Old But Gold: Historical Pathways and Path Dependence[*]

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Abstract

We use the discovery of gold in Brazil as a historical quasi-experiment and show that gold roads are positively associated with population density and nightlight incidence in contemporary times. We then use official documents from the 19th century to build a nationwide transportation network that grew from the gold roads to show that the entire network also correlates with more population density today. Agglomeration spillovers are more likely to be the main mechanism driving the effect of historical pathways on long-run population density equilibrium, generating path dependence instead of historical persistence.

Keywords: Historical Roads, Geography, Path Dependence, Persistence, Population Density
JEL Codes: R12, N96, O18, O43

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1 Introduction

Although significant in connecting isolated regions in the past, historical pathways have become outdated with advancements in transportation technologies such as railways, highways, and airways. While these routes may no longer hold significant economic advantages in the present day, their historical impact on the economy can have lasting effects for two reasons. First, in the case of a single spatial equilibrium, the effect of the historical shock may persist. Once the system has been affected, it may take considerable time to revert to its original equilibrium. Second, in the case of multiple spatial steady states, the effect can create path dependence with or without historical persistence. The historical pathway shock may assist the economy in selecting a specific (new) equilibrium, which can last for generations (Allen and Donaldson, 2022).

Identifying the prevailing dynamics of uniform convergence, persistence, or path dependence in the economy following a shock is a complex task. It requires disentangling the effects of various confounding factors, including geography (first nature or locational fundamentals), fixed durable investments (second nature), migration frictions, and agglomeration spillovers (Lin and Rauch, 2022). In this paper, our main contribution lies in investigating two quasi-experiments related to historical routes and, by distinguishing between these forces, providing suggestive evidence regarding whether the economy, shaped by these historical roads, exhibits a unique population steady state or multiple steady states.[1] Previous studies have explored various aspects of historical roads,[2] but the question of whether the effects of these roads on historical development operate through persistence or path dependence remains an open issue.

We utilize the Brazilian transportation experience as a historical laboratory for our study. Our empirical approach consists of two distinct components. First, we focus on

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[1] The connection between historical roads and town development in Brazil had already been noted by Deffontaines (1938).

[2] See for example, Ahmad and Chicoine (2021); Barsanetti (2021); Bertazzini (2021); Flückiger et al. (2021); Bottasso et al. (2022); Dalgaard et al. (2022); Paik and Shahi (2022); Portugal and Barsanetti (2022); Elizalde et al. (2023)

the historical pathways that emerged during the gold rush in various regions of Brazil during the late 17th century, which we refer to as "gold roads." We consider the impact of these gold roads on current population density to be causal because their formation resulted from explorers venturing randomly into the Brazilian hinterlands in search of mines. Consequently, the location of these pathways is unrelated to any inherent advantages that may have influenced the initial settlement patterns of the population. To further strengthen our identification strategy, we construct least-cost paths that serve as instrumental variables in our analysis.

Our second empirical strategy focuses on the Brazilian transport network developed during the 19th century, which evolved from the gold roads. We construct a unique georeferenced database using historical documents, specifically official government reports from the 1860s and 1870s. This database allows us to establish a comprehensive road network connecting municipalities in 1872. Referred to as "mule roads," this network emerged over several decades due to ground transportation primarily using mules, which served as the primary mode of transportation before the introduction of railroads.[3]

The mule roads are constructed based on historical government reports that provide information on the actual distances traveled between each pair of municipalities in the network. To determine the optimal pathways between municipal seats, we employ a cost measure that considers terrain factors exclusively. Given that these pathways were established using rudimentary technology, we can confidently assert that the builders aimed to minimize costs based solely on the terrain. Notably, a robust correlation exists between the optimal distances and the actual distances traveled. There are two main advantages of integrating the two empirical strategies: 1) while georeferenced information for the mule roads is unavailable, we do possess such information for the gold roads; 2)

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[3] The widespread introduction of railroads in Brazil occurred only at the end of the 19th century and the first decades of the 20th century (Summerhill, 2005). For the transportation advantage of mules in Brazil see, for example, Reis (2023).

by incorporating the mule roads into our analysis, we can ensure that our findings hold broader external validity and are not solely contingent on the specific characteristics of gold roads or mining regions.

In both strategies, we exclude pre-existing locations. For the gold roads, we exclude municipalities that predated the discovery of gold. Likewise, we exclude municipalities listed as nodes in the historical documents for the mule roads. In doing so, our approach is similar to the inconsequential units approach (Redding and Rossi-Hansberg, 2017). Furthermore, our analysis focuses only on municipalities that are traversed by the roads and their neighboring municipalities while incorporating flexible controls for geographical factors. These measures largely address concerns that first-nature effects may be driving the results.

Our findings indicate that historical pathways significantly impact the spatial distribution of population density in present-day municipalities. We observe that a 10% increase in the density of gold roads is associated with a 2.3% increase in population density within a municipality and 1.8% increase in nightlight incidence, as an alternative measure of population density. Similarly, mule roads have a positive but smaller effect on population density and nightlight incidence. The results are robust to a large number of alternatives.

To address concerns about potential confounding factors, we conduct a placebo test by examining the effects of optimal paths between municipalities not documented in official historical records. This analysis allows us to determine whether the observed effects on population density and nightlight incidence are specific to the documented routes or influenced by other unobserved factors. Encouragingly, we find that the effect of "fake" route density on population density and nightlight incidence is approximately zero and statistically insignificant. This result suggests that unobserved first-nature factors do not drive our main results and provides further support for the causal relationship between the historical routes and long-run population density.

We examine historical and present-day factor densities to investigate the potential role of second-nature effects in our findings. Specifically, we explore whether investments in durable capital may be driving the observed effects of gold and mule roads on current population density. Our analysis reveals no correlation between the roads and historical factors, suggesting that the roads did not directly contribute to the development of these factors. We do observe a correlation between the historical roads and modern transportation infrastructure. This correlation suggests that the historical roads may have played a role in the development of modern transportation infrastructure, which could indirectly affect population density. In the next exercise, however, we argue that this likely is not the mechanism at play.

To gain further insights into our previous findings and explore the role of migration frictions, we conduct an analysis using consistent boundaries for every available census data between 1920 and 2010. Surprisingly, we initially observe null effects of historical pathways on population density. However, over the course of the 20th century, the effects of these pathways on population density become substantial and statistically significant. This result leads to two important observations. First, we can rule out the presence of migration frictions, as places with historical pathways do not exhibit higher population density initially, which would suggest restricted mobility. In fact, we observe exactly the opposite, with population density gradually increasing in places with historical pathways. Secondly, we find that the density effects emerge earlier than the development of highways and paved roads and even when the total amount of railways is diminishing. This suggests that present-day transportation factor density alone cannot account for the main results observed. Finally, when incorporating lagged population density in our long-run model, we find that it plays a significant role in capturing the coefficients of historical pathways on current density, which implies that agglomeration spillovers may be the primary driving force in our setting.

As a final exercise, we utilize the historical pathways as instrumental variables to examine the impact of agglomeration spillovers on local wages. By employing the estimated parameters and an economic geography model proposed by Allen and Donaldson (2022), we show that the economy likely operates in the agglomeration and dispersion parameter space region where multiple steady states with path dependence are possible. The findings presented in this study indicate that historical pathways did not yield immediate advantages for nearby areas.[4] During the second half of the 20th century, however, as the economy shifted its center of gravity from the coast to the hinterland and transitioned from rural to urban activities, historical pathways played a pivotal role in resolving a coordination problem in population equilibrium selection, leading to path dependence that persists across generations.

Our paper contributes to two growing strands of literature. First, we contribute to the literature on path dependence and persistence in cities and population (see, for example, Davis and Weinstein (2002), Bleakley and Lin (2012), Bleakley and Lin (2015), Michaels and Rauch (2017), Jedwab et al. (2017), Bakker et al. (2019), Allen and Donaldson (2020), Allen and Donaldson (2022), Brown and Cuberes (2022), Takeda and Yamagishi (2023), and Lin and Rauch (2022) for a review). We contribute to this literature by distinguishing between second-nature forces and agglomeration spillovers within the context of historical roads. Our results add to the understanding of empirically differentiating persistence and path dependence in historical settings. Second, we contribute to the broader literature on historical roads, which traditionally investigates the connections between historical roads and various factors such as trade, institutions, technological knowledge, and modern transportation infrastructure, for example, as explored in studies by Bosker et al. (2013), Martincus et al. (2013), Ahmad and Chicoine (2021), Barsanetti (2021), Bertazzini (2021), Flückiger et al. (2021), Franco et al. (2021), Bottasso et al. (2022), Dalgaard et al. (2022), Paik and Shahi (2022), Portugal and Barsanetti (2022), and Elizalde et al. (2023).

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[4] This is in line with the evidence discussed in Reis (2023), where initial high transportation costs hindered any benefits of being connected to gold roads.

In addition to all these factors, we show that historical roads can also aid in long-run population equilibrium selection, causing path dependence.

In Section 2, we give a detailed account of the historical background, in Section 3 we present the results for the gold roads, in Section 4 we present the results for the mule roads, in Section 5 we discuss path dependence, and Section 6 concludes the paper.

2 Historical Background

Transport Infrastructure in Colonial Brazil After first contact in 1500, Portuguese colonizers settled along the coast since the presence of indigenous tribes and geographical features within the territory presented challenges for exploring the hinterlands. Franciscan friar Vicente de Salvador, the "father of Brazilian history," famously wrote in 1627 that the Portuguese remained on the coast, scratching the shores like crabs. Eventually, several rivers were utilized as the primary type of transportation, whereas ground transportation mainly connected the watercourses (Morais, 2010, p. 31). Gradually, more expeditions towards the country's interior began, opening pathways through the rainforests and hills. One emblematic example is the foundation of São Paulo by a Jesuit mission in 1554.[5]

The pathways followed by many expeditions were not exactly new. Explorers would take advantage of indigenous trails connecting native villages, called *Apés* (Kok, 2009, p. 94). According to Holanda (1975), these trails were primitive – no better than tracks left by tapirs – such that wheeled carts were prohibitive. Therefore, the main expeditions into the Brazilian hinterlands were composed of Jesuit missions and slave raiders – named *Bandeirantes* – who followed primitive indigenous trails mainly using enslaved people as porters (De Abreu, 1998, p. 92).

