 **(d)** 1900

Figure 1: Staggered expansion of the railway network (black) and the locations of the largest Styrian mines in the 19th century (red)

3 Data and Descriptive Statistics

To investigate our research question empirically, we conducted extensive digitization and transcribing of archival material containing historic data on population and endowments in the region of Styria and partly its neighboring areas. We conducted these digitizations ourselves, with help from the Universalmuseum Joanneum in Graz, where the original archival material is located. The data section is organized into three parts. First, we outline the administrative evolution of Styria, providing the historical context for the spatial units used in our analysis. Second, we describe our data sources, detailing their historical origins and the specific information they contain. Finally, we present descriptive statistics derived from these integrated sources to offer a snapshot of the urban landscape across different eras. A more detailed documentation regarding the digitization and transcription procedures, as well as the technical construction of the final dataset, is provided in the Appendix.

3.1 Administrative Units and their Reforms

One of the main challenges in constructing the dataset was to track administrative units over time and to harmonize the various data sources into a coherent dataset with a consistent set of spatial entities. The following section summarizes this process, discussing the relevant administrative units, their evolution over time, and the historical context surrounding each administrative reform. Finally, the administrative units that are pivotal for the subsequent analysis are visualized.

A first element of a more centralized administrative organization of the increasingly modern state apparatus of the Habsburg Empire was the division of Styria into so-called Nummerierungsabschnitte ("numbering segments"). The preceding administrative units - parishes ("Pfarren") and manorial jurisdictions ("Herrschaften") - were unable to meet the new tasks, particularly the systematic enumeration of the population. Manorial jurisdictions were often neither coherent nor clearly delineated territorial units, with the consequence that even individual villages could be composed of parts belonging to several different manorial jurisdictions. This organizational weakness became apparent during the early population counts of 1761, in which the recorded population declined by 39% compared to 1754. Such inconsistencies ultimately led to the promulgation of two patents by Empress Maria Theresa, which reorganized the state administration: First - and more importantly for our purposes - local officials were to carry out a general census ("allgemeine Seelenbeschreibung"), during which the numbering of individual houses was also to be conducted. Second, at a higher administrative level, military districts were established and tasked with organizing recruitment for the armed forces. The first patent gave rise to the "Nummerierungsabschnitte" (enumeration segments),

while the second created the "Werbebezirke" (military districts). In the absence of a standardized definition for "enumeration segments", the clustering of houses remained largely at the discretion of individual conscription officers. This autonomy resulted in significant heterogeneity in segment sizes. Nevertheless, most officers adopted the village ("Ortschaften") as the primary territorial unit and clustered these as formal enumeration segments. While the enumeration segments do not serve an explicit role in our primary empirical analysis they provided the structural framework for subsequent administrative reforms - evolving first into tax municipalities ("Steuergemeinden"), then into cadastral municipalities ("Katastralgemeinden"), and eventually into modern municipalities ("Gemeinden"). In addition, the earliest sources report demographic data according to the enumeration segments, which we aggregated to the spatial units established in 1826 and thereafter.

While the enumeration segments were originally conceived for military purposes, subsequent reforms were primarily driven by fiscal imperatives. Under the Josephinian Land Survey ("Josephinische Kataster"), designed to establish a systematic basis for the land tax ("Grundsteuer"), the segments were expanded to incorporate the surrounding land. This process also involved significant administrative consolidation: smaller segments were aggregated and disproportionately large ones subdivided. Together that resulted in the creation of tax municipalities ("Steuergemeinden"). These units served as the direct precursors to the cadastral municipalities ("Katastralgemeinden") later formalized under the Franciscan Land Survey ("Franziszeischer Kataster"). In summary, the initial 3,756 enumeration segments were aggregated into 2,620 tax municipalities, which were again slightly expanded to 2,680 cadastral municipalities. In our empirical analysis, these cadastral municipalities serve as administrative units for our robustness analysis and are depicted in Figure A1 together with the aforementioned military districts in the appendix. However, our primary empirical specification utilizes the municipality ("Ortsgemeinde") as the unit of analysis. These municipalities were established following the revolutionary year of 1848, which precipitated a comprehensive administrative reorganization of the Habsburg territories. The 228 former military districts were dissolved and replaced by 67 judicial districts ("Gerichtsbezirke") and the Local Government Act of 1849 ("Gemeindegesetz") mandated the creation of our municipalities through the consolidation - and in some instances, the direct adoption - of the earlier cadastral municipalities[4]. These 1849 boundaries established the foundation of the contemporary administrative structure, remaining largely intact to the present day. We adopt these municipalities ("Ortsgemeinde") as the primary unit of

[4]These new administrative divisions fulfilled significantly broader functions than the preceding classifications, which were established primarily to facilitate these broader organizational and statistical purposes. They assumed responsibility, ranging from social welfare provision (such as poor relief) to local public services - including winter road maintenance - and the support of local security apparatuses (such as the Gendarmerie).

analysis for two reasons. First, subsequent census records are only available at this level. Second, using smaller units introduces significant measurement error. Since the historical mapping of villages to cadastral municipalities is not always consistent, administrative reclassifications have a disproportionately large effect on smaller units. Aggregating to the municipal level mitigates these discrepancies. Figure 2 illustrates the spatial distribution of the municipalities nested within their respective judicial districts. In addition, it delineates the post-WWI frontier that separated the predominantly Slovenian and German-speaking regions into Lower and Upper Styria. Throughout the paper, we distinguish between the historical Habsburg crownland and the modern administrative region: We use the term "Old Styria" to refer to the entirety of the Crownland within its pre-1918 borders. Conversely, we use "New Styria" to denote the contemporary boundaries of the Austrian federal state "Styria".

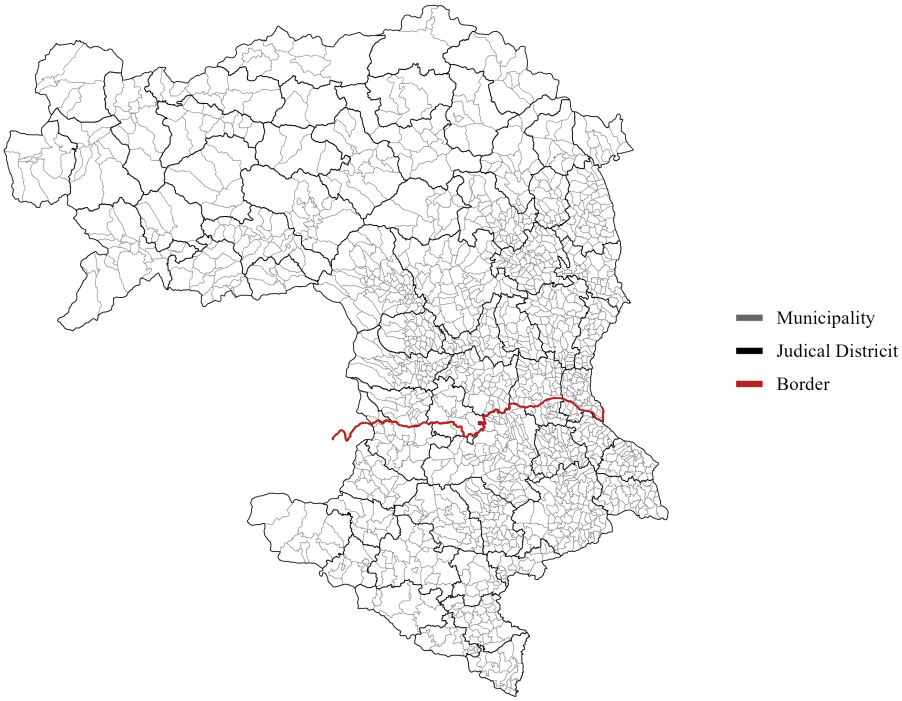


Figure 2: Administrative Units after 1849: Municipalities (grey), juridical district (black) and the future boarder between Slovenia and Austria (red)

3.2 Pre-industrial era: Population enumerations

The first component of our dataset builds on an early project carried out in the late 1980s, originally developed by Manfred Straka (1978), whose outcomes were never digitized or transcribed. The project had two main objectives, both of which are essential for our purposes. First, it aimed to reconstruct the exact boundaries of historical

administrative units - especially with regard to the reforms mentioned above - by tracing which enumeration segments were aggregated into cadastral municipalities and subsequently into municipalities. Second, this reconstruction provided the foundation for locating the statistical representations of the population from that period. While Straka's work covered a broader set of sources, we focus on the earliest reliable population enumerations ("Seelenzählungen") of the Habsburg Empire, conducted in 1782, 1812, and 1846, to characterize the pre-industrial era of the Crownland of Styria. The first census of 1782 originated from Emperor Joseph II's Parish Regulation ("Pfarrenregulierung") of 1783 and 1786. In preparation for this reform, the Emperor ordered an assessment of all parishes, which required recording the specific number of families and inhabitants. This census was conducted by priests between May and June 1782, using the previously described enumeration segments as the administrative basis. While the records provide a nearly complete view of the New Styrian region, the data for the parishes south of the Drava River are missing.
Other census data come from the Military District Censuses ("Werbbezirkszählungen"). Once these districts were established, they were assigned two primary tasks: first, to perform an initial assessment of the population, and second, to track ongoing changes to maintain accurate records for military conscription. The population figures for 1812 are taken from Carl Schmutz's Steiermark Lexikon, as the original primary documents no longer exist. The data for 1846 summarizes the primary records from the final census of that year at a catasteral municipality level. The tables compiled by Manfred Straka already assign each historical enumeration segment to its corresponding cadastral municipality and, subsequently, to its modern municipality. This mapping allowed for the population data from 1782 and 1812 to be aggregated into these higher administrative units.
The appendix includes a scan of these tables, illustrating the structure of this data and further notes on the transcription process.

3.3 Industrial Era: Local Directories and Gazetteers

The second component of our dataset covers the beginning industrial era in Styria, for which we transcribed the Special Local Directories ("Spezialortsrepertorien" 1869 (1872), 1880 (1882)) and Municipality Gazetteers ("Gemeindelexika", 1900 (1905)), which had been previously digitized by a Slovenian research team, but remained untranscribed. In principle, these enumerations represented a continuation of the established population censuses, which were also reformed following the administrative restructuring that succeeded the abolition of the feudal system in 1848. These publications got increasingly comprehensive. First, the data were reported across multiple administrative tiers: Municipal-level data were disaggregated to the village level - a division closely aligned

with the numbering segments. In the 1900 census, these villages were also mapped to their respective cadastral municipalities. Combined with Straka's work, this spatial correspondence provided an additional robustness check for his classification[5]. Second, the enumerations not only focus on population but also report religious denomination, gender and language. The last census even includes a broader characterization of local economic conditions with information on industrial establishments, railway connectivity, and a diverse set of institutional endowments at the cadastral municipality level.
In addition, we expanded this corpus by digitizing and transcribing a similar publication of New Styria for 1930.

3.4 Archive Göth

However, this study's most significant data contribution is the large-scale digitization of the Archiv Göth, a landmark socio-economic census commissioned by Archduke Johann of Austria and conducted by Georg Göth[6]. Göth's objective was to systematically document the socio-economic landscape of Styria through questionnaires distributed to local officials and selected private citizens. These responses served as the foundation for his work, "Das Herzogthum Steiermark, geographisch-statistisch-topographisch dargestellt und mit geschichtlichen Erläuterungen versehen"."[7], published in the mid-19th century based on the Göth archives. It contains detailed information on 8 districts of the Brucker Kreis, then an administrative unit of Styria. The second volume on the 16 other districts of the Brucker Kreis was published in 1841, whereas the third volume on the Judenburger Kreis followed in 1843. Göth did not finish his project because the organization of Styria's administrative divisions changed in 1848. Even though he made attempts to adapt his work, he could not keep up with the continuously changing divisions and therefore decided to stop. The handwritten script of the unpublished fourth volume on the Grazer Kreis is located in the Styrian Provincial Archive as well as the raw materials for these volumes and those administrative units he never accomplished to write about. The surveys, answered in old handwriting (Kurrent) by officials from distinct levels of public administration (parishes, districts, tax communes (Steuergemeinden), Lokalien, Dominia, Herrschaften) are ordered alphabetically by the

[5]The classifications in the 1900 census are largely identical to those in Straka (1978). Where discrepancies arose, we prioritized the clustering provided by the Municipality Gazetteers and used that as a baseline for all periods in our sample.

[6]Archduke Johann was a Habsburg archduke and a key modernizing figure, often referred to as the "Styrian Prince" for his deep commitment to the region's development. Johann was the driving force behind early industrialization and the expansion of infrastructure, most notably the construction of the Southern Railway. Göth himself was an Austrian statistician and archivist at the Joanneum in Graz, as well as a close confidant of Archduke Johann.

[7]"The Duchy of Styria, geographically, statistically, and topographically presented and provided with historical explanations"

name of the units. Since these units differ not only in size but also in their administrative significance, so do the respective surveys. Those sent to tax communes comprise different questions than those addressed to districts or, evidently, parishes.
We digitized the primary raw materials of Göth's survey preserved in the State Archives of Styria ("Landesarchiv Steiermark"). In total, we processed approximately 40,000 pages spanning 1,332 individual surveys - each corresponding to a specific administrative unit of the era - providing a high-resolution account of life in early modern Styria. For our empirical analysis, we rely specifically on the District Summaries ("Bezirkssummaria"), which are extensive tabular records summarizing the socio-economic structure of each cadastral municipality. Figure A2 depicts one of such tables for the district of Lichtenwald. These records provide granular data on the occupational structure, age cohorts and the gender distribution. Additional sample pages with regard to the more qualitative information of the survey as well as a more detailled description of the transcription process can be found in the Appendix.

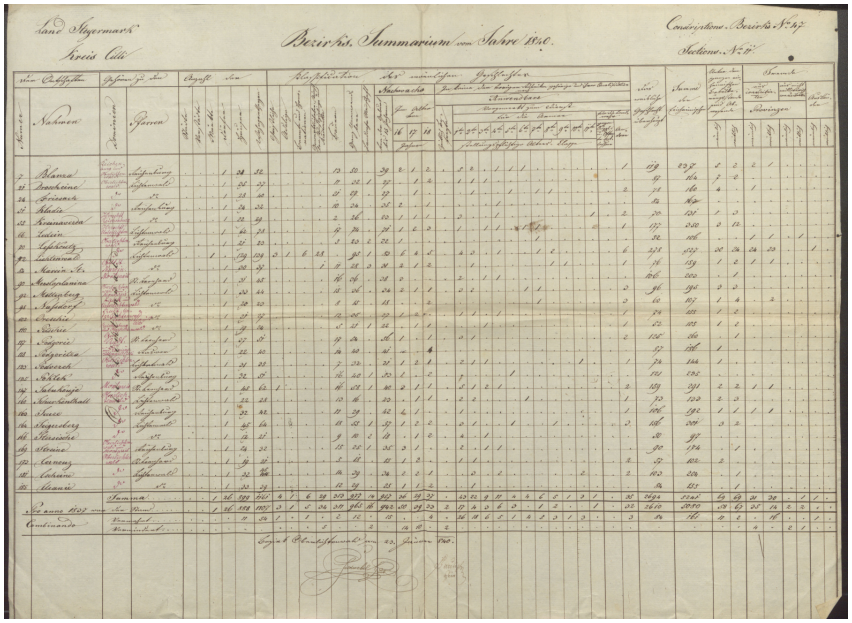


Figure 3: Excerpt from the Göth archives: District Summary of Lichtenwald

3.5 Maps and additional Sources

To exploit the spatial dimension of our data and examine the discussed drivers of industrialization, we integrated additional archival records, focusing primarily on historical maps. First, we georeferenced a historical lexicon from the regional archive to delineate the locations and boundaries of each cadastral municipality and municipality, as well as their encompassing district boundaries (Historische Landeskommission für Steiermark, 1978). Figure 2 presents part of the output of this digitization process. Second, we

reconstruct the 19th-century expansion of the rail network by reconciling modern GIS data (ÖBB, 2025 for Austria and GURS, 2025 for Slovenia) with historical maps (e.g., Artaria & Co., 1875; Freytag, 1900). While a substantial portion of the contemporary network follows original alignments, we use archival maps and secondary literature (Bachinger, 1973; Gallmetzer and Posch, 2012) to recover decommissioned segments. Finally, we assign each segment to temporal bins (1812–1869, 1869–1880, 1880–1900, and 1900–1910) based on completion date. These intervals correspond to our census waves and provide the temporal variation for our staggered difference-in-differences specification. Third, we integrated this with a comprehensive dataset of historical mining from Geosphere Austria (2025), supplemented by primary sources - particularly for the Slovene territories of Lower Styria - to locate 19th-century mining activities (i.e. "Tafeln zur Statistik der Monarchie", 1826). While the primary historical sources are relatively coarse, the Geosphere dataset provides high-resolution data, including information on the scale of mining operations, the type of minerals extracted, and the centuries of activity. Fourth, to examine the role of electrification in industrial development, we digitize archival maps from the Chamber of Commerce and Industry ("Handelskammer für Gewerbe und Industrie", 1930). These sources provide the locations of all coal-fired and hydroelectric power plants, as well as the extent of the high- and low-voltage transmission networks across New Styria.