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[5] It is notably difficult to reach the plains of São Paulo region from the coast because of the *Serra do Mar*, where often a hundred-meter incursion inland means going up one thousand meters in elevation. See Momsen Jr (1963).

Whereas Jesuits and *Bandeirantes* expanded the Brazilian frontier in the central and southern regions, the Portuguese occupation occurred in different ways in the North and Northeast. The Portuguese settlers took advantage of the Amazon basin to explore the region, navigating its rivers in the North. They successfully implemented a sugar cane plantation system near the coast in the Northeast. Farms in the hinterlands supplied livestock products to the large population in the plantations and urban centers. Netto (1974) stresses that relatively modern roads trailed by mules and bullock carts could be found by the end of the 16th centuries connecting villages in the coastal areas of Northeast.[6] In general, however, pathways for ground transportation were few, short, and of poor quality. Their primary purpose was to connect the immediate hinterlands with the coast, as the principal consumers of these areas' output were either the urban population or the European market.

The discovery of gold mines around 1700 in central regions of Brazil – Minas Gerais, Goiás, and Mato Grosso – was a critical event in Brazilian economic history. The focus of production shifted from the sugar cane plantations in the Northeast to the mining areas. Given that the mines were located in the countryside, several longer pathways were opened to connect them with the provinces of Rio de Janeiro and Bahia on the coast. In this scenario, ground transportation was essential to collect taxes on the circulation of merchandise and control the flow of gold (Morais, 2010, p. 22).

The first major route connecting the gold mines with the coast became known as *caminho velho* ("old pathway"). This pathway connected the gold mines to Paraty, in the southwest of Rio de Janeiro. From there, the gold would be shipped by sea to Rio de Janeiro. However, the *caminho velho* was far from optimal. Since it was created by explorers moving towards Brazil's hinterlands in search of gold, this pathway favored

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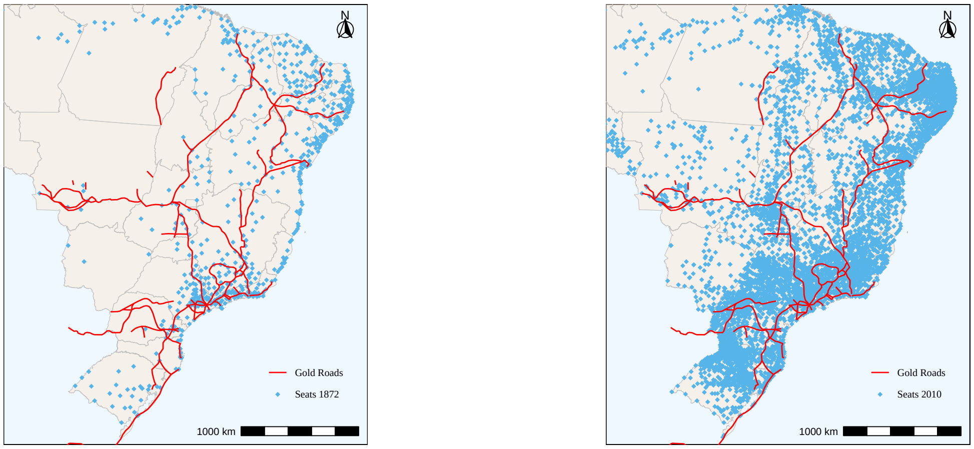
[6] Netto (1974, 39–40) points out two factors that favored ground transportation in the Northeast. First, coastal sailing was dangerous, given the presence of French and Dutch pirates on the Northeast coast. Second, the Dutch occupation of the territory between 1630 and 1654 had the economic integration of the areas as a primary goal.

good geography rather than the time to reach the ports in Rio.[7] In the first decade of the 18th century, a new pathway *caminho novo* ("new pathway") was created, designed to be the fastest route between the gold mines and Rio de Janeiro.

Besides the more commonly known pathways connecting São Paulo, Rio de Janeiro, and Minas Gerais, during the 17th century, a more extensive network of gold roads was built connecting gold deposits in the South, the West, Bahia, and the Northeast. In Figure 1 we show the gold roads compiled by Simonsen (1977), overlaid with the municipality seats in 1872 and 2010. We can see that many of the cities agglomerate along the paths.



(a) Gold roads and cities in 1872

(b) Gold roads and cities in 2010

Figure 1: Gold roads from Simonsen (1977) and cities

These pathways would also be used to conduct trade and bring mules and cattle from the South and the Northeast to the rest of the country. The large-scale usage of mules was another important innovation during this period.[8] These animals were raised on

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[7] The *bandeiras* (expeditions) to find gold were smaller and less militarized relative to the ones aimed at capturing indigenous groups. They followed existing indigenous paths and the river trails, crossing them whenever necessary, avoiding forests mostly. Other orientations for their paths included peaks, the sun, valleys, and accounts from previous expeditions (Santos, 2001).

[8] The mule – a hybrid animal resulting from the crossing of a donkey with a mare – proved an excellent option to trail irregular paths: stable, resistant to climatic and altitude variations (Borges, 2016). Over long distances, it was more resilient and faster than horses. Relative to enslaved people, the mule was faster, traveling 3 to 4 leagues a day, and had a load capacity of 3 to 5 times greater. Mules also had more advantageous biological characteristics for transport than other animal species, requiring less water and being

farms in the far south of Brazil, then transported by land to the interior of São Paulo, where they would be traded in large livestock markets. Then, the economy around gold mining created incentives to expand the connection between provinces in the central and southern regions. (Netto, 1974, 133) describes these pathways by the early 19th century as being winding and rough, appropriate only for the transit of horses and mules. Prado Júnior (1987) summarizes the same scenario emphasizing the independence between regions and their transportation characteristics.

Transport Infrastructure in Brazil after Independence After the gold cycle, animal transport still remained relevant, finding new sources of demand in sugar crops in São Paulo and tobacco production in Bahia, for example (Austregésilo, 1950; Morais, 2010). In both the Northeast and the Southeast, the basis of the domestic market was the triangulation between animal production, communication and transport networks, and export ports. The internal market created an integrated commercial subsystem with *tropeiros* and traders of the most diverse types as participants (Prado Júnior, 1987; Morais, 2010).

After independence in 1822, Brazil was politically organized as an empire. The following years are characterized by many proposals to improve the connectivity between Brazilian regions, following the new political elite's urge for geographical integration across the national territory. Many suggested using new technology, such as railroads and steamboats, whereas others favored modernizing existing ground pathways. These projects were never executed, given their high costs and the central government's large deficit. The main public policies toward improving transport infrastructure focused on subsidies and economic concessions for private investors.

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more energy-efficient. From 1730 to 1875, mule troops dominated long-distance inland transport in Brazil, and their contribution to the country's economic integration is recognized by several scholars (Milet, 1881; Silva, 1947, 1949; Ellis Jr, 1950; Goulart, 1959; Abreu, 1963; Klein, 1989; Monteiro, 1994; Summerhill, 1997; Suprinyak et al., 2006).

The number of pathways increased rapidly after the 1830s (Morais, 2010, p. 72). A possible explanation for this shift is the change in the Constitution, now granting provinces the right to collect taxes over circulating merchandise. Another reason for the surge in the number of pathways after the 1830s is the increased revenue from coffee plantations in São Paulo, incentivizing the expansion of roads connecting them to other markets. Finally, another potential reason is the political strengthening of the conservative party that considered the integration of provinces a matter of national security (Morais, 2010). However, this movement was not enough to connect the country and was cut short by a change in the national strategy towards adopting a railroad system in the middle of the 19th century.

Even with public support through concessions and subsidies, there were only 1,200 kilometers of active railways in 1872. In 1889, Brazil became a republic but maintained the goal of national integration through a train network. In 1922, the railroad system had 29,000 kilometers in use (Netto, 1974, p. 133).[9] Still, as a plan for national integration, the railroad failed. According to Netto (1974), there were four independent networks: one that integrated the central-southern region, one that integrated the Northeast coast from Rio Grande do Norte to Sergipe, one within the state of Bahia, and the last one within the state of Ceará. Indeed, Galvão (1996) argues that Brazil was still a continental country by the end of the 1940s with little geographic interaction. Only in 1951 did the central government prioritize roads as the primary national integration strategy, and we have seen highways' expansion throughout Brazil since then.

The brief history of the ground transportation infrastructure presented in this section is often depicted by the classic expression in Brazilian historiography: "First the tapir, then the Indian, the *bandeirantes*, the mule, the railway, and the highway." Simonsen (1977) mentions that even at the time of his writing in 1937 mules were still being used to connect the cities throughout Brazil. Our empirical strategy focuses on the stage

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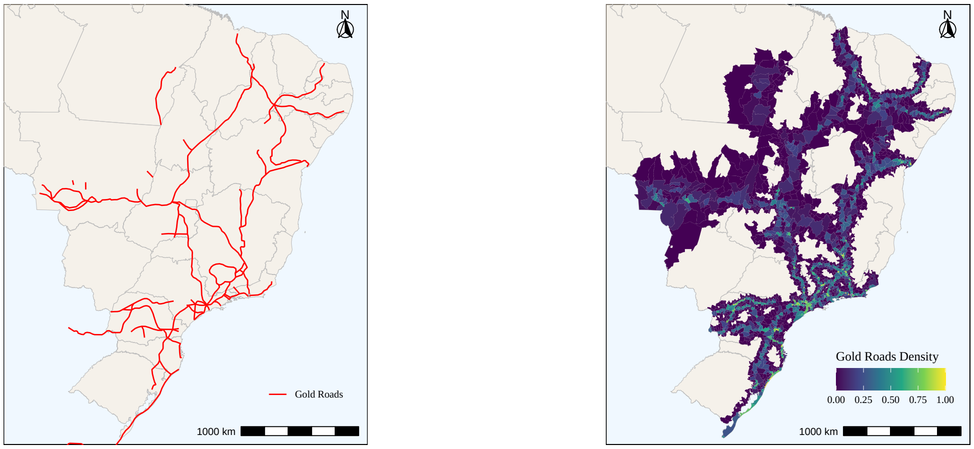
[9] As a comparison, the United States had 85,000 kilometers in 1870 and 135,000 kilometers in 1880.

where ground transportation using mules served as the primary transportation mode in Brazil.

3 Pathways of the Colony: Gold Roads

In this initial analysis, we investigate the gold roads that interconnected the primary gold regions discovered since 1700. Information about the routes taken by these roads was georeferenced from Simonsen (1977), and the resulting map is displayed in Figure 2a. We conduct the study at two geographical levels: municipalities and 25-square-kilometer grid cells. At the municipality level, we assess the impact of gold roads on local economies using road density. Figure 2b illustrates the gold road density in municipalities traversed by gold roads and neighboring areas. At the grid-cell level, we consider the distance to the closest gold road.[10] We begin by presenting the primary results and then explore additional robustness exercises.



(a) Gold roads georeferenced

(b) Gold road density

Figure 2: Gold Roads from Simonsen (1977)

We model the relationship between gold roads and population density as a linear association using the following equation:

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[10] For a detailed explanation of variable construction and the procedures involved in creating the georeferenced dataset used in this section, please refer to Appendix A.1.

$$y_i = \alpha_s + \beta \text{Roads}_i + \mathbf{X}_i' \boldsymbol{\gamma} + \epsilon_i, \tag{1}$$

where y_i represents either population density or nightlight incidence at location i in 2010. The variable Roads_i captures the influence of gold roads on location i and can be measured as either road density or distance to the road. The column vector $\mathbf{X}_i$ contains additional covariates, α_s represents the fixed effects for state or municipality s, and ϵ_i denotes the error term.

We employ multiple strategies to ensure a causal interpretation of β. First, we leverage the as-good-as-random nature of gold roads, as both the timing and the location of gold discovery in Brazil was unexpected, a theme explored in Palma (2022).[11] It was gold mining that would then promote the foundation of the first cities in Brazil's hinterland (Simonsen, 1977). This as-good-as-random process makes it unlikely that omitted confounding factors are correlated with the gold roads. If anything, Simonsen (1977) argues that the first settlements along the roads and deposits were made in infertile regions, which would necessitate food and all types of goods from other regions. Additionally, to strengthen our identification strategy, we construct a set of least-cost paths that serve as instruments for road density and distance to roads.[12] Furthermore, we exclude municipalities that existed prior to 1700 to mitigate confounding variables associated with pre-existing developed regions. By focusing on inconsequential units (Redding and Rossi-Hansberg, 2017), we aim to minimize the influence of historical factors. Finally, to account for natural geographical characteristics, we flexibly control for various features such as temperature, precipitation, elevation, distance to the coast, distance to rivers, and a latitude-longitude polynomial.

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[11] Although it is possible that some routes were constructed after the discovery of mines and followed optimal paths, we present separate results for the *caminho velho* in Appendix D, where historical accounts support the randomness of the road's trajectory.

[12] Results OLS estimation instead of 2SLS yield similar findings, and these results can be provided upon request.

To address the right-skewness of the dependent variables and road density, which include zero-valued observations, we apply the inverse hyperbolic sine (IHS) transformation and interpret the results as elasticities (Bellemare and Wichman, 2020). Additionally, at the municipality level, we focus our analysis on areas traversed by the gold roads and their contiguous neighbors to ensure comparability among geographically similar regions. At the grid level, we include grid cells within a 30km radius from the gold road. The municipality sample consists of 2,096 observations, with population density ranging from 0.23 to 12,998 individuals per square kilometer and colonial pathway density ranging from zero to one. On the other hand, the grid-cell sample comprises 48,914 observations, with a wider range of values, as population density varies from zero to 18,120 individuals per square kilometer. Detailed descriptive statistics are provided in Table A.1 in Appendix A.2.

The main results are displayed in Table 1. Panel A presents the Two-Stage Least Squares (2SLS) estimates with population density as the variable of interest, while Panel B shows the 2SLS estimates with nightlight incidence as the dependent variable. In Column (1), we present a simple 2SLS estimation without covariates or fixed effects; moving to Column (2), state-fixed effects are added to the model; in Column (3), geographic controls are included; and in Column (4), a second-order polynomial of latitude and longitude is added. To account for more spatially disaggregated time-invariant unobservables, Column (5) employs 25km^2 grids as the unit of observation and introduces municipality fixed effects. Standard errors are clustered at the level of 1872 minimum comparable areas (MCAs) as defined by Reis et al. (2011) to address spatial correlation between units. MCAs are areas with stable boundaries associated with 1872 municipalities, which group geographical locations in 2010 that shared common administrative borders in the past.

Overall, the findings suggest a positive association between greater access to gold roads and higher population concentration, as indicated by both population density and

Table 1: Gold roads and current population density

	(1)	(2)	(3)	(4)	(5)
		Municipality			Grid-Cells
Panel A – Dep. Var.: Population Density:					
Gold Roads	0.443^{***}	0.290^{***}	0.226^{***}	0.230^{***}	-0.156
	(0.107)	(0.081)	(0.058)	(0.061)	(0.170)
Observations	2,096	2,096	2,096	2,096	43,620
Cluster Groups	262	262	262	262	1,738
Panel B – Dep. Var.: Nightlights:					
Gold Roads	0.393^{***}	0.227^{***}	0.192^{***}	0.188^{***}	-0.228^{**}
	(0.079)	(0.057)	(0.045)	(0.048)	(0.105)
Observations	2,096	2,096	2,096	2,096	43,647
Cluster Groups	262	262	262	262	1,738
Kleibergen-Paap F:	58.72	69.88	72.45	67.89	36.64
Fixed-Effects:	No	State	State	State	Muni
Geography Controls	No	No	Yes	Yes	Yes
Lat-Long Polynomial:	No	No	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is municipalities and at the municipality level when the unit of observation is the grid cell. Gold Roads refers to the inverse hyperbolic sine transformation of either gold road density (municipalities) or the distance to the nearest gold road (grid cells). Geography variables are the ones present in Table A.1 and a second-order latitude-longitude polynomial. The sample excludes municipalities that already existed in 1700. $^{*}p < 0.1, ^{**} p < 0.05, ^{***} p < 0.01$

nightlight measures. While the effect somewhat diminishes with the inclusion of state fixed effects and geographic controls, the results remain statistically and economically significant. Specifically, based on the specification in Column (4), a ten-percent increase in road density corresponds to a 2.3% increase in population density and a 1.9% increase in nightlight incidence. In specification (5), a 1% increase in the distance to the roads leads to an average reduction of 1.6% and 2.3% in population density and nightlight incidence, respectively. It is worth noting, however, that the estimation at the grid-cell level with population density as the dependent variable yields considerably larger standard errors, resulting in the coefficient on population density being statistically insignificant. This is expected since there is more measurement error in assigning the measure of population density, which is made at the municipality level, to the grid-cell level. In contrast, nightlight incidence is more fine-grained and can be exactly assigned to each grid-cell.

As our model is just-identified, the Kleinberger-Paap F statistic is equivalent to the effective first-stage F statistic proposed by Montiel-Olea and Pflueger (2013). In Table 1, we observe that our F statistic exceeds the conventional threshold of 10 for the Montiel-Olea Pflueger case. Hence, we can confidently employ the conventional 2SLS method without concerns about a weak instrument problem, as highlighted by (Andrews et al., 2019).

3.1 Robustness Analysis

In Appendix B, we demonstrate the robustness of our results through various extensions and alternative specifications. We address potential measurement errors in our main dependent variables and road access measures by re-estimating the model using a $\log(1+y)$ transformation. As shown in Table Table B.1, the results remain unchanged, indicating the robustness of our findings.

To further assess the robustness of our findings, we conduct additional analyses, as presented in Table B.2. Panel A focuses on the use of the inverse hyperbolic sine

(IHS) transformation, while Panel B explores the log(1+) transformation for our density and distance measures of road access. It is also worth considering the possibility of measurement error in our road access measures due to the nature of the data source, as precise route locations are required. To address this concern, we re-estimate the model using alternative measures of road access. Specifically, we include dummy variables indicating whether a road crosses a municipality or a grid cell is within a 10-kilometer of a route. These alternative measures rely on less precise information about the exact locations of the roads. The results remain consistent, as shown in Panel C.

At the municipality level, we demonstrate that the results remain robust when using Minimum Comparable Area (MCA) fixed effects instead of state fixed effects. At the grid level, we test different comparison groups by including grid cells within distances of 30km, 40km, and 50km from the roads. Importantly, the results remain consistent across these alternative specifications, reaffirming the robustness of our findings.

We acknowledge the potential presence of spatial correlation among the units, which can impact the standard errors of our estimates. To address this concern, we incorporate spatial correlation within MCAs at the municipality level and within municipalities at the grid level in our main estimates. In addition to these standard errors, we also calculate standard errors using the spatially autocorrelated method proposed by Conley (2010). These alternative standard errors are also presented in Table B.2.