Beyond the historical analysis, we investigate the long-run effects of nineteenth-century developments on contemporary economic outcomes. To assess current economic conditions, we utilize the Global Human Settlement Layer (GHSL) and satellite-based nighttime light intensity from the Visible Infrared Imaging Radiometer Suite (VIIRS).

3.6 Data Summary and Descriptive Statistics

Table I provides an overview of our data sources, detailing the specific reference years and the corresponding number of population observations available for each period. The numbers on the cadastral municipality data refer to the entire historical Crownland of Styria, whereas the data at municipality level is restricted to the Austrian portion of the province. We observe a difference in archival density: While population enumerations (Straka) and official Gazetteers provide nearly exhaustive coverage of the Crownland, the data retrieved from the Göth archive is less extensive, covering slightly less than half of the region.

Table I: Spatial Resolution of Population Data

	Straka			Göth	Gazetteers	
	1782	1812	1846	1840	1869–1900	1930
Cad. Municipalities	3669	3661	3670	1864	3682	-
Municipalities (New Styria)	986	982	986	418	990	990

Corresponding to the details in Table I, Figure A6 in the Appendix illustrates the spatial coverage of our dataset for the year 1812.
Before focusing on our main period of interest - the 19th century, during which Styria transitioned from an agrarian to an industrial region - we investigate the long-run economic effects of our two primary channels. Figure 4 depicts the population distribution of the Crownland for the year 1975 using GHS data, overlaid with the complete historical railway network in black and the top 25% of 19th-century mining sites by output in red.

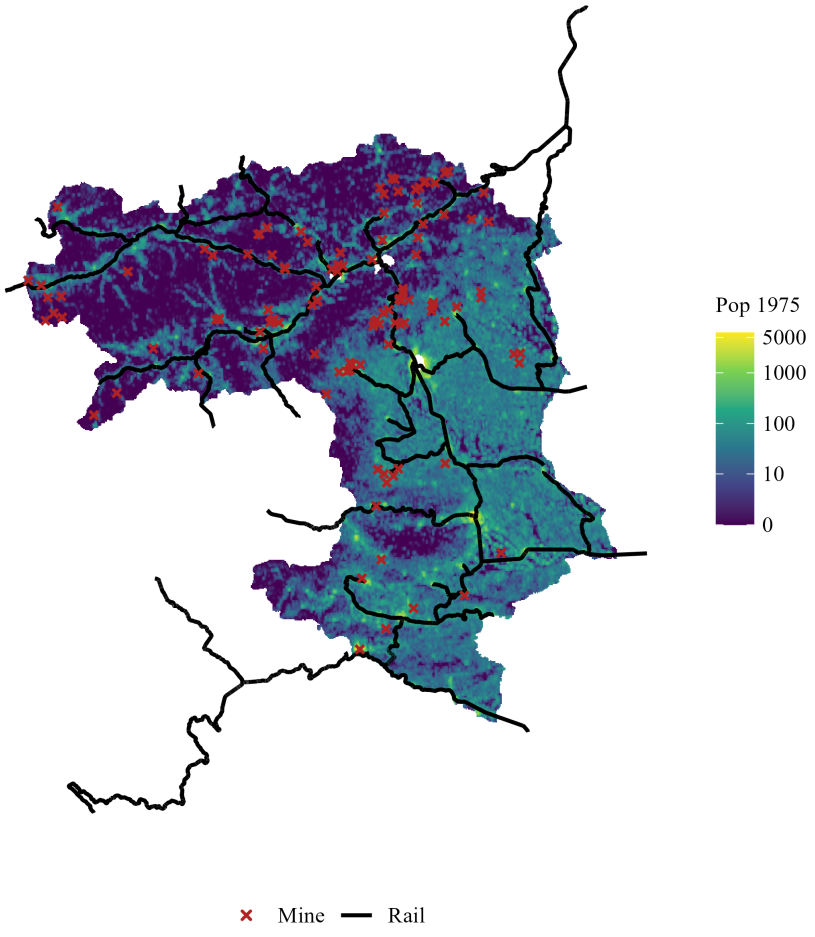


Figure 4: Population distribution of Old Styria in 1975 (GHS-Data) together with railway lines (black) and the largest (25%) mines (in red)

It is immediately apparent that population, and by extension economic activity, remains concentrated along the railway corridors. Furthermore, regions historically characterized by intensive mining activity appear to maintain a economic advantage in the long run as well.

Figure 5 provides further evidence of these patterns, now focusing on the 1900 century - a period marking the initial wave of industrialization in the Crownland. The map displays the spatial distribution of manufacturing, where shaded areas indicate municipalities with at least one active factory, again overlaid with the railway network and large mining sites active in this century.

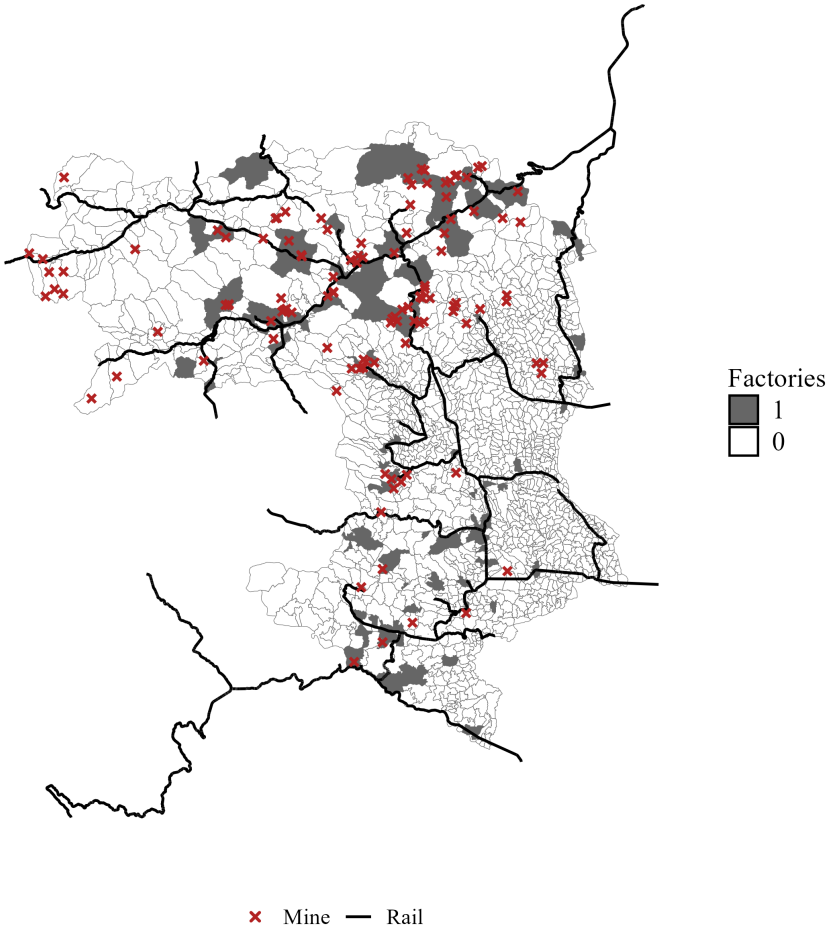


Figure 5: Distribution of factories in 1900 together with railway lines (black) and the largest (25%) mines (in red)

This distribution indicates that factories were predominantly established in close proximity to railway lines, suggesting that infrastructure and access to mining resources played a decisive role in industrial location. Furthermore, a potential interaction between these two channels is visible; specifically, municipalities that benefited from both railway access and local mining sites seem to exhibit a higher concentration of

industrial establishments.
Aside from this assessment of the 1900 and 1975 status quo, our long-run dataset allows for a deeper investigation into the steady process of industrialization by analyzing population development from 1812 to 1900. Figure 6 depicts these growth rates for the different quartiles. It is important to note that the quartile assignments are period-specific; they reflect the within-period distribution rather than fixed absolute thresholds. In the Appendix Figure A5 gives a more detailed (again period specific) decomposition of growth rates for the periods 1782–1812, 1812–1869, and 1869–1900.

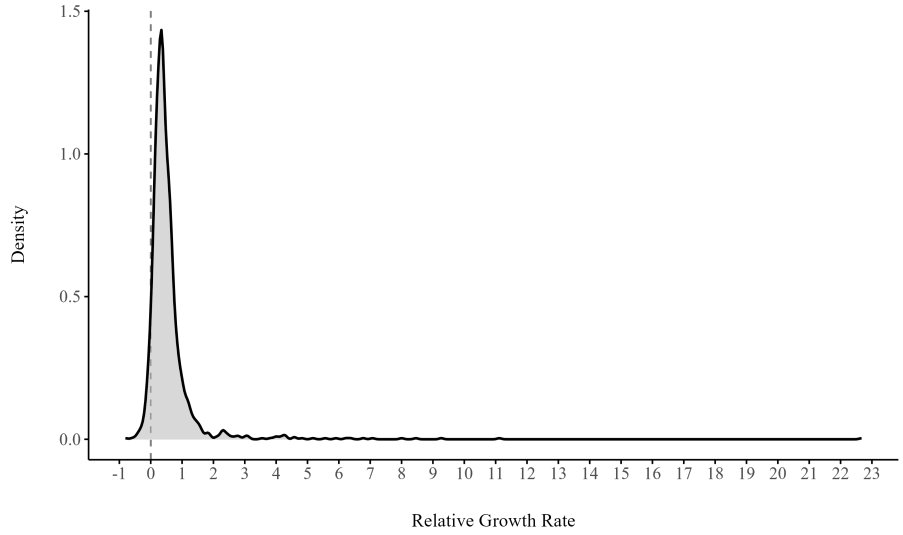


Figure 6: Distribution of population growth rates from 1812 to 1900

Figure 6 illustrates two central features of the Styrian development. First, the period was marked by transformative growth, with localized expansion rates exceeding 1,000 percent. Second, the industrialization process was highly heterogeneous: Demographic gains were concentrated in rapidly accelerating centers. Even within the top quartile of the distribution, significant outliers underscore the unevenness of these gains. In contrast, the majority of municipalities experienced relatively modest population changes, with several recording net declines as labor migrated toward these industrial hubs.
Given our focus on the determinants of the industrialization process, we investigate the respective roles of railway infrastructure and mining activity as primary drivers of regional development in the following. We categorize municipalities based on their access to rail infrastructure, local mining activity, or both using the same cutoffs as in our empirical analysis. To isolate the independent effects of each driver, municipalities possessing both endowments are excluded from the individual rail and mining categories; Consequently, the plots in Figure 7 compare these mutually exclusive groups against a group of regions that lacked access to either endowment.
The descriptive evidence in Figure 7 suggests a strong positive correlation between

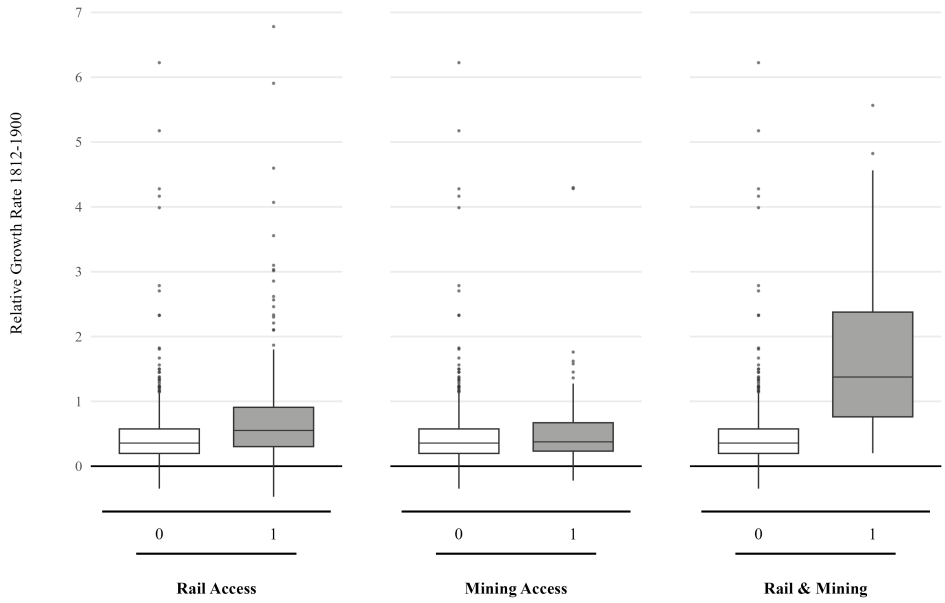


Figure 7: Relative growth rate 1812–1900 clustered by Access to Rail, Mining and both

Notes: The figure displays the distribution of population growth rates clustered by having access to railways, mines and both. Railway access is defined as being within a 2km proximity of a railway line; mining access is defined as being within 1.5km of a mining site. Municipalities which have access to both are excluded from the individual boxplots. Outliers are omitted for visibility.

endowments and demographic expansion. Notably, municipalities possessing both railway access and mineral endowments exhibit the most pronounced population growth.

4 Empirical Setup

In our main model specification we estimate versions of the following equation to examine the impact of infrastructure and resource endowments on regional development:

$$Y_i = \alpha + \beta_1 R_i + \beta_2 M_i + \beta_3 (R_i M_i) + \gamma X_i + \varepsilon_i. \tag{1}$$

where Y_i either denotes the population growth rate in municipality i over the sample period (which changes from one specification to another) or the number of factories in 1900, transformed via the inverse hyperbolic sine. Under the reasonable assumption that the number of of factories was zero before industrialization took hold in Styria, this level can also be read as a growth rate. R_i is a measure of railway access, M_i indicates mining activity and $R_i \times M_i$ captures their interaction. For our primary measures of R_i and M_i, we calculate the Euclidean distance from each municipality's centroid to the nearest railway line and mining site. To facilitate a more intuitive interpretation - where higher values represent greater proximity - we apply the transformation $-log(Distance)$. Our dataset of mines is quite extensive, and includes many small mines. Thus we restrict the baseline measure of M_i to the largest 25% of mines, to focus on economically meaningful mining activity only. X_i denotes a vector of control variables with corresponding coefficients γ, and ε_i is the error term. We use established controls (following Bosker and Buringh 2017): longitude and latitude, distance to rivers, mean elevation, terrain ruggedness, and climatic variables (minimum, maximum, and average temperature). We also include distance to monasteries and religious denomination. To control for urbanization-led growth, we add a distance to towns and a city indicator variable.We categorize the urban centers used to construct these variables into two distinct chronological tiers: a pre-1800 classification (Historical Cities) and a more exhaustive one including towns after the 1884 expansion. We use the stricter historical measure in our main specifications and adjust it in our robustness checks. We also include district fixed effects and agro-ecological suitability indicators. In our main specification, we restrict the sample to the Austrian portion of former Styria. This is because mining records for this region are substantially more granular than the extant data for the Slovenian part, providing detailed information on both mine size and specific resource types. The analysis is conducted at the municipality level, given the completeness of the 1930 population data at this scale. In subsequent robustness tests, we extend the analysis to the full territory of the former Crownland and increase the spatial resolution to the cadastral municipality level.

The positive effect of mines and railways has been documented extensively in the literature. The magnitudes of coefficients we estimate might still be of interest as comparison. However, we think that the interaction of such endowments has received less attention, and so we pay special attention to our estimates of coefficient β_3. In principle,

estimates could go either way. There are models of Resource Curse / Dutch disease that would predict that the combination of increased trade and resources can reduce growth (Bruno and Sachs 1982, Neary 1985). This could be reflected in a negative interaction of rail access and mining. On the other hand, if these endowments re-enforce one another, such that mines are more effective if they can be connected with rail lines, we would expect a positive interaction. In this initial specification, we do not differentiate between resource types (e.g., coal, iron). However, we demonstrate the robustness of our results in the Appendix, where we (i) employ a discrete dummy approach for proximity, (ii) vary the mining size threshold, and (iii) allow for heterogeneity across mineral categories, differentiating between coal and metal mines.

The primary challenge in identifying the impact of transport infrastructure and mining on economic activity is the potential endogeneity of both treatments. For instance, transport infrastructure may be subject to reverse causality if networks are designed to connect already expanding urban centers rather than catalyzing their growth. Similarly, mining activity may be endogenous to local economic conditions, as exploration and extraction might be influenced by initial levels of economic development. Following the literature (e.g. Baum-Snow et al. (2020) and Fernihough and O'Rourke 2021), we employ an instrumental variables (IV) strategy to address these endogeneity concerns and to estimate the causal relationship between transport technology, resources and growth. Regarding railway access, we rely on an incidental connection argument, where intermediate municipalities were connected primarily due to their location along the path between major urban hubs. To ensure the validity of this strategy, we exclude the major cities that were the explicit targets of railway expansion. In the Appendix, we further demonstrate that our results are robust to excluding all municipalities contiguous to these targeted urban centers. For the mining exposure, we rely on geological instruments - specifically lithological composition (rock type) and chronostratigraphic age (rock age) - to proxy for exogenous mining potential. For the endogenous interaction variable we use the interaction of the instruments, as is standard in related estimations. In addition, we conduct placebo tests by regressing pre-industrial population growth on the subsequent locations of transport infrastructure and mining activity.

In addition, we exploit the continuous expansion of the railway network throughout the 19th century. By integrating this temporal variation with our granular population data, we employ a staggered Difference-in-Differences framework. Specifically, we group individual railway lines into cohorts that align with the available census intervals. Hence, each indicated time period refers not to single year, but these different bins (1782-1812, 1812-1846, 1846-1869, 1869-1880, 1880-1900). The baseline relationship is estimated using a Two-Way Fixed Effects specification, as formalized in Equation (2):

$$\ln(\mathrm{Y}_{i,t}) = \alpha_i + \gamma_t + \beta_1 \mathrm{D}^R_{i,t} + \beta_2 (\mathrm{D}^R_{i,t} \times \mathrm{M}_i) + \epsilon_{i,t} \tag{2}$$

where, $\ln(\mathrm{Y}_{i,t})$ is the natural logarithm of the population in municipality i at time t. Similarly, D^R is a binary indicator equal to 1 if municipality i gets access to a railway line at time $t >= g_i$, with g_i being the period when the region gets connected. We use a threshold of 2 km (which is equal to the 20% of the closest municipalities) to proxy rail access, which is adapted in the robustness tests. M_i identifies the distance to municipalities to large mines using a continuous measure, as before and is interacted with rail access, D^R. We will show that results are unchanged when using an indicator approach in the robustness test. α_i and γ_t represent municipality and year fixed effects controlling for time-invariant local characteristics and common regional shocks. Some estimations also include district-by-year fixed effects $\delta_{d,t}$, controlling for time-varying shocks at the district level.

To ensure the validity of the estimates, the identifying assumption relies on the absence of contemporaneous shocks that could simultaneously affect population dynamics and railway expansion. Given the historical context, such shocks are arguably unlikely, as the planning and placement of these railway lines were conducted at the imperial rather than the local level. To further mitigate concerns, we include district-by-year fixed effects ($\delta_{d,t}$).

Furthermore, an additional threat to our identification is the presence of differential pre-trends between treated and control municipalities. If municipalities were already on a different growth trajectory before the railway was completed, our estimates would be biased. To formally test the validity of the parallel trends assumption, we employ an event study design. By decomposing the treatment effect into lead and lag periods relative to the year of railway access, as in Equation (3):

$$\ln(\mathrm{Y}_{i,t}) = \alpha_i + \gamma_t + \sum_{k=-K, k\neq -1}^{L} \beta_k D^k_{i,t} + \sum_{k=-K, k\neq -1}^{L} \theta_k (D^k_{i,t} \times \mathrm{M}_i) + \epsilon_{i,t} \tag{3}$$

$D^k_{i,t}$ are a series of event-time dummy variables, which indicate the number of years relative to the opening of the railway in municipality i. We specify the year immediately preceding the railway opening ($k = -1$) as the reference year.

Finally, as discussed in the literature that the standard Two-Way Fixed Effects estimator can yield biased estimates if treatment effects are heterogeneous over time, we supplement the analysis with a stacked as well as a Two-Stage Difference-in-Differences design.

We extend the analysis by disaggregating the mining effect into coal and metal mining to uncover potential heterogeneity. Specifically, we adapt the baseline specification in Equation (1) to include separate indicators for each mining type (M^C_i and M^M_i) and their

respective interactions with rail access, $R_i \times M_i^C$ and $R_i \times M_i^M$, as shown in Equation (4):

$$\begin{aligned} Y_i = \alpha + \beta_1 R_i + \beta_2 M_i^C + \beta_3 M_i^M \\ + \beta_4 (R_i \times M_i^C) + \beta_5 (R_i \times M_i^M) + \gamma X_i + \varepsilon_i \end{aligned} \tag{4}$$

Consistent with our primary identification strategy, we calculate the minimum distance to these resources by clustering deposits into distinct coal and metal categories.[8] To ensure the results are driven by economically significant operations, we again restrict the sample to the top 25% of mines by size. For identification, we disaggregate our geological instruments accordingly, while maintaining all other controls and specifications from our baseline model.

As before, we investigate the same effects using a staggered Difference-in-Differences framework as in Equation (5):

$$\begin{aligned} \ln(Y_{i,t}) = \alpha_i + \gamma_t + \beta_1 D_{i,t}^R + \beta_2 (D_{i,t}^R \times M_i^C) + \beta_3 (D_{i,t}^R \times M_i^M) \\ + \beta_4 (D_{i,t}^R \times M_i^C \times M_i^M) + \epsilon_{i,t} \end{aligned} \tag{5}$$

Following our previous methodology, we will also provide event-study estimates to formally test the parallel trends assumption and to examine the evolution of these effects.

[8] Coal types include brown coal, hard coal, anthracite, sub-bituminous coal, and general coal. The narrow metal category consists of iron carbonate, magnetite, hematite, limonite, iron, copper, zinc, lead, mercury, manganese, pyrite, pyrrhotite, arsenic, antimony, fluorite, baryte, sparry magnesite, and cryptocrystalline magnesite. The broad metal definition extends this list to include nickel, silver, gold, chromium, bauxite, and aluminum.

5 Results

The results section is organized as follows. We begin by presenting our primary specifications, which investigate the impact of mining proximity and railway access. Subsequently, we explore the potential heterogeneity of these effects by disaggregating mining activities into coal and metal categories. We then present a series of additional results. First, we examine the role of pre-existing human capital by analyzing the impact of artisanal skills on long-run growth. Second, we investigate electrification, focusing both on its regional effects and the determinants of its adoption.

5.1 Railways, Mining and Growth

Table II summarizes placebo tests, examining the effects of mining and railway access in periods preceding the construction of railways in the region. Across the placebo specifications for 1782–1812, neither mining activity nor railway access is associated with statistically significant increases in population growth. Although mining was already present prior to the railway era, this result is not necessarily unexpected. The existing literature, emphasizes that resources became economically relevant only with the onset of industrialization (e.g. Fernihough and O'Rourke 2021). Prior to this period, mining alone appears to have had limited effects on growth on average. Our second placebo test extends the analysis to 1846. For this period, we observe a positive, albeit modest, interaction between railway and mine proximity. This finding is also consistent with the historical timeline of the region: the first major rail links - connecting Graz to Mürzzuschlag (1844) and Graz over Maribor to Celje (1846) - had already commenced operations. Consequently, this small positive coefficient likely captures the nascent effects of the initial railway rollout: This includes the impact of large-scale construction, the immediate gains from the first operation as well as forward-looking economic expectations. Hence, these results already serve as a preliminary validation for our main analysis.

Following the placebo evidence, which suggests that pre-existing trends do not drive our results, OLS estimates provide a reliable baseline. Nevertheless, Table III presents both OLS and IV results, regressing the number of factories in 1900 (transformed via inverse hyperbolic sine) as well as the population growth from 1812-1900 on our distance-based proximity measures and a subset of the controls mentioned above. In column (3) and (8), we restrict the OLS sample to municipalities not explicitly targeted by railway expansion, ensuring comparability with our IV specification. The results in Table III demonstrate that both railway access and mining activity are positively associated with industrial agglomeration. Notably, the interaction term is positive and statistically significant, revealing that locations combining transport infrastructure with

Table II: Railways, Mining, and Economic Growth: OLS and IV Estimates for Placebeo and First Treatment Periode

	Placebo Period (1782–1812)				Treatment Period (1782–1846)			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	-0.002	0.029	0.027	0.138	-0.033***	0.043	0.001	0.257
	(0.008)	(0.021)	(0.024)	(0.135)	(0.010)	(0.028)	(0.032)	(0.178)
Mining	-0.006	0.010	-0.023	0.010	-0.012	0.026	-0.057	0.019
	(0.013)	(0.017)	(0.026)	(0.051)	(0.017)	(0.021)	(0.043)	(0.071)
Rail × Mining		0.014		0.050		0.035***		0.115
		(0.009)		(0.056)		(0.012)		(0.077)
Adj. R^2 0.028	0.030	—	—	0.102	0.109	—	—	
Observations	966	966	959	959	982	982	975	975

Notes: Dependent variable is economic growth. Columns (1)-(2) and (5)-(6) report OLS estimates. Columns (3)-(4) and (7)-(8) report 2SLS (IV) estimates. The placebo period covers 1782–1812; the treatment period covers 1782–1846 with the first railways opening in 1837. Conley (10km) Standard errors in parentheses. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

substantial resource endowments experienced an additional growth advantage. This suggests a strong complementarity between infrastructure and resources. The weaker results with regard to population growth may be explained by the noisier nature of the population data - particularly for the baseline year of 1812 - as well as the smaller sample size available for these specifications. The fact that the IV coefficients exceed the OLS estimates may be driven by three explanations. First, historical data may be subject to measurement error, inducing an attenuation bias. This measurement noise mechanically biases OLS estimates toward zero, The IV approach can correct for that downward bias. Second, while OLS calculates an average effect across the entire sample, the IV identifies the Local Average Treatment Effect (LATE) specifically for the "complier" group - those observations whose treatment was determined by the instrument. If these specific regions had a higher latent potential for industrial growth than the average region, the IV coefficients will naturally be larger. Third, contrary to our initial assumption of positive selection, railways may have been prioritized in lagging or poor regions to stimulate development or for strategic military reasons. In this case, the OLS estimates would be downward biased.

Further, we show the results of our static TWFE model (1)-(4) in Table IV using different versions of fixed effects together with specifications robust to heterogeneous treatment effects (5)-(12). Specifically, we employ the Two-Stage Difference-in-Differences (2SDiD) estimator proposed by Gardner (2021). This method first identifies fixed effects from untreated observations, effectively using the average of all pre-treatment periods to establish a robust counterfactual for the second-stage estimation of treatment effects.

Table III: Railways, Mining, and Economic Outcomes: Grouped by Dependent Variable

	Dependent Variable: Log Factories 1900					Dependent Variable: Δ Population 1812-1900				
	OLS			IV		OLS			IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rail	0.056***	0.160***	0.165***	0.066**	0.470***	0.197***	0.703***	0.700***	0.422**	2.285**
	(0.009)	(0.023)	(0.020)	(0.033)	(0.115)	(0.030)	(0.076)	(0.077)	(0.203)	(1.030)
Mining	0.056***	0.108***	0.115***	0.049	0.210***	0.220***	0.470***	0.472***	0.074	0.982*
	(0.014)	(0.017)	(0.016)	(0.040)	(0.064)	(0.048)	(0.058)	(0.059)	(0.208)	(0.523)
Rail × Mining		0.048***	0.051***		0.181***		0.234***	0.234***		0.875*
		(0.010)	(0.009)		(0.051)		(0.032)	(0.033)		(0.450)
Adj. R^2	0.204	0.223	0.189	—	—	0.122	0.166	0.153	—	—
Observations	982	982	975	975	975	966	966	959	959	959
First-stage F (R)	—	—	—	48.8	28.9	—	—	—	47.9	28.3
First-stage F (M)	—	—	—	48.3	29.6	—	—	—	46.6	28.4
First-stage F (I)	—	—	—	—	28.4	—	—	—	—	27.6

Notes: Dependent variable is the number factories between in 1900 ((1)–(5)) and population growth from 1812-1900 ((6)–(10)). Austrian portion of Styria is considered. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables and share of protestants in 1900. Columns (1)–(3) and (6)–(8) report OLS estimates, with column (3) and (8) restricting the sample to the IV sample size. Columns (4)–(5) and (9)-(10) report IV estimates. Geological Instruments are selected using LASSO and estimated via 2SLS. For the IV estimation, Graz, Liezen, Bruck, Leoben, Fehring, Deutschlandsberg and Murau are excluded, as for these the incidental connection argument does not hold. First-Stage F-Statistics are reported. Standard errors are Conley (10 km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We complement it with a Stacked Difference-in-Differences approach following Cengiz et al. (2019). This method involves creating cohort-specific datasets for each treatment year, comparing treated municipalities only to those that are not-yet or never treated within the same event window.

Table IV: Comparison of DiD Estimates: TWFE, Two-Stage, and Stacked Approach

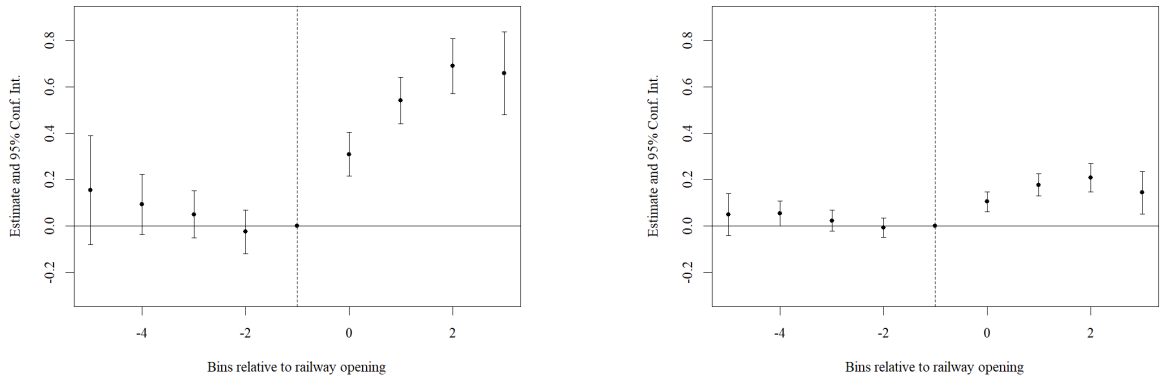
	Dependent Variable: ln(Population)											
	TWFE				**Two-Stage DiD**				**Stacked DiD**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Railway Access	0.150***	0.487***	0.143***	0.522***	0.174***	0.489***	0.162***	0.498***	0.137***	0.466***	0.135***	0.489***
	(0.044)	(0.132)	(0.044)	(0.137)	(0.024)	(0.075)	(0.026)	(0.078)	(0.021)	(0.069)	(0.022)	(0.071)
Railway × Mining		0.166***		0.183***		0.161***		0.170***		0.154***		0.166***
		(0.058)		(0.060)		(0.031)		(0.032)		(0.028)		(0.029)
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dist × Year FE	–	–	✓	✓	–	–	✓	✓	–	–	✓	✓

Notes: Standard errors in parentheses are Conley SE (10km) for TWFE (Cols 1–4) and clustered at the municipality level for 2SDiD and Stacked DiD. Columns (5)–(8) follow Gardner (2021). Columns (9)–(12) employ the Stacked DiD approach (Cengiz et al., 2019). Mining refers to proximity to historical mine locations. Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Again, it is demonstrated that railway access had a positive and statistically highly significant effect on population growth across all specifications. This impact was amplified in mining areas, as evidenced by the positive and robust interaction term. We observe qualitatively similar results across all specifications, with the magnitude of the coefficients showing only marginal variations between the TWFE approach and the alternative 2SDiD and stacked DiD models. Our results remain robust to alternative distance cutoffs for railway access and to the use of various dummy indicators for mining activity for all different estimation strategies (see Appendix).

Furthermore, Figure 9 presents the results of our dynamic event study estimates (with

year and municipality fixed effects). For both the baseline (Panel (a)) and the interaction (Panel (b)) effect, the estimated coefficients in the pre-treatment period support the parallel trends assumption. Following the railway opening, a sustained and significant upward trend in population growth is observed. Again, also the complementarity of railway and mining potential is apparent.