In general, our main estimates are robust to various potential concerns. Both Table B.1 and Table B.2 demonstrate consistent and significant coefficients across different specifications, indicating the stability and reliability of our results presented in Table 1.

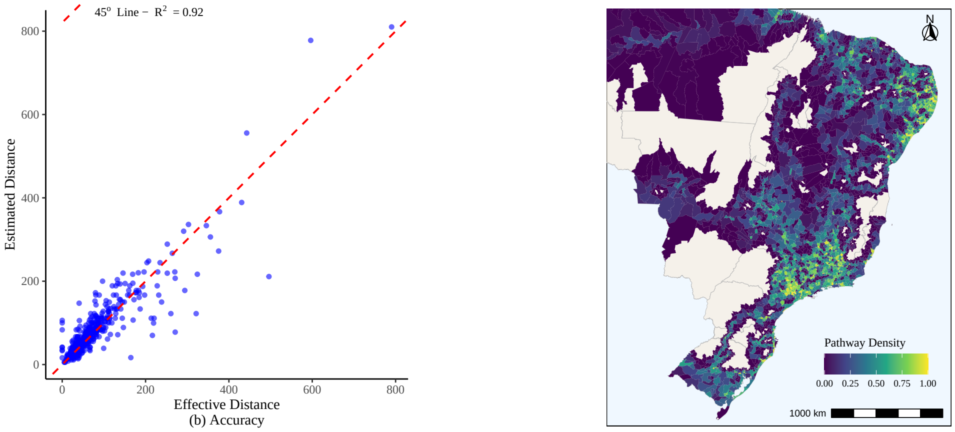
4 Pathways of the Empire: Mule Roads

In this section, we expand our analysis to incorporate information on *all* documented connections between municipal seats in 1872. With this nation-wide exercise we address the possibility that our previous findings may not be applicable to other contexts, as our focus was solely on a specific set of historical roads and regions associated with the Gold Rush during the colonial period in Brazil. In this section, we broaden the scope of our analysis to encompass the entire transportation network, which covers a broader time period and a larger geographical area.

We source the data utilized in this analysis from official documents issued by the Brazilian imperial government in 1863 and 1873. These documents contain information regarding distances between municipality seats traveled primarily by ground transportation, where mules were predominant. Consequently, we refer to this network of routes as mule roads. As the precise routes taken are not specified in the documents, we construct least-cost paths connecting the municipality seats. For a comprehensive account of the data construction, including the data sources, please consult Appendix A. In this regard, our estimates can be seen as analogous to the reduced-form estimates of a 2SLS approach if we had access to the exact route locations.

Although a direct comparison between the estimated and actual pathways is not possible, we can assess the accuracy of our estimated pathways by examining the information on the distance traveled along each route. Figure 3a depicts the relationship between effective distances and estimated distances. It is evident that our estimates closely align with the 45-degree line. To further evaluate the goodness of fit, we calculate the coefficient of determination, denoted as $R^2 = 1 - \frac{\sum_i (x_i - y_i)^2}{\sum_i (y_i - \bar{y})^2}$, where x_i represents the estimated distance of pathway i, y_i represents the effective distance, and $\bar{y}$ denotes the mean value of y_i. The calculated R^2 value of 92% indicates that only 8% of the variance in the effective distances remains unexplained by the variance in the estimated distances.

Table 2 provides further insights into the relationship between the two analyses. It reveals a robust and positive association between gold roads and the broader mule transportation network. This finding suggests that the gold pathways are integral to



(a) Length comparison (b) Mule road density

Figure 3: Mule Roads

Notes: R^2 is the sum of squared errors (estimated distance minus effective distance) over the sum of the squared difference between the effective distance and its mean value.

the extensive historical transportation system that evolved over centuries preceding the establishment of modern transport infrastructure in the 20th century.

With the identified routes at hand, we posit a linear relationship between a dependent variable y and the density of pathways, akin to Equation (1). Once again, y_{ir} represents the IHS-transformed values of either population density or nightlight incidence. The model incorporates state or municipality fixed effects and includes covariates. At the municipality level, our primary sample consists of municipalities intersected by mule roads and their immediate neighboring municipalities, as depicted in Figure 3b. At the grid-cell level, the explanatory variable is the distance of a grid cell to the nearest mule road. The sample exclusively includes grid cells within a 30-kilometer radius of a mule road. Irrespective of the dependent variable, the control vector $\mathbf{X}$ encompasses the geographical variables outlined in Table A.2, excluding the area variable, which is omitted from the grid-level analysis.

The causal interpretation of β hinges on the premise that the least-cost paths are determined by geographical characteristics between two municipality seats. By excluding the municipalities that served as that already existed in 1872, we narrow our focus

Table 2: Gold roads and mule roads

	(1)	(2)	(3)	(4)	(5)
	Municipality				Grid-Cells
Dep. Var.: Mule Roads					
Gold Roads	1.03***	0.849***	0.692***	0.654***	2.04***
	(0.202)	(0.120)	(0.109)	(0.107)	(0.436)
Observations	2,096	2,096	2,096	2,096	38,455
Cluster Groups	262	262	262	262	1,555
Kleibergen-Paap F:	58.72	69.88	72.45	67.89	30.53
Fixed-Effects:	No	State	State	State	Muni.
Geography Controls:	No	No	Yes	Yes	Yes
Lat-Long Polynomial:	No	No	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. Mule/Gold Roads refers to the inverse hyperbolic sine transformation of either mule/gold road density (municipalities) or the distance to the nearest mule/gold road (grid cells). Geography variables are the ones present in Table A.1 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1700. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

to inconsequential units where individual geographical features do not determine the pathway selection.

We present the estimated coefficients in Table 3. In Column (1), the simple OLS estimates of β are shown. Columns (2) to (4) include state fixed effects, and errors are clustered at the MCA level for all columns. Column (2) reports the fixed effect estimate of β for the full sample without controls. Column (3) adds the geography covariates, and Column (4) includes a second-order latitude-longitude polynomial. Consistent with the previous section, panel A reveals a positive relationship between mule roads and population density. Panel B reaches the same conclusion when nightlights are the dependent variable, although the coefficient is smaller than in the previous analysis. Finally, in Column (5), a grid-cell analysis is performed, where the mule roads variable is measured as the distance from the grid centroid to the nearest road.

In panel A of Table 3, Column (1) shows that a ten-percent increase in mule road density is associated with a 1.8% increase in population density and a 1.5% increase in nightlight incidence. When state fixed effects and geography controls are included, the independent effect of mule roads becomes slightly smaller in magnitude but remains statistically significant at the 1% level.

The combined results from this section and the previous section provide strong evidence of a positive relationship between historical pathways and the spatial distribution of population density. In the following subsections, we delve deeper to demonstrate the causal interpretation of our findings.

4.1 Robustness Analysis

Again, our results remain robust to various alternative transformations and specifications, as outlined in the previous section. The robustness exercises presented in Table B.3 and Table B.4 confirm the consistency of our findings. The relationships hold for alternative transformations of the dependent variables and road access measures at

Table 3: Mule roads and population density

	(1)	(2)	(3)	(4)	(5)
	Municipality				Grid-Cells
Panel A – Dep. Var.: Population Density:					
Mule Roads	0.180***	0.119***	0.056***	0.051***	-0.056***
	(0.026)	(0.017)	(0.011)	(0.011)	(0.011)
Observations	3,301	3,301	3,301	3,301	70,331
Cluster Groups	364	364	364	364	3,060
Panel B – Dep. Var.: Nightlights:					
Mule Roads	0.152***	0.104***	0.051***	0.045***	-0.048***
	(0.021)	(0.016)	(0.011)	(0.011)	(0.007)
Observations	3,301	3,301	3,301	3,301	70,344
Cluster Groups	364	364	364	364	3,060
Fixed-Effects:		State	State	State	Muni.
Geography Controls:	No	No	Yes	Yes	Yes
Lat-Long Polynomial:	No	No	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. Mule Road refers to the inverse hyperbolic sine transformation of either mule road density (municipalities) or the distance to the nearest mule road (grid cells). Geography variables are the ones present in Table A.2 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1872. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

the municipality or grid levels. The results are consistent across different spatial fixed effects and assumptions regarding the spatial correlation between error terms among observation units.

4.2 Placebo Analysis

In this section, we address two important concerns related to our identification strategy. The first concern pertains to the possibility that our measure of historical pathways primarily captures the influence of natural geographical features, thereby leading to our treated units being located in geographically advantageous areas compared to the comparison group. Despite controlling for geographical variables, including higher-order polynomials, and limiting our analysis to geographically similar areas, it is still plausible that there exist unobservable geographic factors influencing our estimates. The second concern relates to our estimated effects being primarily driven by the fact that these historical pathways simply served as optimal routes between pre-existing developed areas. If this is true, our estimates could be biased in favor of our hypothesis. While we have already taken a preliminary step by excluding municipalities that already existed at the same time as the historical pathways, the following discussion provides additional evidence.

To address both questions, we create fictitious least-cost connections between municipality seats not documented in historical records. This exercise replicates the approach taken in our main estimations but employs "fake" historical roads instead of actual ones. If our main results are influenced by first-nature factors or some sort of optimal path bias, the estimates in this section should show some similarities to our previous findings.