(a) Baseline Railway Effect

(b) Interaction: Railway $\times$ Mining

Figure 8: Event Study Estimates: Dynamic Effects on Population Growth

Notes: The figure displays event-study coefficients with 95% confidence intervals. Panel A shows the average impact of railway access, while Panel B presents the estimator of the interaction between railways and mining. The year preceding the opening ($k = -1$) is used as the reference period. Specification with year and municipality fixed effects.

5.2 Coal, Metal, Railways and Growth

We further analyze whether the complementarity between mining and railway access can be disentangled to identify which specific resource served as the primary catalyst for growth. Table V represents again the OLS and IV specification grouped by the dependent variable, number of factories and population growth between 1812-1900.

Table V: Impact of Railways and Specific Mining Resources (Coal vs. Metal)

	Dependent Variable: Log Factories 1900						Dependent Variable: Δ Population 1812–1900					
	OLS			IV			OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail	0.157***	0.219***	0.274***	0.782***	0.436***	0.771***	0.850***	0.847***	1.252***	3.101**	2.043**	3.093**
	(0.026)	(0.032)	(0.037)	(0.192)	(0.129)	(0.164)	(0.086)	(0.109)	(0.123)	(1.554)	(0.962)	(1.350)
Coal	0.097***		0.084***	0.317***		0.258***	0.568***		0.526***	1.130*		0.762**
	(0.018)		(0.018)	(0.101)		(0.098)	(0.058)		(0.058)	(0.584)		(0.371)
Metal		0.103***	0.093***		0.171***	0.104*		0.314***	0.252***		0.693*	0.490*
		(0.021)	(0.021)		(0.051)	(0.060)		(0.071)	(0.069)		(0.379)	(0.257)
Rail × Coal	0.042***		0.034***	0.274***		0.212**	0.271***		0.246***	1.091*		0.660*
	(0.010)		(0.010)	(0.077)		(0.093)	(0.033)		(0.034)	(0.608)		(0.382)
Rail × Metal		0.053***	0.046***		0.119***	0.057		0.207***	0.156***		0.598*	0.401*
		(0.010)	(0.010)		(0.040)	(0.059)		(0.034)	(0.033)		(0.330)	(0.227)
Adj. R^2	0.213	0.217	0.234	—	—	—	0.191	0.139	0.210	—	—	—
Observations	982	982	982	975	975	975	966	966	966	959	959	959
First-stage F (Rail)	—	—	—	23.71	23.71	23.71	—	—	—	23.17	23.17	23.17
First-stage F (Coal)	—	—	—	60.87	—	60.87	—	—	—	59.97	—	59.97
First-stage F (Metal)	—	—	—	—	67.74	67.74	—	—	—	—	65.82	65.82

Notes: The dependent variable is the number of factories in 1900, transformed by the inverse hyperbolic sine in columns (1)–(6) and population growth from 1812–1900 in columns (7)–(12). All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature, and share of protestants. Columns (1)–(3) and (4)–(6) report OLS estimates; columns (7)–(9) and (10)–(12) report 2SLS IV estimates. Geological Instruments are selected using LASSO and estimated via 2SLS. For the IV estimation, Graz, Liezen, Bruck, Leoben, Fehring, Deutschlandsberg and Murau are excluded, as for these the incidental connection argument does not hold. First-Stage F-Statistics are reported. Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table V illustrates a consistent pattern of complementarity between mining and railways, even after distinguishing between resource types. While both metal and coal—and their respective interactions with the railway—remain statistically significant across most specifications, coal emerges as the primary driver of this effect. This is evidenced by its robust significance across all specifications and its larger relative effect size, suggesting that coal-driven energy production was a particularly potent catalyst for rail-integrated industrialization. We adapt this specification by using an indicator approach in the robustness checks.

In addition, we report the results of our TWFE estimate in Table VI.

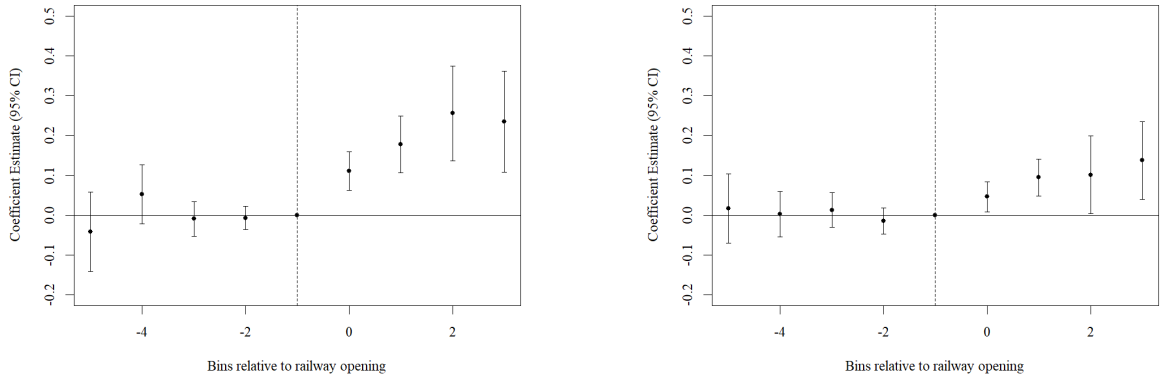
Table VI: Railway Access and Specific Resource Potentials: Coal vs. Metal (Distance Based Approach)

	Dependent Variable: ln(Population)									
	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)
Rail	0.166***	0.595***	0.380***	0.737***	1.350***	0.156***	0.563***	0.395***	0.740***	1.275***
	(0.025)	(0.096)	(0.104)	(0.139)	(0.394)	(0.026)	(0.099)	(0.093)	(0.132)	(0.388)
Rail × Coal		0.190***		0.183***	0.451***		0.180***		0.173***	0.410***
		(0.036)		(0.035)	(0.146)		(0.038)		(0.036)	(0.146)
Rail × Metal			0.074**	0.054**	0.278**			0.082***	0.066***	0.261**
			(0.031)	(0.026)	(0.126)			(0.028)	(0.024)	(0.125)
Rail × Coal × Metal					0.097**					0.085*
					(0.046)					(0.047)
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	–	–	–	–	–
Dist × Year FE	–	–	–	–	–	✓	✓	✓	✓	✓

Notes: Standard Errors in parentheses are Conley (10km). Resource indicators refer to a continuous distance measure to closest mine being part of the top 25% largest mines. (1)–(5) include year and municipality FE; (7)–(11) use District-by-Year FE. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Again, we show the robust and highly significant complementarity between mining and railway across all specifications for both resources. Interestingly also the triple

interaction is significant, indicating that especially a broad set of resources together with access to markets gave an additional advantage. Figure 9 displays the event-study estimates for the interactions of railway access with coal and metal mining, respectively.



(a) Interaction: Railway × Coal Mining

(b) Interaction: Railway × Metal Mining

Figure 9: Event Study Estimates: Dynamic Effects on Population Growth

Notes: The figure displays event-study coefficients with 95% confidence intervals. Panel A shows the average impact of the interaction of railway and coal access, while Panel B presents the estimator of the interaction between railways and metal mining. The year preceding the opening ($k = -1$) is used as the reference period. Specification with municipality and district and year fixed effects.

Reassuringly, both panels in Figure 9 exhibit no significant pre-trends, supporting the parallel trends assumption. Following the arrival of the railway, we observe a sharp and persistent divergence in population growth. This divergence is particularly pronounced for the coal-railway interaction in Panel (a), which shows a larger shift compared to the metal-railway interaction in Panel (b). These dynamic estimates reinforce our previous conclusion that coal-driven energy production served as the primary catalyst for industrialization.

5.3 Additional Results

In the following subsection, we examine additional findings. Specifically, we investigate the role of pre-existing human capital and the subsequent impact of electrification to provide a more comprehensive view of the regional economic transition.

5.3.1 Early-Modern Skill

Beyond our main specification, where we show the complementarity of infrastructure and resources, we explore additional channels often emphasized in the literature on regional development and industrial diffusion. A pivotal dimension is the role of pre-modern skills respectively human capital. In general, economic historians have noted that several European regions had reached an advanced stage of proto-industrial sophistication by the late 18th century, placing them on a developmental trajectory comparable to parts of England. In particular, Wehler (1987, p. 25) argues that "the German-speaking lands of Central Europe possessed a socio-economic and political potential that provided a distinct advantage prior to the Industrial Revolution" with ”highly developed industrial regions that closely followed the English growth centers”. He also highlights an additional mechanism noting that the ”presence of commercial enterprises and technical aids were necessary to implement the English achievements so quickly and effectively” (ibid., p. 65). Furthermore, Mokyr (eg. 2002, 2009 and 2010) emphasizes the interplay between ”propositional knowledge” and ”prescriptive knowledge”, noting that craftsmen were essential to bridge the gap between science and practical application. Additionally, pre-industrial centers may have been more likely to establish favorable institutions incentivizing innovation in the first place. Beyond these potentially positive mechanisms, several factors could also suggest a negative relationship. First, the presence of entrenched artisan skills may create a ”competence trap”, where reliance on traditional expertise hinders the adoption of disruptive technologies, thereby constraining long-run growth. Second, these specialized skills were often embedded within early-modern institutions - most notably guilds. While the literature remains divided on their net effect, a significant body of historical research posits that guilds functioned primarily as rent-seeking entities that stifled innovation and served as a barrier to economic expansion rather than a catalyst for it (e.g. Ogilvie 2019). While we highlight only a subset of potential channels, these arguments underscore why pre-existing skills may played a significant role for industrialization.

To proxy for these pre-modern skills, we leverage the survey by Göth (1837), which provides detailed occupational data for half of our municipalities. Specifically, we employ two distinct proxies to capture the regional endowment of human capital: the share of craftsmen relative to the total male population as well as the absolute number

of people in this sector. Both specifications seem theoretically reasonable: While a high artisanal share reflects the skill density of a region, the absolute count accounts for the possibility that a minimum threshold of qualified personnel is required for industrial adoption, irrespective of the rest of the population. We adapt Equation 1 accordingly:

$$Y_i = \alpha + \beta_1 R_i + \beta_2 M_i + \beta_3 (S_i^{1837}) + \beta_4 (R_i M_i) + \beta_5 (R_i S_i^{1837}) + \beta_6 (M_i S_i^{1837}) + \gamma X_i + \varepsilon_i. \quad (6)$$

where, S_i represents either this share of craftsman or the absolute number (transformed using the inverse hyperbolic sine) and $(R_i \times S_i^{1837})$ and $(M_i \times S_i^{1837})$ being the interaction between our railway and mining proximity measures and these pre-existing skills, respectively.

The aforementioned mechanisms primarily address the unconditional effect of the skill variable. However, the empirical literature remains sparse regarding the interaction between historical skills and infrastructure or resources. Theoretically, the sign of this relationship is ambiguous, as it ultimately depends on the degree of complementarity between pre-modern artisan expertise and the technical requirements of the industrial era. If artisanal skills are also useful within modern production processes the interaction between railways and skills should be positive: Railways facilitate the arrival of new technologies that perfectly align with the existing skill set. Conversely, if traditional skills hinder the adoption of new technologies, this interaction may be negative, highlighting a conditional competence trap: New technologies are implemented more rapidly in regions with lower levels of pre-modern skills, because established processes in previously high-skilled regions cannot be displaced as quickly.

Table IV reports the OLS estimates for the regression of the number of factories as well as of population growth from 1846 to 1900 on mining, railways, and pre-modern skills, both with and without the baseline controls. A similar table using the absolute number of craftsman as a measure for pre-industrial skill is provided in the Appendix. For this analysis, we utilize the full sample of Styrian regions to increase our sample size. Column (1) and (7) initially suggests a strong relationship between pre-modern skills and subsequent factory growth. However, this relationship loses significance once we control for urbanization via the city dummy (Columns (5) ann (11)). This indicates that our skill proxy primarily captures the effects of pre-existing urban density rather than a standalone human capital channel. Furthermore, we find no significant interaction between skills and railways with regard to factories, suggesting that the railway did not necessarily benefit "high-(or low-)skill" regions more than others. The OLS regression using population growth would rather suggest the opposite: regions with a high baseline share of artisanal population grew significantly slower upon integration into the railway network. While these findings are theoretically consistent with "human capital traps" where legacy skills impede the transition to modern production, it could be that the results are driven by a spatial reallocation mechanism, similar to Baum-Snow

et al. (2020): The skill variable does not just capture human capital, but also serve as a proxy for localized centers. As transport costs fall, these secondary hubs lose their comparative advantage to primary cities. Hence, this negative interaction between rail access and initial skill levels can also be interpreted as as a consequence of increased trade integration within the urban hierarchy.

Beyond the investigation of pre-modern skills, Table IV serves as a robustness check for our primary findings. Despite a significant reduction in sample size due to the availability of the occupational data in Göth (1837), and the inclusion of additional part of the region, the core results remain consistent. The interaction between infrastructure and mining remains positive, stable, and statistically significant across all specifications.

Table VII: Railways, Mining and Skill (Share): Grouped by dependent variable

	Dependent Variable: Log Factories 1900						Dependent Variable: Δ Population 1846-1900					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Skill	4.398***	2.858***	7.797**	7.700**	4.256	3.547	9.294***	4.113*	-2.021	-2.598	-9.085	-13.00**
	(1.074)	(1.089)	(3.089)	(3.053)	(3.124)	(3.130)	(2.275)	(2.227)	(6.164)	(6.183)	(6.337)	(6.490)
Mining		0.046***	0.081***	0.070***	0.080***	0.089***		0.116***	0.314***	0.334***	0.352***	0.576***
		(0.012)	(0.020)	(0.023)	(0.023)	(0.033)		(0.026)	(0.039)	(0.047)	(0.047)	(0.068)
Rail		0.034***	0.126***	0.112***	0.122***	0.119***		0.142***	0.561***	0.567***	0.586***	0.712***
		(0.010)	(0.029)	(0.030)	(0.030)	(0.035)		(0.020)	(0.058)	(0.062)	(0.061)	(0.072)
Rail × Mining			0.035***	0.028***	0.031***	0.033***			0.153***	0.153***	0.158***	0.191***
			(0.010)	(0.010)	(0.010)	(0.012)			(0.020)	(0.021)	(0.021)	(0.024)
Rail × Skill			-0.019	-0.057	-0.544	-0.153			-2.693*	-2.889**	-3.807***	-4.702***
			(0.720)	(0.712)	(0.713)	(0.695)			(1.436)	(1.442)	(1.446)	(1.440)
Mining × Skill			2.140*	1.962	1.457	1.325			-1.775	-1.915	-2.865	-3.223
			(1.255)	(1.241)	(1.233)	(1.223)			(2.503)	(2.513)	(2.500)	(2.535)
City Dummy					0.559***	0.448***					1.053***	1.120***
					(0.131)	(0.127)					(0.266)	(0.263)
Controls	–	–	–	✓	✓	✓	–	–	–	✓	✓	✓
Fixed Effects	–	–	–	–	–	✓	–	–	–	–	–	✓
Adj. R^2	0.021	0.058	0.079	0.109	0.129	0.249	0.021	0.121	0.183	0.185	0.201	0.280
Observations	738	738	738	738	738	738	738	738	738	738	738	738

Notes: Dependent variable is number of factories and population growth (1846–1900). The whole Crownland (Austran and Slovenian part) is considered. Skill represents the share of craftsmen. Mining captures the distance to 19th-century mines. Baseline controls include controls for distance to city centroid, elevation, terrain ruggedness, temperature variables and share of protestants in 1900. City dummy is added when indicated. In (6) and (12) district fixed effects are included as well as additional controls: Absolute longitude and latitude, a suitability indicator and average maximal temperature. Standard errors are Conley (10km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3.2 Electricity Expansion

In addition to the expansion of the railway network, the late 19th and early 20th centuries saw the emergence of electrification as a secondary transformative infrastructure roll-out in Styria. This development leveraged the region's geography: the abundance of alpine rivers suited for early hydro-electric installations and the availability of coal for thermal generation. We incorporate this characteristics into our instrumental variable strategy by utilizing the topographic suitability for hydropower (e.g., river gradient and flow) and proximity to coal deposits as exogenous predictors of early grid access. We adapt Equation 1 in the following way:

$$Y_i = \alpha + \beta_1 R_i + \beta_2 M_i + \beta_3 E_i + \beta_4 (R_i M_i) + \beta_5 (E_i M_i) + \beta_6 (R_i E_i) + \gamma X_i + \varepsilon_i. \tag{7}$$

with E_i being a proximity measure to any kind of voltage line, alongside the interaction terms $(R_i \times E_i)$ and $(E_i \times M_i)$, which represent potential synergies between electricity and rail, and electricity and mining, respectively. Beyond our instrumental variable strategy, we conduct a placebo exercise. Table V summarizes the results of these placebo tests. We regress nineteenth-century population growth on the twentieth-century electricity infrastructure and compare these estimates to the effects observed during the actual built-up period. The results show that up until 1900, electricity proximity has no significant impact on growth, suggesting the absence of a pre-trend. The coefficients become significantly positive when considering the actual expansion horizon through 1930, indicating the positive growth effects of having access to electricity. This results also holds in column (4), where the electricity coefficients are jointly significant at the 1 percent level.

While the aggregate measure of electricity access - without differentiation by voltage capacity - exhibits no statistically significant pre-trends, this finding is contingent upon the classification of infrastructure capacity. Specifically, the placebo test fails when restricted to high-voltage transmission lines, which show a significant correlation with pre-treatment growth. This suggests that the placement of high-capacity grid infrastructure was endogenous, likely directed toward municipalities that were already on a superior developmental trajectory. Hence, we extent our analysis with our IV strategy, where we use upstream river flow as well as distance to coal mines as exogenous variation on electricity line placement and add population growth from 1869 to 1900 and number of factories in 1900 as additional controls. Table VI summarizes these results. In these specifications, we adjust the mining variable to measure the proximity to any mine (no size adjustment) operational during the twentieth century. Our primary measure of electrification is again defined as the log-transformed inverse distance to the nearest transmission line. Columns 1 through 4 report results for all transmission infrastructure irrespective of voltage capacity, while columns 5 through 8 focus specifically

Table VIII: Mining, Railways, Electricity and Population Growth

	1812–1900		1812–1930	
	(1)	(2)	(3)	(4)
Mining	0.1909***	0.4652***	0.2202***	0.5233***
	(0.0506)	(0.0655)	(0.0715)	(0.0930)
Rail	0.1750***	0.6683***	0.2343***	0.8062***
	(0.0327)	(0.0875)	(0.0471)	(0.1243)
Electricity	0.0413	−0.0297	0.1224***	0.0329
	(0.0292)	(0.0667)	(0.0413)	(0.0947)
Mining × Rail		0.2410***		0.2721***
		(0.0372)		(0.0528)
Mining × Electricity		−0.0293		−0.0479
		(0.0300)		(0.0426)
Rail × Electricity		0.0087		0.0416
		(0.0199)		(0.0282)
R^2	0.144	0.177	0.169	0.197
Observations	982	982	982	982

Notes: All columns report OLS estimates. The dependent variable is population growth for the respective time horizon. Mining refers only to the larges 25% of mines. Austrian portion of Styria is considered. All specifications include the full set of baseline controls described in the text. Conley (10km) standard errors are reported in parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

on 20kV lines. We find robust OLS evidence that electrification is positively associated with population growth. However, our instrumental variables approach provides only limited support for a causal interpretation of this effect.

Building on our observation that electricity lines were not placed randomly but were highly path-dependent, we investigate the underlying determinants of the electricity rollout. Table VI summarizes the OLS results - and the first stage relationship within our previous exercise - for regressing proximity to electricity lines - considering both the aggregate network and lines above 20kV - on geographic factors, historical population and factory growth, railway distance, a city dummy, and our two primary instruments: upstream water volume (hydro-potential) and distance to carboniferous rock strata (coal availability).

Two important patterns emerge from the determinants analysis in Table VI. First, the expansion of the electricity network was highly path-dependent, favoring regions that were already experiencing growth and those with high levels of industrialization. Notably, the number of pre-existing factories is the dominant predictor for the placement of high-voltage transmission lines ($\geq$ 20kV), which were technically necessary to sustain production. In contrast, population density is only significant when considering the broader, lower-voltage network. Second, Table VI reveals a strong complementarity between transport and power infrastructure: proximity to a railway line significantly increases the likelihood of being closer to the electrical grid. This pattern likely stems

Table IX: Railways, Electricity, and Population Growth 1900–1930

	All Voltage Lines				20kV Lines			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.030***	0.030**	0.058	0.058	0.028***	0.047***	-0.219	-0.092
	(0.007)	(0.013)	(0.037)	(0.061)	(0.007)	(0.013)	(0.409)	(0.205)
Elec	0.032***	0.036***	0.098**	-0.117	0.029***	0.038***	0.400	0.360
	(0.006)	(0.011)	(0.047)	(0.210)	(0.007)	(0.011)	(0.514)	(0.253)
Mining	0.011	0.012	-0.013	-0.030	0.017*	0.026*	-0.001	0.011
	(0.009)	(0.012)	(0.018)	(0.031)	(0.009)	(0.014)	(0.048)	(0.030)
Rail × Elec		0.008*		-0.203		0.011**		0.055
		(0.004)		(0.168)		(0.004)		(0.140)
Mining × Rail		0.001				0.005		
		(0.008)				(0.007)		
Mining × Elec		-0.002				0.002		
		(0.007)				(0.007)		
Adj. R^2	0.133	0.133	—	—	0.124	0.128	—	—
Observations	989	989	989	989	989	989	989	989
F-Stat (Rail)	—	—	69.9	45.2	—	—	69.9	45.2
F-Stat (Elec)	—	—	23.4	14.4	—	—	41.3	25.1
F-Stat (Interact)	—	—	—	5.5	—	—	—	29.3

Notes: Dependent variable is population growth 1900–1930. Austrian portion of Styria is considered. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables, share of protestants in 1900, population growth from 1869-1900 and number of factories in 1900. Mining refers to all mines in the 20th century. „Elec“ refers to distance to the nearest voltage line (any voltage in (1)–(4), 20kV in (5)–(8)). IV specifications use 2SLS with geological instruments: upstream water volume (hydro-potential) and distance to carboniferous rock strata (coal availability). Standard errors are Conley (10 km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

from two distinct channels. On the one hand, proximity to the railway may capture unobserved regional prosperity - induced by 19th-century rails - which is not fully reflected in our factory counts or population figures. On the other hand, and more importantly, this result points toward a ”technological path dependency”: The railway era fostered a specific set of organizational capacities and technical skills within connected municipalities. These local competencies lowered the barriers to adopting and installing the next major innovation: the electrical grid. Together, these two patterns uncover a regional ”Matthew Effect” of industrialization. Regions that were already prosperous due to their 19th-century integration into the railway and mining networks became the primary beneficiaries of subsequent innovations. Consequently, rather than acting as a regional equalizer, the rollout of electricity served to reinforce the pre-existing spatial inequalities - also consistent with polarization theories of regional development (see e.g. Mydral 1959).

Table X: Determinants of Electricity (different voltage lines)

	Any Line		20 kV Lines	
	(1)	(2)	(3)	(4)
Rail Access	0.2128***	0.1420***	0.2076***	0.1893***
	(0.0378)	(0.0433)	(0.0351)	(0.0347)
Ruggedness	−0.0027**	−0.0026	−0.0060***	−0.0038***
	(0.0014)	(0.0016)	(0.0013)	(0.0013)
Elevation	−0.0013***	−0.0028***	−0.0008***	−0.0006**
	(0.0003)	(0.0004)	(0.0002)	(0.0003)
City Dummy	0.9020***	0.8272**	−0.0551	0.2835
	(0.3497)	(0.3393)	(0.3250)	(0.2721)
Growth (1812-1900)	0.0895**	0.0512	0.0258	−0.0208
	(0.0388)	(0.0380)	(0.0361)	(0.0305)
Factories 1900	0.2313*	0.1676	0.4011***	0.1757*
	(0.1320)	(0.1327)	(0.1227)	(0.1064)
Upstream Volume	0.00113***	0.00110***	0.00183***	0.00191***
	(0.00038)	(0.00040)	(0.00035)	(0.00032)
Distance Carbon Rock	−0.0126***	−0.0093	−0.0331***	−0.0124*
	(0.00388)	(0.00873)	(0.00361)	(0.00700)
Fixed Effects	–	✓	–	✓
Adjusted R^2	0.31	0.38	0.37	0.58
Observations	990	990	990	990

Notes: Dependent variable is proximity to voltage line. Austrian portion of Styria is considered. Columns (2) and (4) include district fixed effects. Additional controls are absolute longitude and latitude. Conley (10km) standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6 Conclusion

This paper has examined the drivers of industrial diffusion in the South-Eastern Alps, leveraging a newly constructed high-resolution dataset spanning nearly 150 years. This dataset is useful in itself, beyond the scope of this paper alone.

Second, we provide an analysis of factors that contributed to local growth in the region. Our findings confirm existing knowledge, namely the immense importance of transport infrastructure and resources for economic growth. In contrast to the standard linear effects often described in the literature, we demonstrate that non-linearities, the complementarity between these two factors, were crucial. We also show that it was especially, but not only, coal which drove that relationship. In addition, our findings diverge interestingly from results reported elsewhere, particularly the low importance of existing skills and electricity, and the great importance of the complementarity of rail and mining.

Studying the spread of ideas is not only of historic interest, but holds important lessons for the economic development of countries that are technologically catching up. In particular, the importance of the interaction of resources and transportation suggests that technological transfer is not a linear process, but the complex result of multiple investments that need to come together to be particularly impactful.

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Appendix A1: Dataset Construction

Appendix part A1 provides a comprehensive overview of the dataset construction process. It focuses specifically on the primary sources, followed by a technical description of the digitization and transcription workflow.

A1.1: Maps and administrative units

Our main analysis focuses on the municipal level, reflecting the spatial restructuring following the 1849 reforms. However, within our project, we also reconstructed the older administrative units of Styria and use it as robustness test for our results. Figure A1 depicts this historical structure of the Crownland, utilizing cadastral municipalities as the primary unit (in grey) and military districts as the higher-order administrative tier (in black). The red border indicates the partition of the Crownland between Austria and Slovenia following the First World War.

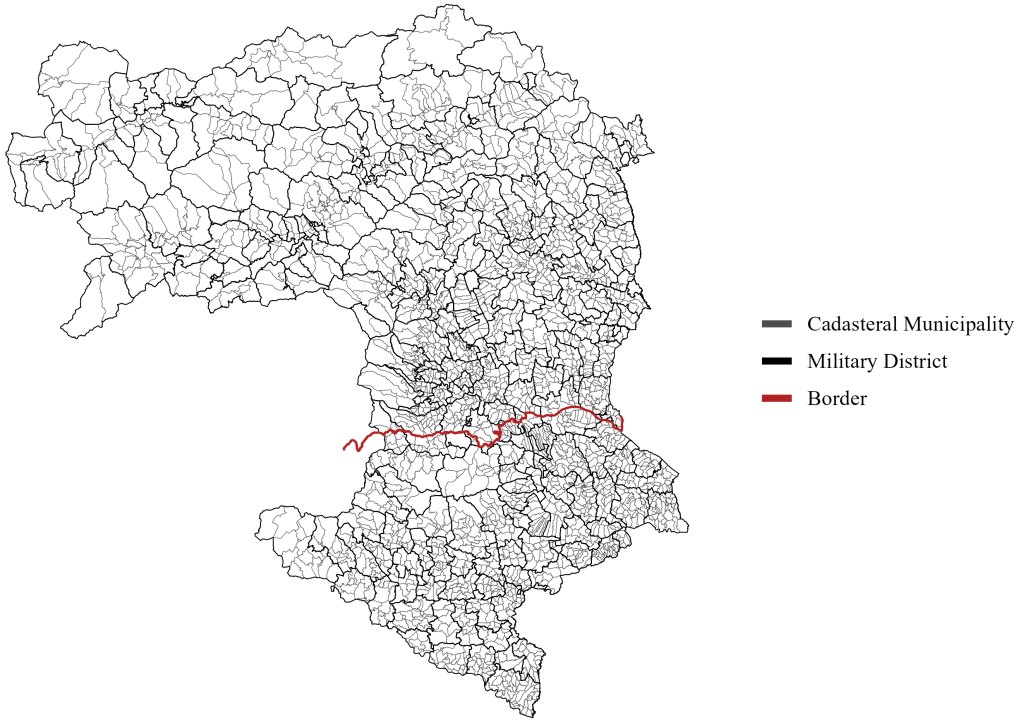


Figure A1: Administrative Units before 1849: Cadasteral Municipalities (grey), military districts (black) and the future boarder between Slovenia and Austria (red)

The spatial data are derived from historical maps digitized specifically for this project by the Styrian Provincial Archives and the University of Graz Library. These maps

were georeferenced using the same procedure for all different maps (Maps on catasteral municipalities, municipalities, separate map on military districts as well as the electricity map): Georeferencing was conducted in QGIS using approximately 150 ground control points, primarily positioned along political boundaries. Subsequently, the map colors were classified: specific RGB values were identified using QGIS processing tools and converted into raster values. These color codes were then systematically assigned to specific classes (e.g., municipal or district boundaries), resulting in a thematically classified raster. To facilitate further data processing, the classified raster was vectorized. This process generated numerous small polygons, particularly along color transitions and as a result of digitization artifacts. These were identified using area filters (e.g., area $< 1\ m^2$) and either removed or merged with adjacent larger areas. Specifically, a "length" attribute was first generated to calculate the extent of each object; subsequently, a Python script was used to filter the minor fragments.To refine the spatial data, the vector objects were first smoothed using eight iterations, allowing for a slight coordinate shift (tolerance of 0.5). The data were then converted back into a high-resolution raster (cell size 0.005) to facilitate skeletonization. Using the SAGA Skeleton tool, the centerlines of the boundaries were extracted. Any remaining structural inconsistencies were adjusted manually. The resulting lines were converted into polygons and manually attributed with the respective administrative names. These polygons were then assigned to the respective military and judicial districts. Since it was not always possible to uniquely assign data from various sources for certain cadastral municipalities or municipalities, these were merged or separated to align with the quantitative data and the divisions in the 1900 gazetteer. Consequently, there are two layers for the maps of administrative units: first, the original reflecting the digitized historical maps, and second, an adjusted map corresponding to the dataset and its aggregations. While all shapefiles will be provided, all representations in this paper refer to these adapted maps, as they represent the underlying structure of the data.
The electricity network was georeferenced using the same procedure. However, the transmission lines and power plants were manually traced. Each component of the energy infrastructure was then assigned specific attributes: Transmission Lines were attributed with its specific voltage level (kV) and power plants were categorzied by type of technology. A binary indicator was assigned to denote the operational status (active vs. inactive).

A1.2.1: Archival Work - Göth

This appendix provides a detailed overview of the archival work with regard to Georg Göth's work. It expands on the composition of the primary archive and describes the technical process of digitization and the subsequent transcription of the records.

The archival collection comprises 55 boxes, containing 1,332 individual surveys. These represent various administrative units of the historical structure, ranging from the five larger districts ("Kreise") of Styria, the military districts to individual curacies, parishes, manorial jurisdictions, magistrates, and villages. The surveys are organized alphabetically by the name of the administrative unit rather than by administrative hierarchy. This order was maintained throughout the digitization process.
Scanning was performed at the regional archive ("Landesarchiv Steiermark") using a book scanner at a resolution of 400 dpi. Every document within the surveys was scanned without pre-selection, including cover letters, response forms, and personal notes, some by Göth himself used for his publications. This resulted in a total of 44221 pages. Tables or documents exceeding the maximum scan dimensions were divided into smaller segments, which require manual reassembly. Larger organizational units, such as the four districts, naturally contain more extensive information, while smaller units typically provided more concise responses.
Beyond the quantitative data contained in Göth's records, depicted in the main part of the paper, the bulk of the survey responses are qualitative and written in Kurrent script. Figure A2 displays a sample page from a response form for the military district of Lichtenwald. Characteristic of most files in this collection, each entry begins with a number corresponding to the specific survey question, followed by the respective answer.