We present the placebo results in Table 4. In general, at the municipality level, the effects of the fake optimal paths on population density and nightlight incidence are approximately zero and statistically insignificant. However, at the grid-cell level, the estimates are statistically significant but much smaller than those in Table 3. These

Table 4: Fake roads and population density

	(1)	(2)	(3)	(4)	(5)
	Municipality				Grid-Cells
Panel A – Dep. Var.: Population Density:					
Fake Roads	0.063***	0.018	0.015	0.009	-0.039***
	(0.022)	(0.014)	(0.010)	(0.009)	(0.010)
Observations	3,161	3,161	3,161	3,161	80,480
Cluster Groups	341	341	341	341	3,005
Panel B – Dep. Var.: Nightlights:					
Fake Roads	0.011	0.006	0.005	-0.005	-0.028***
	(0.017)	(0.012)	(0.009)	(0.008)	(0.006)
Observations	3,161	3,161	3,161	3,161	80,580
Cluster Groups	341	341	341	341	3,005
Fixed-Effects:	No	State	State	State	Muni.
Geography Controls:	No	No	Yes	Yes	Yes
Lat-Long Polynomial:	No	No	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. Fake Roads refers to the inverse hyperbolic sine transformation of either fake road density (municipalities) or the distance to the nearest fake road (grid cells). Geography variables are the ones present in Table A.2 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1872. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

combined results suggest that neither of the identification issues discussed earlier can fully account for the results obtained in the previous analyses, further supporting our hypothesis.

5 Discussion: persistence or path dependence?

In this section, we aim to identify the main drivers behind the effect of historical pathways on current population density and determine whether this effect is primarily attributed to historical persistence or path dependence. To address this question, we draw on the framework proposed by Allen and Donaldson (2020, 2022), which allows us to empirically distinguish between these two concepts.

In Section 5.1 and Section 5.2, we examine whether the historical or current factor densities are the key drivers of our results. This approach is influenced by the discussion in Bleakley and Lin (2012) and their consideration of various factors, although we were unable to include variables such as housing units, rents, and values due to data limitations in many Brazilian municipalities. In Section 5.3, we examine the timing of the effects of historical roads to gain a deeper understanding of the underlying mechanisms that likely drive our results. By assessing the temporal patterns, we can uncover which mechanisms are more plausible in shaping the observed effects. Building upon the findings in this section, in Section 5.4 we estimate the agglomeration spillover coefficient using the optimal gold road paths as an instrument for population density. This estimation is equivalent to the local average treatment effect of agglomeration spillovers on wages for the areas with gold roads. Finally, using the estimated agglomeration coefficient, we offer a first approach in empirically distinguishing between persistence and path dependence, shedding light on the extent to which the effects of historical pathways have persisted over time or whether they have influenced long-term population density equilibrium selection.

5.1 Historical factor densities

The relationship we observe between gold and mule roads and population density over time could potentially be driven by early investments in durable capital in regions with historical pathways. The investments that may have not yet depreciated could be a key factor underlying the association between historical pathways and population density. Examples of such sunk capital may include the development of railroads, schools, factories, and other infrastructure.

To investigate the hypothesis of investments in sunk capital, we modify the regression model Equation (1) by replacing the dependent variable y_i with the density of historical factors in 1920. In this analysis, we control for geography variables, including a second-order latitude and longitude polynomial, and exclude municipalities that existed already in 1700. The unit of observation in this analysis is municipalities in 1920. When comparing different time periods, we use MCAs for consistent boundaries across periods.

The historical factors we consider as proxies for investments in sunk capital include the following variables: railroad stations, railroad length, literate men (both in terms of number and share), teachers per capita, the ratio of manufacturing workers to agricultural workers, the share of non-agricultural workers, the share of transportation sector workers, and a measure of employment diversity based on the inverse of the Herfindahl-Hirschman index (HHI). The employment diversity measure provides an indication of the level of sectoral concentration, with higher values indicating greater employment diversity.

The estimated effects of gold roads on historical factors are shown in Table 5. We employ 2SLS estimation, using least-cost paths as an instrument. For the analysis at the municipality level in 1920, the Kleibergen-Paap F statistic exceeds 200, and for the analysis at the MCAs level, the Kleibergen-Paap F statistic exceeds 74, alleviating concerns about weak instrument problems.

Panel A of Table 5 presents the marginal effects of gold roads on various historical factors in 1920. In Column (1), we use population density in 1920 as the dependent variable in the benchmark regression. The estimated coefficient for gold roads is positive but statistically insignificant, consistent with the findings in Figure 4 discussed below. The coefficients in all other columns are close to zero and statistically insignificant. In Panel B, we repeat the regression with the inclusion of population density in 1920 as a control variable. The coefficients for gold roads remain unchanged, while in some columns, there is a positive relationship with population density.

In Panel C, we examine the relationship between gold roads and current population density while controlling for the historical factor density in each column. The objective of this analysis is to assess the impact of controlling for historical factors on the gold road coefficient. We observe that the gold road coefficient is highly stable and virtually unaffected by the inclusion of any of the historical factors.

Overall, our analysis does not provide support for the sunk investment hypothesis in 1920. Contrary to the hypothesis, regions influenced by the gold roads did not exhibit any advantage during this time period. This finding is consistent with the results presented in Table C.2 in Appendix C, which show similar results when conducting the analysis using mule roads.

Table 5: Gold roads and factor densities in 1920

	(1) Pop. Den.	(2) Stations	(3) Rail	(4) Lit. Men	(5) Lit. Men (%)	(6) Teachers PC	(7) Manu /Agr	(8) Manu. (%)	(9) Transp. (%)	(10) HHI
Panel A – Unconditional Effect:										
Gold Roads	0.016	-0.005	-0.007	0.005	-0.009	-0.020	-0.023	-0.002	-0.004	-0.038
	(0.023)	(0.005)	(0.061)	(0.021)	(0.010)	(0.021)	(0.024)	(0.002)	(0.031)	(0.039)
Panel B – Conditional on Population Density:										
Gold Roads		-0.005	-0.007	-0.007	-0.009	-0.023	-0.027	-0.002	-0.010	-0.044
		(0.005)	(0.061)	(0.012)	(0.010)	(0.021)	(0.025)	(0.002)	(0.031)	(0.039)
Log(Pop. Dens. 1920)		0.009	0.009	0.825***	0.010	0.206***	0.245***	0.013***	0.301***	0.407***
		(0.008)	(0.115)	(0.069)	(0.022)	(0.039)	(0.055)	(0.004)	(0.066)	(0.131)
Observations	903	903	903	903	903	903	903	903	896	903
Cluster Groups	358	358	358	358	358	358	358	358	356	358
Panel C – 2010 Population Density Conditional on Factor Density:										
Gold Roads	0.225***	0.195***	0.226***	0.208***	0.209***	0.198***	0.192***	0.195***	0.211***	0.195***
	(0.053)	(0.059)	(0.059)	(0.052)	(0.062)	(0.061)	(0.062)	(0.061)	(0.061)	(0.062)
Factor Density	0.782***	1.81***	0.148***	0.703***	0.396***	0.259***	0.249***	2.77***	0.190***	0.188***
	(0.073)	(0.357)	(0.026)	(0.059)	(0.147)	(0.083)	(0.061)	(0.859)	(0.035)	(0.051)
Observations	625	625	625	625	625	625	625	625	619	625

Notes: 2SLS estimates using least-cost paths as an instrument. Clustered standard errors at the MCA level in parentheses in Panels A and B. Robust standard errors in Panel C. Gold Roads refers to the inverse hyperbolic sine transformation of gold road density. All columns control for state fixed effects, geography variables presented in Table A.1, a latitude-longitude second-order polynomial, and exclude municipalities that already existed in 1700. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

5.2 Present-day factor densities

We now examine present-day factor densities as an additional approach to investigate if sunk investments are driving the observed results. If historical factors did not contribute significantly to the effects of historical pathways, as we observed in the previous section, it is still possible that other contemporary forces are influencing the relationship. These could include factors such as modern infrastructure developments, amenities and disamenities, or government investments.

In Table 6, we present the results of the 2SLS estimation of Equation (1) with present-day factor densities as the dependent variable in each column. In Panel A, we observe positive and statistically significant effects of gold roads on all factors without any additional controls. However, in Panel B, when we control for population density, we find that the gold road coefficient remains significant only for the transportation factors. This suggests that the presence of gold roads played a significant role in shaping the location of modern transportation infrastructure. Next, we delve deeper in this question.

Table 6: Gold road density and current factor densities

	(1) Stations	(2) Rail	(3) Road	(4) Crime	(5) Gov. Spen.	(6) Gov. Empl.
Panel A – Unconditional Effect:						
Gold Roads	0.062***	0.386***	0.436***	0.506***	0.134***	0.178***
	(0.018)	(0.114)	(0.111)	(0.131)	(0.034)	(0.060)
Panel B – Conditional on Population Density:						
Gold Roads	0.049***	0.281**	0.341***	0.114	0.015	-0.015
	(0.016)	(0.120)	(0.120)	(0.089)	(0.014)	(0.027)
Log(Pop. Dens. 2010)	0.058***	0.457***	0.412***	1.64***	0.498***	0.807***
	(0.012)	(0.071)	(0.073)	(0.045)	(0.007)	(0.016)
Observations	2,096	2,096	2,096	2,065	2,065	2,065
Cluster Groups	262	262	262	262	262	262

Notes: 2SLS estimates using least-cost paths as an instrumental variable. Clustered standard errors at the MCA level in parentheses. All columns control for state fixed effects, geography variables presented in Table A.1, a latitude-longitude second-order polynomial, and exclude municipalities that already existed in 1700. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