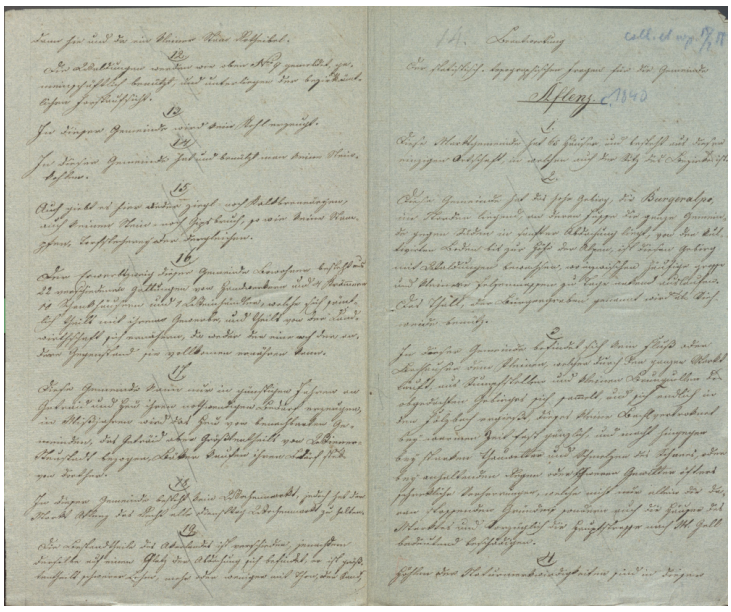


Figure A2: Excerpt from the Göth archives: Sample Page of answersheet

Although we do not exploit the full breadth of this qualitative material in this paper, we transcribed the entirety of the archive, given the following procedure:
The transcription process was conducted via Transkribus for both layout analysis and

text recognition. Initial efforts focused on the directly accessible qualitative information within the Göth survey, specifically the “District Summaries” and livestock inventories, which were provided by the majority of military districts and contained data for all cadastral municipalities. All archival documents were uploaded to Transkribus using an automated Python script. The transcription itself followed three distinct lines of operation. First, the table layouts were identified by establishing a "Ground Truth" set of 100 tables to train a custom Transkribus model. As the automated results were not entirely satisfactory, the recognized table structures were manually adjusted and aligned. For recurring layouts, structures were determined manually and propagated to identical tables using the Transkribus copy function. Second, baselines were identified using the pre-trained “Mixed Line Orientation” model, which utilizes a heterogeneous layout paradigm particularly beneficial for these historical tables. We fine-tuned this model by selecting “Keep existing structure”," using “Upscale” for image scaling, and setting the “Minimum Baseline Length” to “small”, as shorter lengths yielded excessive line detection; furthermore, baselines were split at table boundaries to ensure each remained within its respective cell. Third, the final text recognition was performed using the “Titan I Super Model”, a transformer-based engine trained on multiple languages—including German, English, Dutch, French, Finnish, and Swedish - which a Character Error Rate (CER) of 2.95% on the validation set.

To ensure the accuracy of both locations and quantitative data, we implemented a dual correction strategy involving machine and manual intervention. Place names were corrected using a Large Language Model (LLM) and harmonized with Straka’s orthography. Quantitative data underwent manual verification: since each district summary includes an original total, we cross-referenced the sum of individual municipality values against the reported district total. Discrepancy were then manually compared to the original archival scans. In cases where the historical summation was found to be erroneous, values were corrected based on the municipal sum and flagged in the dataset. Together these district summaries allowed for the extraction of detailed information on population and occupational structures, specifically regarding social status, the number of villages, markets, and towns, as well as counts of locals, foreigners, gender distributions, and military eligibility. Livestock tables provided a summary of animal populations. Because submission times varied, data was reported for 1837, 1840, or 1843. For districts providing multi-year data, we calculated internal growth rates to interpolate or extrapolate values to a 1840 base year. For districts lacking temporal data, we applied average growth rates calculated across the 1834–1843 period based on third-order nearest neighbors.

It is important to note that municipalities for which no information was documented in the Göth archive were of course treated as missing values. Within the district summaries, missing entries were interpreted as true zeros only if other rows within

the same subcategory were populated. For example, if the occupational breakdown specified the number of farmers but left the entry for nobility blank or marked with a dot, that entry was interpreted as a true zero. Conversely, if no occupations were recorded for the municipality at all, the entire category was treated as a missing value. The archive also contains additional information in tabular form, primarily regarding land use (e.g., fields, meadows, etc.). These data were not adjusted using the aforementioned steps, as they were not of immediate relevance to our research question; however, the results of the initial transcription are available online. Furthermore, isolated economic data - such as municipal income and expenditures - were present for certain districts. Because these records were not consistently available across all administrative units, they were not used in our analysis.
We will provide the original archival images alongside their corresponding transcriptions in our online data repository at the end of this project.

.0.1 Vita of Göth

Georg Göth, the collector of the survey material we plan to digitize, was born in 1803 in Reindorf, now a district of Vienna. After finishing high school, Göth started his studies at the University of Vienna, with his main interest being mathematics. In 1827 he started to work as an educator for the children of a high-rank official of the monarchy in Maria Zell in the north of Styria. There, he met Archduke Johann for the first time, whose nearby located country residence Brandhof was finished around that period. Archduke Johann then employed Göth as secretary for the Landwirthschaftsgesellschafts-Filiale Brandhof. Due to Göth's diligence and business acumen, the archduke offered him a position in Vordernberg in 1810, where he worked as a second private secretary, librarian and archivist. This position granted him access to the archives and libraries of the archduke. Due to the variety of assignments at the monarchy's various estates in the region and his task of accompanying the archduke on his annual visits of the Landwirthschaftsgesellschaft's other branches, he was made familiar with the institutional structure of the monarchy in Styria, on the one hand, and with the region's inhabitants, on the other hand. This knowledge helped Göth to finish his first work for the Archduke Johann, which was published in 1832: "Darstellung des landwirthschaftlichen Zustandes der Filiale Brandhof". During this period, Archduke Johann traveled through the Middle East and Göth used this time to further his description of Styria, while waiting for the establishment of a chair in mathematics at the Joanneum in Graz, an appointment to which was promised to him by the archduke. This process, however, took longer than expected and in 1838 Göth was advised by the archduke to apply for a position as librarian and custodian of the Landwirthschaftsgesellschaft in Vienna. The monarch's praise led to him being given this position, which he occupied

until 1841 when he was appointed professor for mathematics at the Technical Institute at the Joanneum in Graz. The rigor Göth put in this work led to it being sent to other officials as a sample on how to conduct such descriptions. The publication of his subsequent work about the Styrian iron industry "Vordernberg in der neuesten Zeit oder geschichtliche Darstellung der Vereinigung der Radgewerken nebst Beschreibung des Berg- und Hüttenbetriebes daselbst" was postponed and did not take place before 1839 due to it being opposed by the monarchy's Montanist chamber. However, this work contributed to his good reputation and led to him being awarded the Great Golden Medal for Art and Science by the King of Sweden. In 1859 he was appointed director of studies at the Joanneum in Graz. He resigned partly in 1865 and continued only as the Joanneum's custodian until he had to fully resign in 1868 due to a severe illness. Georg Göth died on the 4th of March in 1873 (Leitner 1878, Göth 1840).

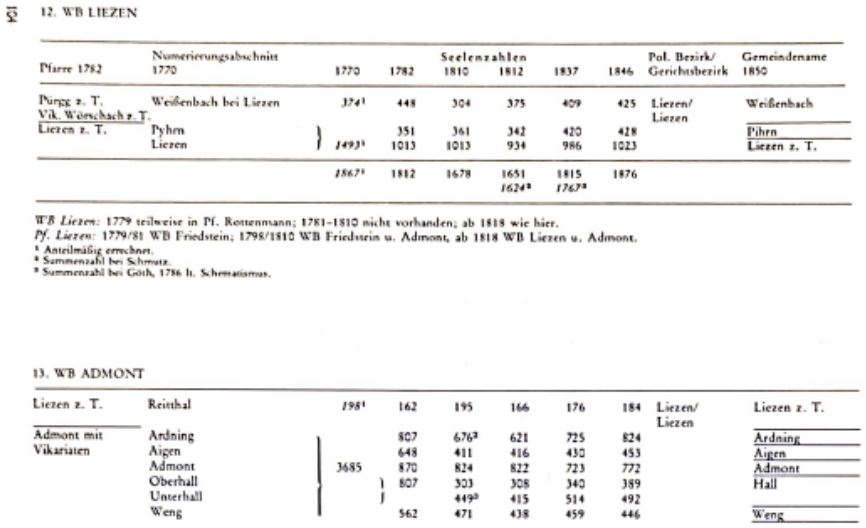
A1.2.2: Archival Work - Population Enumerations and Gazetteers

In addition to the Göth archive, we transcribed the population enumerations summarized in Straka (1978) and the official gazetteers. The transcription process was significantly more straightforward, as these materials were printed not handwritten and utilized modern typography. We used the same approach for both sources using a layout-aware OCR pipeline that combines deep-learning-based table recognition with the Tesseract engine to ensure the structural integrity of the tabular data. We did not train a bespoke model to perfectly fit the respective layouts, as the results from the general models, supplemented by manual adjustments, proved sufficient for our research objectives[9]. For quality control, we again compared the transcribed district (Straka) and municipality (Gazetteers) totals against our own calculated sums, manually correcting any discrepancies. Due to the printed format, such manual interventions were required significantly less frequently than with the handwritten records in the Göth archive. This datasets was merged with the Göth archive using the nomenclature established by Straka for the (cadastral) municipal names. The harmonization was conducted by matching observations based on both the military district and the cadastral municipal name; this dual criteria was essential, as cadastral municipal names frequently recur across different districts. We aggregated the Straka data - originally reported at the level of enumeration segments - to the levels of both cadastral municipalities and municipalities. This process allowed for the construction of two distinct datasets corresponding to these respective administrative units.

The following figures provide examples of these distinct sources. Figure A3 displays a page from the Straka (1978) publication, which is organized by military districts; our

[9]However, we suggest such an approach when a larger corpus of these gazetteers - which exist for all Crownlands of the Empire - is transcribed. In that scenario, training a specialized model would be more efficient than the labor needed to correct the inaccuracies of generic models manually.

analysis focuses specifically on the columns for 1782, 1812, and 1846. As previously noted, each enumeration segment was assigned to a municipality. The presence of curly brackets in the source indicates a summation, which was frequently used to signify that multiple segments were aggregated into a single cadastral municipality.



52 12. WB LIEZEN

Pfarre 1782	Numerierungsabschnitt 1770	Seelenzahlen 1770	1782	1810	1812	1837	1846	Pol. Bezirk/ Gerichtsbezirk	Gemeindename 1850
Pürgg z. T.	Weißenbach bei Liezen	374[1]	448	304	375	409	425	Liezen/ Liezen	Weißenbach
Vik. Wörschach z. T.									
Liezen z. T.	Pyhrn		351	361	342	420	428		Pihrn
	Liezen	1493[1]	1013	1013	934	986	1023		Liezen z. T.
		1867[1]	1812	1678	1651 *1624*[2]	1815 *1767*[2]	1876		

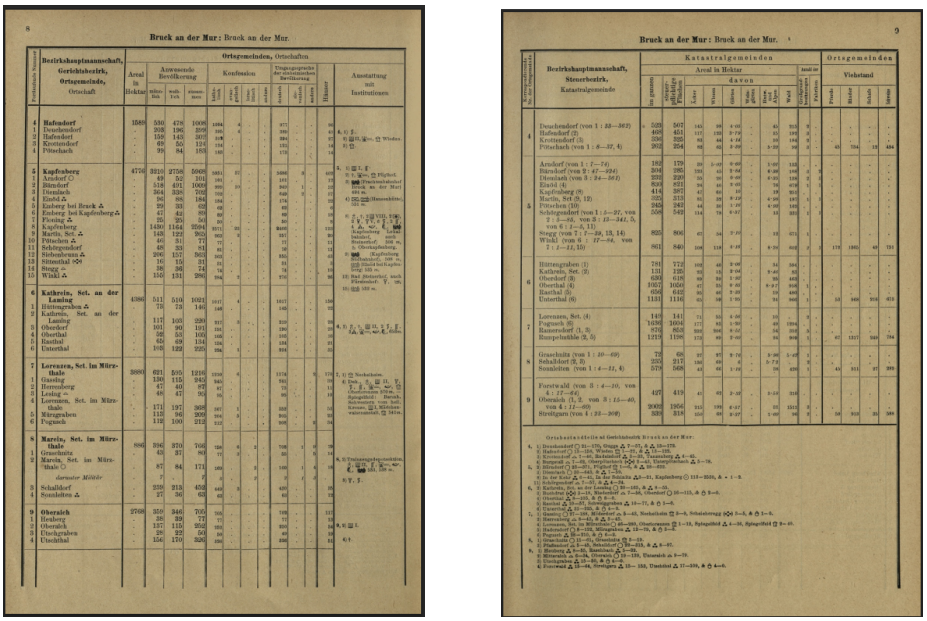
WB Liezen: 1779 teilweise in Pf. Rottenmann; 1781–1810 nicht vorhanden; ab 1818 wie hier.
Pf. Liezen: 1779/81 WB Friedstein; 1798/1810 WB Friedsteirn u. Admont, ab 1818 WB Liezen u. Admont.
[1] Anteilmäßig errechnet.
[2] Summenzahl bei Schmutz.
[3] Summenzahl bei Göth, 1786 lt. Schematismus.

13. WB ADMONT

Liezen z. T.	Reitthal	198[1]	162	195	166	176	184	Liezen/ Liezen	Liezen z. T.
Admont mit Vikariaten	Ardning		807	676[2]	621	725	824		Ardning
	Aigen		648	411	416	430	453		Aigen
	Admont	3685	870	824	822	723	772		Admont
	Oberhall		807	303	308	340	389		Hall
	Unterhall			449[2]	415	514	492		
	Weng		562	471	438	459	446		Weng

Figure A3: Sample Page from Straka (1978) Illustrating Enumeration Segments

Figure A4 provides a representative excerpt from the more recent series of Special Local Directories and Municipality Gazetteers, focusing specifically on the volume for the year 1900. Each municipality entry in this volume is organized across two pages: the first A4a summarizes socio-economic and demographic characteristics, while the second A4b provides data on livestock holdings, industrial establishments, and other institutional variables for the corresponding units . Earlier editions of the gazetteers were restricted to demographic data, corresponding only to the layout presented on the left-hand page of this volume, and excluded the pictographic representations found in the final column.



(a) Population Statistics **(b)** Livestock Inventory

Figure A4: Sample Pages from the 1900 Municipal Gazetteers (*Gemeindelexikon*)

Appendix A2: Additional descriptive graphs and data

Figure A5 presents the distribution of population growth rates across the specified sub-periods.

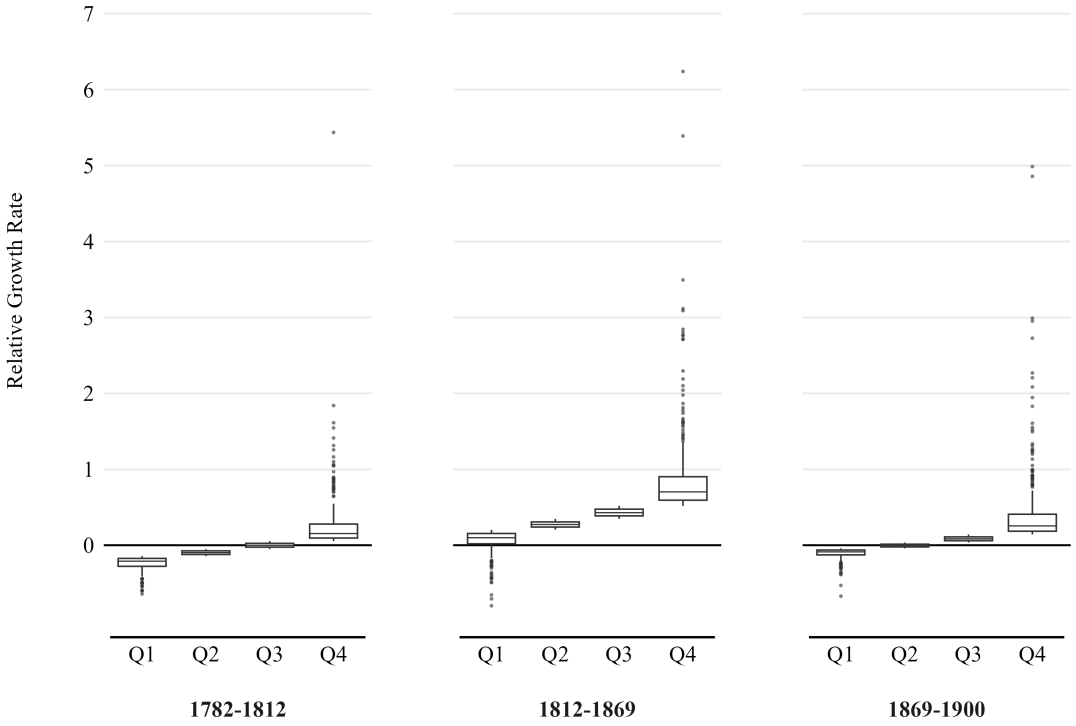


Figure A5: Population growth rates by quartiles for short-term periods: 1782–1812, 1812–1869, and 1869–1900.

Figure A6 displays the (log) population distribution of Styria at the year 1812. For better visibility centers like Graz are excluded (white), while grey indicates municipalities with missing data.