5.3 Timing of the effects

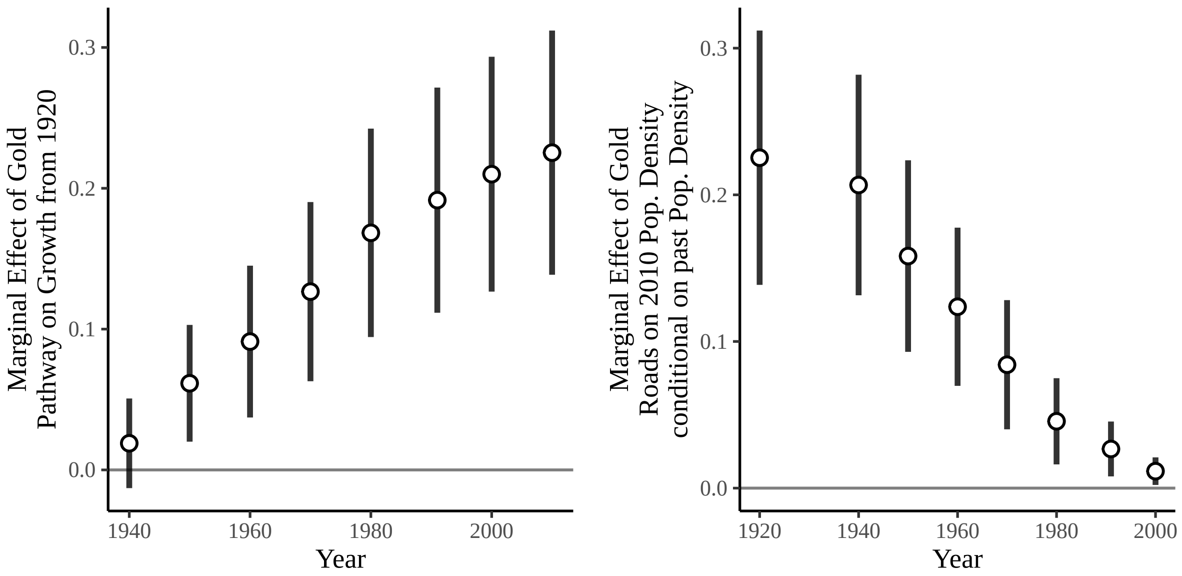
We now use MCAs to study the effects of the historical pathways on population density growth of regions over time. We estimate Equation (2) bellow using population density data from the every census year between 1920 and 2010:

$$y_{i,t} = \alpha_s + \beta \text{Roads}_i + y_{i,1920} + \mathbf{X}_i' \boldsymbol{\gamma} + \epsilon_i, \tag{2}$$

where $y_{i,t}$ denotes the population density of geographical location i and year t always controlling for the population density of location i in 1920 and geographical features in $\mathbf{X}_i'$ as in Equation (1).

The results are displayed in Figure 4a. We show that the advantages promoted by historical pathways between 1920 and 1940 are around zero. The point estimates, however, become increasingly larger and statistically significant from 1950 until the 1990s. From the 1990s to 2010, the increase in the point estimate diminishes but is still increasing with each census. If there were migration frictions, the municipalities with the historical pathways would have already higher population density initially, and higher density later could indicate that these people could not move out. We find the opposite result, indicating that migration friction is not a mechanism in our results.

In Figure 4b, we examine the relationship between population density and the coefficients of gold roads by modifying Equation (2), with population density in 2010 fixed on the left-hand side and varying the population density on the right-hand side. The figure displays the coefficients of gold roads as the lagged density varies on the horizontal axis. These findings indicate that the influence of population density capturing the effect of the gold roads coefficient only becomes evident in the 1950s and becomes progressively stronger with each decade. Moreover, when conditioning on population density in 2000, the explanatory power of gold roads in explaining population density in 2010 is substantially diminished.



(a) Gold roads and growth

(b) Gold roads and lagged density

Figure 4: Timing

Notes: Sample contains 622 comparable areas. Points represent marginal effects and solid lines are 90% heteroscedasticity-robust confidence intervals.

In conjunction with the findings in Section 5.2, we interpret these two sets of results as evidence that modern transportation infrastructure is not the primary driving force behind our main results. First, the growth effects observed in regions with gold roads begin as early as the 1950s, while the development of highways and paved roads in Brazil is a much more recent phenomenon. Additionally, the peak era of railway development in Brazil occurred until the 1930s, and the total length of railways has actually decreased since the 1950s, only recently resuming.[13] So the timing of transportation infrastructure development does not coincide with the timing of the gold roads effect on population density. Second, the period from 1950 to 1980, during which the influence of lagged density on the gold roads coefficient intensifies, coincides with significant population growth and rural-to-urban migration in Brazil. This suggests that the gold roads served

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[13] See Summerhill (2005) for more details about railroad development and Morten and Oliveira (2023) about paved roads.

as a coordinating mechanism for the agglomeration of families and workers, becoming the primary mechanism driving our results.

5.4 Agglomeration spillovers, persistence, and path dependence

In this section, we utilize the optimal paths derived from the historical pathways as instruments for population density in a regression on hourly wages to further explore the mechanism of agglomeration spillovers. Consistent with previous literature (e.g., Bleakley and Lin (2012)), we employ individual-level census data from IPUMS for 2010 and focus on male workers aged between 25 and 65 years old. Hourly wages are set as the dependent variable, and we incorporate individual-level controls and the standard geographical controls.

Table 7 presents the estimated agglomeration coefficients, ranging from 0.053 to 0.15, depending on whether geographical controls are included and whether the analysis focuses on the gold roads or the mule roads. These estimates are consistent with the typical range found in the literature, which falls between 0.03 and 0.08 (Rosenthal and Strange, 2004; Combes and Gobillon, 2015). With these coefficients at hand, we can employ an economic geography model based on Allen and Donaldson (2022) framework to gain further insights into whether the economic shift induced by the historical pathways exhibits characteristics of persistence or path dependence.

In this model, different combinations of parameter values lead to various equilibrium outcomes: (1) the "black hole" equilibrium, characterized by equilibrium multiplicity and no predictive power over the economy; (2) an unstable unique equilibrium; (3) a unique equilibrium with uniform convergence; (4) multiple steady states where shocks can generate path dependence, with or without historical persistence. The interplay between contemporaneous and historical agglomeration spillovers, along with the dispersion forces parameter, determines the region in the parameter space where the economy resides.

Table 7: Population density and hourly wages

	Gold Roads		Mule Roads	
Panel A – OLS				
Population Density 2010	0.070***	0.098***	0.066***	0.095***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	3,174,893	3,174,893	3,066,685	3,066,685
Cluster Groups	990	990	1,245	1,245
Panel B – 2SLS				
Population Density 2010	0.053***	0.065**	0.079***	0.150***
	(0.011)	(0.032)	(0.007)	(0.035)
Observations	3,174,893	3,174,893	3,066,685	3,066,685
Cluster Groups	990	990	1,245	1,245
Kleibergen-Paap F	51.05	12.28	158.66	15.48
Individual Controls	Yes	Yes	Yes	Yes
Geography and Poly.	No	Yes	Yes	Yes

Notes: Clustered standard errors at the municipality level in parentheses. Hourly wage is the inverse hyperbolic sine transformation of wage per hour. 2SLS instruments population density using the inverse hyperbolic sine transformation of either gold road or mule road density. Geography variables are the ones present in Table A.1 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1700 (Gold Roads) or in 1872 (Mule Roads). Individual controls include age, squared age, and indicators of race, sex, education attainment, marital status, and employment status. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

The quantitative analysis relies on a spatial equilibrium model inspired by the tradition of Rosen-Roback-Glaeser. Specifically,

$$\ln w_{it} = \alpha_1 \ln L_{it} + \alpha_2 \ln L_{i,t-1} + \ln \bar{A}, \tag{3}$$

$$\ln w_{it} = \left(\frac{1}{\theta} - \beta_1\right) \ln L_{it} + (-\beta_2) \ln L_{i,t-1} + \frac{1}{\theta} \ln IMMA_{it} - \ln \bar{u}_{it}, \tag{4}$$

where in both equations, w_{it} represents the wage for workers, L_{it} represents the population in municipality i at time t, and $L_{i,t-1}$ represents the lagged population. In Equation (3), the term $\bar{A}it$ represents the unobserved productivity factor. In Equation (4), the terms $\bar{u}it$ and $IMMA_{it}$ represent the unobserved amenities and the migration market access variable, respectively.

The parameters $\alpha_1 + \beta_1$ represent the contemporaneous agglomeration spillovers, $\alpha_2 + \beta_2$ represent the historical agglomeration spillovers, and θ represents the dispersion effect. The estimated values in Table 7 provide a range for the productivity spillovers $\alpha_1 + \alpha_2$, which varies from 0.05 to 0.15. The remaining parameters are borrowed from the literature. The contemporaneous amenities spillovers from housing, β_1, account for one-third of household expenditure, thus it is set to -0.33. The historical amenities spillovers that also arise from this housing stock, β_2, are assumed to be approximately durable over the lagged period in the model, resulting in a value of 0.33. The dispersion effect, or migration to wage elasticity, is estimated to be $\theta = 4.5$, based on the study by Morten and Oliveira (2023), which examines the effects of road development on migration and trade in Brazil.

Allen and Donaldson (2022) suggest that if the absolute value of $[1 - \theta(\alpha_1 + \beta_1 + \alpha_2 + \beta_2]^{-1}$ is above one, it indicates the existence of multiple steady states in the economy across different geographical regions. When applying our estimated values, this indicator ranges from 1.29 to 3.07, comfortably exceeding the threshold of 1. Therefore, we can conclude that the economy has multiple steady states. Furthermore, if we assume that both productivity spillovers are non-negative or that the contemporaneous spillover α_1 is bounded by 0.55 and the dispersion effect θ is always greater than 2.63, then the economy falls into the parameter space region of path dependence with partial convergence, indicating the absence of historical persistence.

This result further supports our findings that the initial impact of the gold and mule roads on the economy did not generate immediate and persistent effects. During the 20th century, however, these roads played a crucial role in facilitating coordination among workers and families, leading to the selection of a higher-density equilibrium. This finding indicates the presence of path dependence, where the historical pathways shaped the long-term distribution of population density.

6 Conclusion

In this paper, we investigate the long-run effects of historical pathways in the distribution of economic activity in Brazil. We show through two experiments compelling evidence that Brazilian municipalities in 2010 are affected by historical dependence from the permanent shock of historical pathways. The first experiment gives us the exact historical roads created after the discovery of the gold mines, initiating the Gold Rush era in Brazil. The municipalities along the roads are arguably exogenous for our purposes, as the gold discovery was fortuitous, and the geography of the hinterlands was not well known to the settlers. The second experiment allows us to generalize our earlier findings, whereby we reconstruct the historical transport network during the late 1800s.