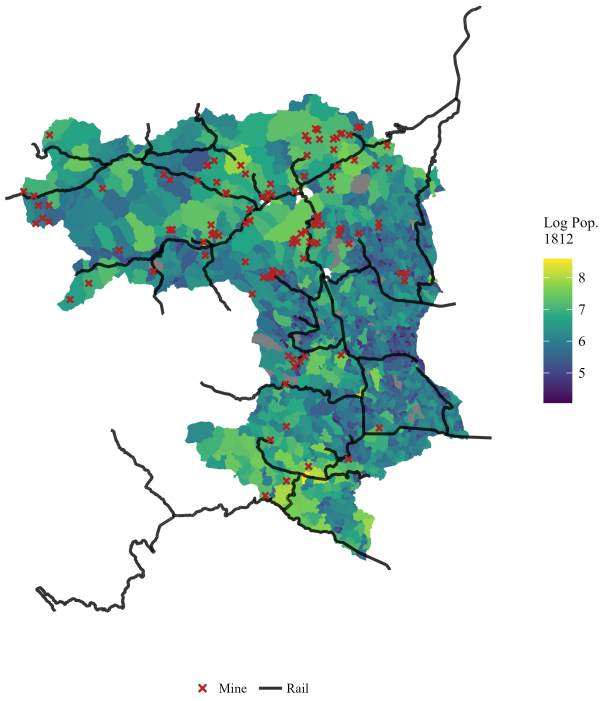


Figure A6: Logarithmic population distribution of Styria in 1812 at the municipality level together with mining sites and the railway network as of 1900. Major urban centers are excluded (white), and missing data are indicated in grey

Appendix: Robustness Results

Appendix: Robustness - IV and OLS Mining and Rail

In Table A1, we investigate whether the size of mining operations influences the magnitude of the observed economic effects. We vary the threshold for inclusion in our proximity measure, calculating the distance to the nearest mining site using four distinct sets: all documented mines, and the top 50%, 25%, and 10% of mines by output size. The findings confirm that our results are robust to the inclusion of smaller mines. However, as expected, the magnitude of the coefficients increases as we focus on larger mines. This suggests that, while the presence of any mining activity mattered, the largest mining operations exerted a significantly stronger impact on industrialization.

Table A1: Railways, Mining, and Economic Outcomes: Robustness by Mining Size

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812-1900			
Mining Def.:	All	50%	25%	10%	All	50%	25%	10%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.124***	0.146***	0.160***	0.164***	0.467***	0.556***	0.703***	0.756***
	(0.016)	(0.019)	(0.023)	(0.026)	(0.052)	(0.065)	(0.076)	(0.086)
Mining	0.074***	0.092***	0.108***	0.118***	0.303***	0.351***	0.470***	0.474***
	(0.015)	(0.016)	(0.017)	(0.017)	(0.050)	(0.055)	(0.058)	(0.058)
Rail × Mining	0.041***	0.046***	0.048***	0.045***	0.164***	0.185***	0.234***	0.231***
	(0.008)	(0.009)	(0.010)	(0.010)	(0.027)	(0.030)	(0.032)	(0.033)
Adj. R^2	0.216	0.221	0.223	0.227	0.143	0.147	0.166	0.167
Observations	982	982	982	982	966	966	966	966

Notes: This table reports OLS estimates for the impact of railway access and mining resources on industrial and demographic outcomes. Austrian part of Styria is considered. Columns (1)–(4) use the log number of factories in 1900 as the dependent variable; columns (5)–(8) use population growth between 1812 and 1900. The mining variable is defined across four thresholds: the full sample (All), and the top 50%, 25%, and 10% of mining sizes respectively. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables, and share of protestants in 1900. Standard errors are Conley (10km) reported in parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In addition to the continuous approach, we test the robustness of our results using indicator variables. These dummies equal 1 when a municipality falls within a specific proximity threshold and 0 otherwise. We opted for the continuous measure in our main specification for two primary reasons. First, it avoids the use of an arbitrary cutoff, as there is little theoretical guidance on the precise distance at which mining or railway effects diminish. Second, a continuous measure better captures the spatial nature of these economic processes, which likely diffuse across municipal boundaries rather than stopping abruptly at a threshold (Other approaches would be possible to circumvent that). Nevertheless, for this exercise, we apply a 20% cutoff, where the closest 20% of municipalities are assigned a value of 1.

As shown in Table A2, the results remain qualitatively consistent with our main findings, particularly regarding the robust and positive interaction between mining and railways. While the standalone effect of mining becomes weaker or statistically insignificant in the broader categories (Columns 1–2), it regains high significance when restricting the

sample to the largest mining operations (Columns 3–4). This should not be of too much concern as it would be consistent with the idea that the optimal spatial threshold varies by mine size: while a 20% distance cutoff may be too broad for smaller, localized mines to show a statistical effect, it aligns well with the broader economic reach of larger, more productive mines.

Table A2: Robustness: Indicator Variable Approach by Mining Size

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812-1900			
Mining Def.:	All	50%	25%	10%	All	50%	25%	10%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail (Dummy)	0.115***	0.112***	0.092***	0.105***	0.315***	0.292***	0.345***	0.343***
	(0.030)	(0.029)	(0.028)	(0.028)	(0.100)	(0.099)	(0.097)	(0.098)
Mining (Dummy)	0.019	0.012	0.077***	0.098***	0.169*	0.126	0.213**	0.239**
	(0.030)	(0.029)	(0.029)	(0.028)	(0.101)	(0.099)	(0.099)	(0.097)
Rail × Mining	0.222***	0.246***	0.348***	0.279***	1.013***	1.185***	1.120***	1.063***
	(0.058)	(0.058)	(0.059)	(0.059)	(0.197)	(0.197)	(0.204)	(0.202)
Adj. R^2	0.201	0.203	0.238	0.230	0.133	0.141	0.141	0.140
Observations	982	982	982	982	966	966	966	966

Notes: This table reports OLS estimates using indicator variables for railway and mining proximity. The rail and mining dummy equals 1 for the closest 20% of municipalities. Columns (1)–(4) use the number of factories (IHS) in 1900; columns (5)–(8) use population growth (1812–1900). The mining variable varies by the size of the mines included in the proximity calculation (All, top 50%, 25%, and 10%). All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature, and share of protestants. Standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

To ensure that our results are not driven by urban spillover effects, we don't just exclude the major regional centers - Graz, Bruck an der Mur, Leoben, Liezen, Murau, Deutschlandsberg, and Fehring - as in our main specification, but also exclude their immediate neighboring municipalities[10]. We use the same instruments, same distance transformation and again focus on economical meaningful mines being part of the top 25% of the largest mines. Table A3 gives the results for this specification showing a similiar picture as in our main specifications.

[10]Andritz, Ardning, Bösenbach, Burgegg, Donawitz, Eggenberg, Feldkirchen, Fölling, Frauenberg, Freidorf, Göss, Gösting, Hafendorf, Hafning, Höflach, Johnsdorf, Kainbach, Kapfenberg, Lassing, Laßnitz (Murau), Leibenfeld, Liebenau, Niklasdorf, Oberaich, Pernegg, Petersdorf I (Fehring), Petzelsdorf in der Weststeiermark, Pichldorf, Proleb, Pyhrn, Rinegg, Schiefer, St. Georgen ob Murau, St. Peter (Leoben), St. Peter (Liebenau), Stolzalpe, Straßgang, Sulz (Landsberg), Tratten, Waltendorf, Weinberg, and Weißenbach b. Liezen.

Table A3: Railways, Mining, and Economic Outcomes: OLS and IV Estimates - Excluding all municipalities contingent to the local hubs

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812–1900			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.049***	0.152***	0.066*	0.569***	0.154***	0.600***	0.269*	3.094**
	(0.009)	(0.023)	(0.035)	(0.125)	(0.021)	(0.055)	(0.161)	(1.493)
Mining	0.057***	0.109***	0.081**	0.269***	0.203***	0.429***	0.282*	1.335**
	(0.014)	(0.017)	(0.034)	(0.065)	(0.034)	(0.041)	(0.167)	(0.629)
Rail × Mining		0.047***		0.223***		0.203***		1.256*
		(0.010)		(0.055)		(0.023)		(0.644)
Adj. R^2	0.207	0.225	—	—	0.168	0.232	—	—
Observations	941	941	941	941	928	928	928	928
First-stage F (R)	—	—	20.67	20.67	—	—	20.39	20.39
First-stage F (M)	—	—	47.35	47.35	—	—	45.64	45.64
First-stage F (I)	—	—	—	23.07	—	—	—	22.57

Notes: The dependent variable is the number of factories in 1900, transformed by the inverse hyperbolic sine in columns (1)–(4) and population growth from 1812–1900 in columns (5)–(8). All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature, and share of protestants. Columns (1)–(2) and (5)–(6) report OLS estimates; columns (3)–(4) and (7)–(8) report 2SLS IV estimates. Major regional centers and their adjacent municipalities are excluded from the OLS and IV sample to satisfy the incidental connection argument. Standard errors are Conley (10 km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In addition, we want to investigate convergence by extending our main specification to incorporate the logarithmic level of population at the beginning of our observation period in 1812. All other factors remain unchanged from our primary analysis. Across both OLS and IV specifications for the number of factories in 1900 (Columns 1–4), we observe positive and statistically significant coefficients for the 1812 population, supporting a divergence story. However, with regard to our second dependent variable, initial population size did not significantly impact subsequent population growth rates.

Table A4: Regression Results: Railways, Mining, and Economic Outcomes

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812-1900			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.052***	0.149***	0.077*	0.635***	0.199***	0.722***	0.462**	3.660**
	(0.0087)	(0.0225)	(0.0392)	(0.2083)	(0.0300)	(0.0767)	(0.1962)	(1.4425)
Mining	0.056***	0.103***	0.146***	0.322***	0.220***	0.477***	0.244	1.252**
	(0.0139)	(0.0171)	(0.0438)	(0.0779)	(0.0480)	(0.0583)	(0.1654)	(0.5079)
Rail × Mining		0.045***		0.263**		0.240***		1.505**
		(0.0096)		(0.1036)		(0.0325)		(0.6840)
Log Pop 1812	0.132***	0.128***	0.085***	0.066**	0.041	0.021	-0.002	-0.107
	(0.0166)	(0.0164)	(0.0255)	(0.0254)	(0.0572)	(0.0558)	(0.0695)	(0.1475)
Adj. R^2	0.251	0.267	—	—	0.122	0.168	—	—
Observations	982	982	975	975	966	966	959	959

Notes: Dependent variable is the number of factories in 1900 ((1)–(4)) and population growth from 1812-1900 ((5)–(8)). Columns (1)–(2) and (5)–(6) report OLS estimates. Columns (3)–(4) and (7)–(8) report IV estimates. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature, and share of protestants. Standard errors are Conley (10km) in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Robustness - Different Mining Indicator

Our primary specification employs a parsimonious measure of mining potential, defined by the geographic proximity to the nearest mine showing that even with this simple specification we get robust results. We extend this analysis by constructing a more comprehensive mining indicator, given in Equation (8):

$$Potential_i = \sum_{j=1}^{k} \frac{Q_j^2 \cdot \frac{1}{n_{q(j)}}}{\log\left(d_{ij} + 2\right)} \tag{8}$$

We integrated three core features within this measure: First, we differentiate by size, again by quartiles, and use a quadratic weight to the size-quartiles of the mines (Q_j^2), as large-scale mining hubs should exert a disproportionately stronger pull on local industrialization. Second, we account for diminishing marginal returns to resource abundance through the saturation term $1/n_{q(j)}$. Here, $n_{q(j)}$ represents the cumulative count of mines belonging to the same quartile q in the vicinity of municipality i. The first mine should provide the primary impetus for growth, the marginal contribution of each subsequent mine of the same is harmonically discounted. Third, the potential is weighted by the log-transformed distance, $\log(d_{ij} + 2)$, as of course closer mines should exert larger gains. We vary the number of considered nearest mines (k) between 5 and 50 to test the sensitivity of our results and again also differentiate between mine types. We address the noise in lower-levels of the indicator by employing two strategies. First, we use a binary dummy approach that isolates municipalities in the top decile (90th

percentile) of mining potential, capturing the effects of major industrial hubs. We again vary this threshold. Second, we implement a truncated continuous approach, where we preserve the original variation of the potential index for observations above a high threshold while setting all values below this threshold to zero. Table A5 reports the results using a truncated continuous variable, which takes the actual potential value for municipalities in the upper decile of the sample and zero otherwise with k being equal to 5, so only the 5 closest mines are considered.

Table A5: Railways, Mining, and Economic Outcomes: Grouped by Dependent Variable

	Dependent Variable: Log Factories 1900					Dependent Variable: Δ Population 1812-1900				
	OLS			IV		OLS			IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rail	0.060***	0.047***	0.043***	0.088***	0.003	0.221***	0.130***	0.125***	0.412***	0.037
	(0.009)	(0.009)	(0.008)	(0.032)	(0.026)	(0.029)	(0.029)	(0.029)	(0.135)	(0.146)
Mining	0.029***	0.059***	0.067***	0.017	0.134***	0.122***	0.328***	0.341***	0.198	0.705***
	(0.007)	(0.009)	(0.008)	(0.036)	(0.049)	(0.024)	(0.030)	(0.031)	(0.182)	(0.247)
Rail × Mining		0.027***	0.031***		0.134***		0.182***	0.190***		0.581**
		(0.005)	(0.005)		(0.041)		(0.017)	(0.018)		(0.255)
Adj. R^2	0.202	0.221	0.191	—	—	0.127	0.215	0.206	—	—
Observations	982	982	975	975	975	966	966	959	959	959
First-stage F (R)	—	—	—	53.700	14.169	—	—	—	52.627	13.819
First-stage F (M)	—	—	—	53.700	14.169	—	—	—	52.627	13.819
First-stage F (I)	—	—	—	—	8.226	—	—	—	—	8.153

Notes: Dependent variable is log factories in 1900 ((1)–(5)) and population growth from 1812-1900 ((6)–(10)). Controls: distance to city centroid, city dummy, elevation, ruggedness, temperature, and share of protestants. Columns (1)–(3) and (6)–(8) OLS; (4)–(5) and (9)–(10) IV. Geological Instruments are selected via LASSO. Standard Errors in parentheses are Conley (10 km). Using truncated continuous variable with threshold 90%. First-Stage F-Statistics are reported. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A6 reports the results with a dummy variable equal to 1 for municipalities with a resource potential in the upper 10th percentile of the sample with k being equal to 5, so only the 5 closest mines are considered.

Table A6: Railways, Mining, and Economic Outcomes: Grouped by Dependent Variable

	Dependent Variable: Log Factories 1900					Dependent Variable: Δ Population 1812-1900				
	OLS			IV		OLS			IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rail	0.061***	0.047***	0.044***	0.088***	0.0006	0.222***	0.131***	0.129***	0.416***	0.031
	(0.009)	(0.009)	(0.008)	(0.032)	(0.027)	(0.029)	(0.029)	(0.029)	(0.136)	(0.152)
Mining	0.133***	0.280***	0.314***	0.079	0.685***	0.563***	1.574***	1.587***	0.950	3.549***
	(0.034)	(0.045)	(0.041)	(0.176)	(0.243)	(0.115)	(0.146)	(0.150)	(0.894)	(1.225)
Rail × Mining		0.126***	0.144***		0.671***		0.183***	0.866***		2.898**
		(0.026)	(0.024)		(0.205)		(0.018)	(0.086)		(1.284)
Adj. R^2	0.201	0.219	0.187	—	—	0.125	0.212	0.196	—	—
Observations	982	982	975	975	975	966	966	959	959	959
First-stage F (R)	—	—	—	53.700	13.234	—	—	—	52.627	12.902
First-stage F (M)	—	—	—	53.700	13.234	—	—	—	52.627	12.902
First-stage F (I)	—	—	—	—	7.878	—	—	—	—	7.812

Notes: Dependent variable is the number factories between in 1900 ((1)–(5)) and population growth from 1812-1900 ((6)–(10)). Austrian portion of Styria is considered. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables and share of protestants in 1900. Columns (1)–(3) and (6)–(8) report OLS estimates, with column (3) and (8) restricting the sample to the IV sample size. Columns (4)–(5) and (9)-(10) report IV estimates. Geological Instruments are selected using LASSO and estimated via 2SLS. For the IV estimation, Graz, Liezen, Bruck, Leoben, Fehring, Deutschlandsberg and Murau are excluded, as for these the incidental connection argument does not hold. We use a dummy variable that takes the value of 1 if the municipality's resource potential is in the top decile (90th percentile) of the distribution. First-Stage F-Statistics are reported. Standard errors are Conley (10 km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We perform a series of robustness checks by varying the intensity thresholds at the 95th, 90th, 80th, and 70th percentiles for the truncated continuous variable (Table A7) and the dummy variable (Table A8).