Our results further suggest that historical roads served as coordination devices, guiding population agglomeration spillovers and the selection of the long-run population density equilibrium.

Overall, this study contributes to understanding the long-term consequences of historical pathways to the distribution of economic activity across space and time by combining different empirical strategies and databases, including a novel database from historical records retracing the development of the nationwide transportation network. The findings have important implications for policymakers and urban planners, highlighting the significance of historical infrastructure in shaping regional economic development. As highlighted by Lin and Rauch (2022), by recognizing the existence of path dependence, policymakers can design temporary policies that can cause permanent effects and influence the geographic distribution of economic activity.

A Data details

A.1 Variables and procedures

Units of observations The analysis was conducted at two primary levels: municipalities and grid cells. Municipalities are defined as administrative boundaries established by each state legislature. We utilized municipal boundaries from the years 2010 and 1920. To ensure consistency when comparing different years, we employed Minimum Comparable Areas (MCAs) as defined by Reis et al. (2011). The shapes and seat locations of each municipality in 1920 and 2010 were obtained from Pereira et al. (2019), and the MCAs are aggregations of these shapes. For grid-cell data, we collected information at the 1x1 kilometer level and aggregated it to the 5x5 kilometer level by extracting the median value for each variable of interest.

Historical Roads The gold roads were georeferenced using a map compiled by Simonsen (1977). The *caminho velho*[1] was georeferenced using a map compiled by Costa (2005). In both cases, we utilized ArcMap to accurately represent the roads using linestrings.

The network data used in this study is derived from historical statistical reports produced in 1863 and 1973. These reports contain information about the municipalities that were connected by the transport network, as well as the actual distances covered between these locations. The provincial governments were responsible for preparing and reporting the data on effective distances, following instructions from the Empire's Business Secretariat. Examples of these historical reports are presented in Figure A.1, which displays a sample of the matrices available in the statistical reports for the province of *Espírito Santo* and the post office report for the province of *Minas Gerais*, respectively.

After digitizing the reports, several steps and verification processes were undertaken before the data could be utilized. Firstly, it was crucial to identify the municipalities by

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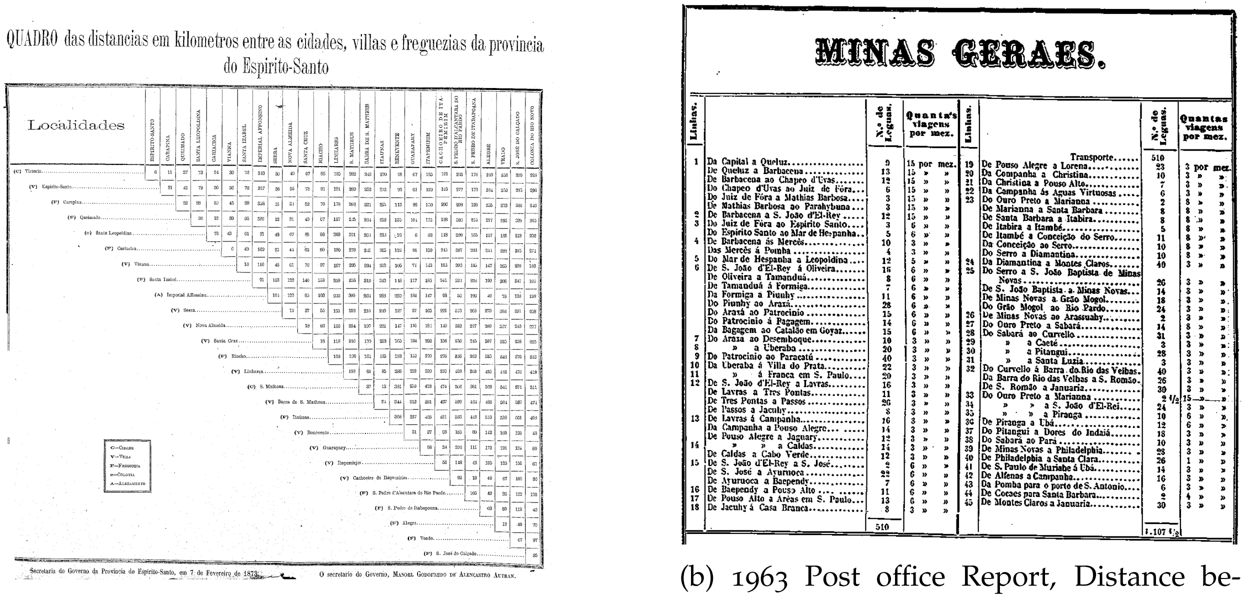
[1] See Appendix D below.



QUADRO das distancias em kilometros entre as cidades, villas e freguezias da provincia do Espirito-Santo

C—Cidade
V—Villa
F—Freguezia
c—Colonia
A—Aldeamento

Secretaria do Governo da Provincia do Espirito-Santo, em 7 de Fevereiro de 1873.

O secretario do Governo, Manoel Godofredo de Alencastro Autran.

(a) 1973 Statistical Report, Distance between the locations of the province of *Espŕito Santo*

MINAS GERAES.

Linhas.		N.º de Leguas.	Quanta's viagens por mez.
1	Da Capital a Queluz	9	15 por mez.
	De Queluz a Barbacena	13	15 » »
	De Barbacena ao Chapeo d'Uvas	12	15 » »
	Do Chapeo d'Uvas ao Juiz de Fóra	6	15 » »
	Do Juiz de Fóra a Mathias Barbosa	3	15 » »
	De Mathias Barbosa ao Parahybuna	3	15 » »
2	De Barbacena a S. João d'El-Rey	12	15 » »
3	Do Juiz de Fóra ao Espirito Santo	3	6 » »
	Do Espirito Santo ao Mar de Hespanha	5	6 » »
4	De Barbacena ás Mercês	10	3 » »
	Das Mercês á Pomba	4	3 » »
5	Do Mar de Hespanha a Leopoldina	12	5 » »
6	De S. João d'El-Rey á Oliveira	16	6 » »
	De Oliveira a Tamanduá	8	6 » »
	De Tamanduá á Formiga	7	6 » »
	Da Formiga a Piuhy	11	6 » »
	Do Piuhy ao Araxá	28	6 » »
	Do Araxá ao Patrocinio	15	6 » »
	Do Patrocinio á Bagagem	14	6 » »
	Da Bagagem ao Catalão em Goyaz	15	6 » »
7	Do Araxá ao Desemboque	10	3 » »
8	» a Uberaba	20	3 » »
9	Do Patrocinio ao Paracatú	40	3 » »
10	Da Uberaba á Villa do Prata	22	3 » »
11	» á Franca em S. Paulo	20	3 » »
12	De S. João d'El-Rey a Lavras	16	3 » »
	De Lavras a Tres Pontas	11	3 » »
	De Tres Pontas a Passos	26	3 » »
	De Passos a Jacuhy	8	3 » »
13	De Lavras á Campanha	16	3 » »
	Da Campanha a Pouso Alegre	14	3 » »
	De Pouso Alegre a Jaguary	12	3 » »
14	» » a Caldas	14	3 » »
	De Caldas a Cabo Verde	12	3 » »
15	De S. João d'El-Rey a S. José	2	6 » »
	De S. José a Ayuruoca	22	6 » »
	De Ayuruoca a Baependy	7	6 » »
16	De Baependy a Pouso Alto	11	6 » »
17	De Pouso Alto a Arêas em S. Paulo	13	6 » »
18	De Jacuhy á Casa Branca	8	3 » »
		510	

Linhas.		N.º de Leguas.	Quantas viagens por mez.
	Transporte	510	
19	De Pouso Alegre a Lorena	23	3 por mez.
20	Da Campanha a Christina	10	3 » »
21	Da Christina a Pouso Alto	7	3 » »
22	Da Campanha ás Aguas Virtuosas	6	3 » »
23	Do Ouro Preto a Marianna	2	8 » »
	De Marianna a Santa Barbara	8	8 » »
	De Santa Barbara a Itabira	8	8 » »
	De Itabira a Itambé	5	8 » »
	De Itambé a Conceição do Serro	11	8 » »
	Da Conceição ao Serro	10	8 » »
	Do Serro a Diamantina	10	8 » »
24	Da Diamantina a Montes Claros	40	3 » »
25	Do Serro a S. João Baptista de Minas Novas	26	3 » »
	De S. João Baptista a Minas Novas	14	3 » »
	De Minas Novas a Grão Mogol	18	3 » »
	Do Grão Mogol ao Rio Pardo	24	3 » »
26	De Minas Novas ao Arassuahy	2	3 » »
27	Do Ouro Preto a Sabará	14	8 » »
28	Do Sabará ao Curvello	31	3 » »
29	» a Caeté	3	3 » »
30	» a Pitangui	28	3 » »
31	» a Santa Luzia	3	3 » »
32	Do Curvello á Barra do Rio das Velhas	40	3 » »
	Da Barra do Rio das Velhas a S. Romão	26	3 » »
	De S. Romão a Januaria	30	3 » »
33	Do Ouro Preto a Marianna	2 1/2	15 » »
34	» » a S. João d'El-Rei	24	3 » »
35	» » a Piranga	10	6 » »
36	De Piranga a Ubá	12	6 » »
37	Do Pitangui a Dores do Indaiá	18	3 » »
38	Do Sabará ao Pará	10	3 » »
39	De Minas Novas a Philadelphia	28	3 » »
40	De Philadelphia a Santa Clara	26	1 » »
41	De S. Paulo de Muriahe á Ubá	14	3 » »
42	De Alfenas a Campanha	16	3 » »
43	Da Pomba para o porto de S. Antonio	6	3 » »
44	De Cocaes para Santa Barbara	2	4 » »
45	De Montes Claros a Januaria	30	3 » »
		1.107 1/2	

(b) 1963 Post office Report, Distance between the locations of the province of *Minas Gerais*

Figure A.1: Historical Documents

their old names and georeference them to determine the geographic coordinates of their headquarters. Subsequently, we converted the distances initially measured in leagues to kilometers for consistency. Finally, we constructed the distance matrices between the municipal seats based on the 1872 administrative division, utilizing both the historical pathways and the postal routes. To fill in any missing information, we digitized additional historical official records from provincial governments, which allowed us to capture distances between locations in different provinces. This complementary data enabled us to establish interconnections between paths, resulting in an origin and destination matrix that covered a significant portion of the national territory.