While the results remain qualitatively consistent across all specifications, we observe that the explanatory power and coefficient magnitudes diminish as the threshold is broadened. This pattern aligns with the economic intuition that the effect of resources is concentrated in high-intensity mining hubs. Specifically, adopting a 70th percentile cutoff would categorize approximately 300 municipalities as 'mining intensive' - a definition that lacks plausibility. Therefore, the stricter cutoffs (90th and 95th percentiles) provide a more accurate representation of the reality in 19th-century Styria. Our truncated continuous variable addresses these concerns, as it does not treat all mining municipalities as identical and preserves the underlying variation in resource potential. Still by using a narrow definition of the upper tail, we filter out the 'noise' from municipalities with minor deposits with little effect on population movements.

Table A7: Railways, Mining, and Economic Outcomes: Robustness truncated Cutoffs

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812-1900			
Cutoff:	95%	90%	80%	70%	95%	90%	80%	70%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.050***	0.047***	0.045***	0.045***	0.147***	0.130***	0.108***	0.102***
	(0.009)	(0.009)	(0.009)	(0.010)	(0.028)	(0.029)	(0.030)	(0.034)
Mining	0.075***	0.059***	0.042***	0.028***	0.442***	0.328***	0.254***	0.163***
	(0.011)	(0.009)	(0.008)	(0.007)	(0.035)	(0.030)	(0.026)	(0.024)
Rail × Mining	0.035***	0.027***	0.020***	0.011***	0.259***	0.182***	0.149***	0.092***
	(0.007)	(0.005)	(0.005)	(0.004)	(0.022)	(0.017)	(0.015)	(0.014)
Adj. R^2	0.225	0.221	0.211	0.200	0.249	0.215	0.198	0.150
Observations	982	982	982	982	966	966	966	966

Notes: This table reports OLS estimates using a truncated continuous mining potential variable across different intensity thresholds. Austrian part of Styria is considered. Columns (1)–(4) use the log number of factories in 1900 as the dependent variable; columns (5)–(8) use population growth between 1812 and 1900. The potential variable is censored at the 70th, 80th, 90th, and 95th percentile respectively, setting all values below the threshold to zero. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables, and share of protestants in 1900. Standard errors are reported in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A8: Railways, Mining, and Economic Outcomes: Robustness by Dummy Mining Cutoffs

	Dependent Variable: Log Factories 1900				Dependent Variable: Δ Population 1812-1900			
Cutoff:	95%	90%	80%	70%	95%	90%	80%	70%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rail	0.050***	0.047***	0.046***	0.049***	0.147***	0.133***	0.117***	0.126***
	(0.009)	(0.009)	(0.009)	(0.010)	(0.028)	(0.029)	(0.031)	(0.034)
Mining	0.383***	0.280***	0.175***	0.099***	2.262***	1.541***	1.079***	0.569***
	(0.056)	(0.045)	(0.036)	(0.031)	(0.179)	(0.147)	(0.120)	(0.105)
Rail × Mining	0.177***	0.126***	0.085***	0.035*	1.293***	0.841***	0.631***	0.323***
	(0.035)	(0.026)	(0.021)	(0.018)	(0.111)	(0.084)	(0.069)	(0.061)
Adj. R^2	0.225	0.219	0.207	0.196	0.249	0.207	0.184	0.133
Observations	982	982	982	982	966	966	966	966

Notes: This table reports OLS estimates for the impact of railway access and mining resources on industrial and demographic outcomes across different mining intensity thresholds. Austrian part of Styria is considered. Columns (1)–(4) use the log number of factories in 1900 as the dependent variable; columns (5)–(8) use population growth between 1812 and 1900. The mining variable is a dummy indicating if a municipality's potential falls above the 70th, 80th, 90th, and 95th percentile respectively. All specifications include controls for distance to city centroid, city dummy, elevation, terrain ruggedness, temperature variables, and share of protestants in 1900. Standard errors are Conley (10km) reported in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In addition, we apply the aforementioned staggered Difference-in-Differences framework, maintaining the original railway distance threshold, while varying the cutoffs for the truncated continuous mining indicator in Table A9. Showing again this strong interaction effect of mining and resources.

In addition, we decompose the mining effect by category to investigate whether specific resource types drive the results. Specifically, we re-calculate the mining indicators separately for metal and coal deposits. For each category, the indicator is restricted

Table A9: Robustness: Railway Access and Mining Potential (Varying Intensity Cutoffs)

	Dependent Variable: Economic Outcome											
	0.90 Threshold				**0.95 Threshold**				**0.80 Threshold**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail	0.166***	0.156***	0.108***	0.103***	0.166***	0.156***	0.121***	0.114***	0.166***	0.156***	0.092***	0.087***
	(0.045)	(0.043)	(0.020)	(0.021)	(0.045)	(0.043)	(0.023)	(0.020)	(0.045)	(0.043)	(0.021)	(0.021)
Rail × Mining			0.099***	0.094***			0.107***	0.105***			0.081***	0.077***
			(0.026)	(0.020)			(0.031)	(0.022)			(0.024)	(0.021)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Dist × Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Standard errors in parentheses are Conley SE (10km). This table reports the robustness of the railway access effect across different mining intensity thresholds (0.90, 0.95, and 0.80) using the mining indicator. Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

to the five closest mines ($k = 5$) within the specified category. Table A10 presents the results using our standard 90% threshold for the mining potential indicator. To ensure the robustness of our findings, Table A11 provides alternative estimates using a more conservative 80% cutoff of the truncated continuous mining measure.

Table A10: Railway Access and Specific Resource Potentials: Coal vs. Metal

	Dependent Variable: ln(Population)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail	0.166***	0.114***	0.147***	0.097***	0.102***	0.096***	0.156***	0.112***	0.138***	0.096***	0.099***	0.096***
	(0.025)	(0.021)	(0.024)	(0.023)	(0.022)	(0.023)	(0.026)	(0.023)	(0.025)	(0.024)	(0.023)	(0.024)
Rail × Coal		0.074***		0.073***	0.066***	0.072***		0.067***		0.066***	0.062***	0.065***
		(0.022)		(0.022)	(0.020)	(0.021)		(0.021)		(0.021)	(0.020)	(0.021)
Rail × Metal			0.044	0.041	-0.263				0.042	0.040	-0.154	
			(0.031)	(0.028)	(0.207)				(0.027)	(0.025)	(0.197)	
Rail × Coal × Metal					0.239	0.035					0.153	0.033
					(0.176)	(0.023)					(0.167)	(0.021)
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	–	–	–	–	–	–
Dist × Year FE	–	–	–	–	–	–	✓	✓	✓	✓	✓	✓

Notes: Conley SE (10km). Resource potentials are truncated continuous (T50) with a cutoff of 0.9. "Metal" refers to the narrow-narrow (MetNarNar) classification. Triple Interaction in (5, 6, 11, 12) tests Rail × Coal × Metal. (1)–(6) use municipality and year fixed effects; (7)–(12) use municipality and District-by-Year FE. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A11: Railway Access and Specific Resource Potentials: Coal vs. Metal (80% cutoff)

	Dependent Variable: ln(Population)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail	0.166***	0.118***	0.138***	0.089***	0.097***	0.088***	0.156***	0.117***	0.128***	0.088***	0.091***	0.088***
	(0.025)	(0.023)	(0.026)	(0.026)	(0.025)	(0.026)	(0.026)	(0.024)	(0.026)	(0.026)	(0.026)	(0.026)
Rail × Coal		0.046***		0.046***	0.039**	0.044***		0.041**		0.041**	0.038**	0.039**
		(0.018)		(0.017)	(0.017)	(0.017)		(0.017)		(0.016)	(0.016)	(0.016)
Rail × Metal			0.041*	0.041**	-0.109				0.043**	0.043**	-0.040	
			(0.022)	(0.021)	(0.081)				(0.019)	(0.018)	(0.075)	
Rail × Coal × Metal					0.125	0.038**					0.070	0.038**
					(0.077)	(0.019)					(0.070)	(0.016)
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	–	–	–	–	–	–
Dist × Year FE	–	–	–	–	–	–	✓	✓	✓	✓	✓	✓

Notes: Conley SE (10km). Resource potentials are truncated continuous (T50) with a cutoff of 0.9. "Metal" refers to the narrow-narrow (MetNarNar) classification. Triple Interaction in (5, 6, 11, 12) tests Rail × Coal × Metal. (1)–(6) use municipality and year fixed effects; (7)–(12) use municipality and District-by-Year FE. Significance codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Appendix: Robustness - TWFE Mining and Rail

We investigate how our staggered DiD results are affected by using different cutoffs for the railway access indicator variable. In the initial specification we use 2km as a threshold, which is similar to the closest 30% of municipalities. I change that to 1 (15%) and 3 km (40%) respectively.

Table A12: TWFE with varying Railway Distance Thresholds (1km, 2km, 3km)

	Dependent Variable: ln(Population)											
	1 km Threshold				**2 km Threshold**				**3 km Threshold**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail Access	0.200***	0.567***	0.183***	0.579***	0.150***	0.487***	0.143***	0.522***	0.120***	0.401***	0.114**	0.480***
	(0.054)	(0.163)	(0.052)	(0.152)	(0.044)	(0.132)	(0.044)	(0.137)	(0.042)	(0.137)	(0.044)	(0.149)
Rail × Mining		0.183***		0.194***		0.166***		0.183***		0.138**		0.174***
		(0.070)		(0.064)		(0.058)		(0.060)		(0.059)		(0.062)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dist × Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes

Notes: Standard errors in parentheses are Conley SE (10km). Columns (1)–(4) use 1km, (5)–(8) 2km, and (9)–(12) use 3km railway thresholds. Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

While the primary TWFE specification employs a continuous measure of mining potential, I extend the analysis by introducing a binary indicator for mining. Keeping the railway access threshold at the standard 2km level, I construct a mining dummy that equals one for municipalities within the top 5th, 10th, and 15th percentiles of proximity to the largest mines.

Table A13: TWFE Estimates with Varying Mining Proximity Thresholds

	Dependent Variable: ln(Population)											
	5% Mining Threshold				**10% Mining Threshold**				**15% Mining Threshold**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Railway Access	0.150***	0.116***	0.143***	0.110***	0.150***	0.099***	0.143***	0.096***	0.150***	0.089***	0.143***	0.088***
	(0.044)	(0.035)	(0.044)	(0.033)	(0.044)	(0.031)	(0.044)	(0.030)	(0.044)	(0.028)	(0.044)	(0.029)
Railway × Mining		0.567***		0.546***		0.394***		0.377**		0.323***		0.305**
		(0.152)		(0.166)		(0.133)		(0.148)		(0.121)		(0.141)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dist × Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes

Notes: Standard errors in parentheses are Conley SE (10km). The columns vary the definition of the Mining Dummy based on proximity thresholds (5%, 10%, 15%). Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

In the Two-Stage DiD specification, I test multiple railway thresholds and substitute the continuous mining measure with a binary indicator as well.

Table A14: Two-Stage DiD with Varying Railway Distance Thresholds (1km, 2km, 3km)

	Dependent Variable: ln(Population)											
	1 km Threshold				**2 km Threshold**				**3 km Threshold**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail Access	0.217***	0.562***	0.199***	0.560***	0.174***	0.489***	0.162***	0.498***	0.148***	0.406***	0.142***	0.440***
	(0.040)	(0.120)	(0.039)	(0.114)	(0.024)	(0.075)	(0.026)	(0.078)	(0.020)	(0.066)	(0.022)	(0.069)
Rail × Mining		0.177***		0.185***		0.161***		0.170***		0.129***		0.148***
		(0.049)		(0.046)		(0.031)		(0.032)		(0.028)		(0.028)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dist × Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes

Notes: Standard errors in parentheses are clustered at the municipality level and corrected for the two-stage GMM procedure (Gardner, 2021). Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A15: Two-Stage DiD with Varying Mining Proximity Thresholds

	Dependent Variable: ln(Population)											
	5% Mining Threshold				**10% Mining Threshold**				**15% Mining Threshold**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rail Access	0.174***	0.143***	0.162***	0.129***	0.174***	0.124***	0.162***	0.110***	0.174***	0.115***	0.162***	0.103***
	(0.024)	(0.023)	(0.026)	(0.025)	(0.024)	(0.022)	(0.026)	(0.024)	(0.024)	(0.022)	(0.026)	(0.024)
Rail × Mining		0.501***		0.509***		0.341***		0.358***		0.278***		0.283***
		(0.135)		(0.129)		(0.092)		(0.092)		(0.071)		(0.074)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dist × Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes

Notes: Standard errors in parentheses are clustered at the municipality level and corrected for the two-stage GMM procedure (Gardner, 2021). Signif. codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Appendix: Robustness - Rail and Skill

In addition to the density of skilled labor, we consider the absolute number of craftsmen in 1837 as a proxy for pre-industrial skill. While the share of craftsmen indicates local economic specialization, the absolute could even matter more, accounting for the possibility that industrialization required a critical mass of skilled individuals to implement new technologies, independent of the overall employment structure of the municipality. Table A16 reports the OLS results of this skill regression only varying the definition of the skill variable, again disaggregated by dependent variable. As previously observed, there is a negative relationship for the interaction term between rail and skill, even though this is only significant with regard to population. However, for the factory variable, skill exhibits a positive standalone effect, and a positive correlation can also be observed in its interaction with mining. These results, especially the contradicting findings between the dependent variables, require further investigation. Decomposing these effects will be part of the future work within this project.

Table A16: Railways, Mining and Skill (Absolute Number IHS) and Economic Outcomes: Grouped by dependent variable

	Dependent Variable: Factories 1900 (IHS)						Dependent Variable: Δ Population 1846-1900					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Skill	0.068***	0.053***	0.129***	0.118***	0.096***	0.062*	0.081***	0.018	-0.089	-0.087	-0.137**	-0.197***
	(0.010)	(0.010)	(0.027)	(0.028)	(0.028)	(0.032)	(0.021)	(0.021)	(0.055)	(0.057)	(0.057)	(0.066)
Mining		0.032**	0.046**	0.048*	0.057**	0.086**		0.116***	0.348***	0.371***	0.392***	0.632***
		(0.013)	(0.022)	(0.025)	(0.025)	(0.035)		(0.026)	(0.044)	(0.051)	(0.051)	(0.073)
Rail		0.030***	0.112***	0.101***	0.109***	0.123***		0.146***	0.634***	0.636***	0.655***	0.797***
		(0.010)	(0.031)	(0.032)	(0.032)	(0.037)		(0.020)	(0.063)	(0.066)	(0.066)	(0.077)
Rail × Mining			0.032***	0.026**	0.028***	0.035***			0.170***	0.170***	0.173***	0.208***
			(0.010)	(0.011)	(0.011)	(0.012)			(0.021)	(0.022)	(0.022)	(0.025)
Rail × Skill			0.002	-0.000	-0.004	-0.003			-0.040***	-0.041***	-0.049***	-0.060***
			(0.007)	(0.007)	(0.007)	(0.007)			(0.014)	(0.014)	(0.014)	(0.014)
Mining × Skill			0.029***	0.026***	0.023**	0.013			-0.031	-0.031	-0.038*	-0.049**
			(0.010)	(0.010)	(0.010)	(0.011)			(0.020)	(0.021)	(0.021)	(0.023)
City Dummy					0.466***	0.392***					1.052***	1.055***
					(0.123)	(0.120)					(0.251)	(0.248)
Controls	–	–	–	✓	✓	✓	–	–	–	✓	✓	✓
Fixed Effects	–	–	–	–	–	✓	–	–	–	–	–	✓
Adj. R^2	0.062	0.083	0.113	0.136	0.151	0.256	0.018	0.118	0.188	0.190	0.208	0.288
Observations	738	738	738	738	738	738	738	738	738	738	738	738

Notes: Dependent variable is number of factories (IHS) and population growth (1846–1900). Skill represents the absolute number of craftsmen (IHS). Mining captures the distance to 19th-century mines. Baseline controls include controls for distance to city centroid, elevation, terrain ruggedness, temperature variables and share of protestants in 1900. City dummy is added when indicated. In (6) and (12) district fixed effects are included as well as additional controls: Absolute longitude and latitude, a suitability indicator and average maximal temperature. Standard errors are Conley (10km). Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.