Using the available information regarding the locations included in the historical transport network during the mid-19th century, we proceeded to establish the least-cost paths between each pair of municipal seats in 1872. To accomplish this, we adopted an approach employed in several studies investigating the causal impact of transportation systems on economic development. Specifically, we utilized the reciprocal of the terrain ruggedness index (TRI) as a transition matrix to construct the least-cost paths using

Dijkstra's method. These paths allowed for connections through all eight adjacent cells. It is important to note that the TRI does not directly consider elevation; rather, it captures the variation in elevation between neighboring areas. Consequently, areas with higher variation in elevation are indicative of more challenging terrains for transportation.

Economic activity Our primary indicators of economic activity consist of population density and nightlight incidence. At the municipality level, population density is derived by dividing the population data obtained from the all Brazilian census from 1920 to 2010 by the corresponding area. Nightlight incidence is determined by calculating the median intensity of nighttime lights in cloudless skies using satellite data provided by the Earth Observation Group. For grid-level population data, we utilized rasters generated by the Center for International Earth Science Information Network, which incorporated 2010 census tract data. This approach was preferred over using census tracts directly, as the size and shape of census tracts are influenced by population density. Additionally, we employed nighttime lights in cloudless skies as an supplementary metric to gauge levels of development.

Geography Geographical variables, including temperature, precipitation, and elevation, were acquired through satellite data sourced from the National Institute for Space Research. These variables represent the median values within each municipality or grid cell. Furthermore, we calculated the distances to the coast and rivers based on data from the same sources. All distances were measured in kilometers.

Modern Transportation Information about the location of railway, train stations, and roadways are from shapefiles provided by the Brazilian Ministry of Transportation.

Modern and Historical Factors Information regarding education and sectoral composition in 1920 is from the Brazilian census in 1920. In 2010, crime is measured as the homicide rate collected from the Brazilian Institute of Applied Economics. Public expenditure was collected from the Brazilian Department of Treasury, whereas public employment is from the a database produced by the United Nations Development Programme using census data. Individual-level wage data is from the Brazilian census of 2010 prepared by IPUMS.

Spatial Operations Most spatial operations were computed using R's simple features package (Pebesma, 2018). Areas where constructed using South America Albers Equal Area Conic projection, whereas distances where computed using South America Albers Equidistant Conic projection. Least-coast paths were constructed using geopandas.

A.2 Summary statistics

Below we present descriptive statistics for the main variables at both municipality and grid-cell level. Table A.1 refers to the gold road sample, whereas Table A.2 refers to the network sample.

Table A.1: Descriptive statistics – Gold Roads

Variables	Count	Mean	Std. Dev.	Min	Max
Panel A - Municipality:					
Pop. Density	2096	163.52	809.42	0.23	12998.98
IHS(Pop. Density)	2096	3.99	1.53	0.23	10.17
IHS(Nightlights)	2096	2.67	1.14	0.92	5.3
Gold Road Density	2096	0.14	0.22	0	1
IHS(Gold Road Density)	2096	1.67	1.96	0	5.3
Ruggedness	2096	45.14	30.49	2.19	187.45
Elevation	2096	547.14	306.16	1.86	1640.35
Precipitation	2096	1342.6	358.98	429.3	2789.36
Temperature	2096	21.73	3	13.75	27.64
Area	2096	1210.86	3104.94	3.57	84215.61
Dist. to River	2096	85809.43	63859.21	0	328388.78
Dist. to Coast	2096	354912.9	330374.6	0	1719448.9
Panel B - Grid Cell:					
Pop. Density	48914	71.66	513.33	0	18120.54
IHS(Pop. Density)	48914	5.27	2	0	13.72
IHS(Nightlights)	48914	2.36	1.19	0	5.3
HIS(Dist. to Gold Road)	48914	9.93	1.03	0.51	11
Ruggedness	48826	42.33	34.69	0	297.23
Elevation	48827	557.24	313.33	0.04	2377.03
Precipitation	48900	1328.72	378.63	382.2	3423.59
Temperature	48900	22.23	3.14	10.64	28.06
Dist. to River	48914	99487.68	73733.13	0	364918.84
Dist. to Coast	48914	495423.1	415906.7	0	1689078.3

Table A.2: Descriptive statistics – Mule Roads

Variables	Count	Mean	Std. Dev.	Min	Max
Panel A - Municipality:					
Pop. Density	3301	124.48	651.27	0.23	12998.98
IHS(Pop. Density)	3301	4	1.38	0.23	10.17
IHS(Nightlights)	3301	2.61	1.12	0.89	5.3
Mule Road Density	3347	0.23	0.29	0	1
IHS(Mule Road Density)	3347	2.37	2.11	0	5.3
Ruggedness	3301	43.71	31.71	0.02	184.33
Elevation	3301	464.44	309	1.86	1640.35
Precipitation	3301	1284.44	419.17	367.2	2976.68
Temperature	3301	22.65	2.95	13.75	27.8
Area	3347	1206.31	5131.39	3.57	159536.71
Dist. to River	3347	95271.75	72175.27	0	473148.58
Dist. to Coast	3347	302419.8	307348.3	0	1915375.7
Panel B - Grid Cell:					
Pop. Density	70641	49.22	363.28	0	18120.54
IHS(Pop. Density)	70641	5.42	1.87	0	13.72
IHS(Nightlights)	70641	2.22	1.19	0	5.3
IHS(Dist. to Mule Road)	70641	9.76	1.12	0.93	11
Ruggedness	70465	38.58	33.57	0	305.58
Elevation	70443	475.12	316.57	0.08	2154.14
Precipitation	70521	1292.7	443.59	354.5	3659.8
Temperature	70521	22.97	3.01	11.38	27.92
Dist. to River	70641	95816.05	73167.55	0	348558.44
Dist. to Coast	70641	393285.7	342243	0	1617071.7

B Robustness

The main results presented in Tables 1 and 3 are robust to alternative transformations of the dependent variables and alternative speficications. Specifically, as depicted in Tables B.1 and B.3, the results are unchanged when we apply a log(1+) transformation in either the development variables or access variables. The results also stand when we use dummies indicating proximity to the roads as variables of interest. Tables B.2 and B.4 show the results when we alter several specification choices. At the municipality level, we show that the results are not sensitive to either using MCA fixed effect or Conley standard errors. At the grid level, the results are robust to changing the control group to grid cells within 40km and 50km, and Conley standard errors (Conley, 1999).

Table B.1: Gold roads and population density – Alternative Transformations

	(1)	(2)	(3)	(4)
Dependent Var. Transform	Log(1 +)		IHS	
Dependent Variable	Pop. Density	Nightlight Den.	Pop. Density	Nightlight Den.
Panel A - Municipalities				
Gold Roads	0.267***	0.207***	0.833***	0.728***
	(0.071)	(0.052)	(0.235)	(0.181)
Observations	2,096	2,096	2,096	2,096
Cluster Groups	262	262	262	262
Access Transform:	Log(1 +)	Log(1 +)	Has Path	Has Path
Fixed-Effects:	State	State	State	State
Panel B - Grid Cells				
Gold Roads	-0.172	-0.219**	0.035	0.218
	(0.163)	(0.093)	(0.326)	(0.197)
Observations	43,620	43,647	43,620	43,647
Cluster Groups	1,738	1,738	1,738	1,738
Road Transformation	Log(1 +)	Log(1 +)	Within 10km	Within 10km
Fixed-Effects:	Muni	Muni	Muni	Muni

Notes: Standard errors in parentheses. They are clustered at the MCA level when the unit of observation is municipalities and at the municipality level when the unit of observation is the grid cell. Gold Roads refers to either the indicated transformation of either gold road density (municipalities) or the distance to the nearest gold road (grid cells). All columns include geography controls presented in Table A.1, a latitude-longitude second-order polynomial, and remove municipalities that already existed in 1700. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

Table B.2: Gold roads and population density – Alternative specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Municipality				Grid-Cell					
Dependent Variable	Pop. Density		Nightlight Den.		Pop. Density			Nightlight Den.		
Panel A: IHS Transform of Density and Distance										
Gold Roads	0.192***	0.230***	0.154***	0.188***	-0.116	-0.079	-0.156	-0.190**	-0.165**	-0.228**
	(0.069)	(0.060)	(0.041)	(0.050)	(0.151)	(0.155)	(0.181)	(0.086)	(0.077)	(0.107)
Observations	2,096	2,096	2,096	2,096	55,470	66,162	43,620	55,514	66,223	43,647
Cluster Groups	262	2,062	262	2,062	2,017	2,260	41,870	2,017	2,260	41,897
Panel B: Log(1 +) Transform of Density and Distance										
Gold Roads	0.219***	0.267***	0.164***	0.207***	-0.130	-0.094	-0.172	-0.181**	-0.156**	-0.219**
	(0.079)	(0.070)	(0.044)	(0.056)	(0.142)	(0.144)	(0.174)	(0.075)	(0.067)	(0.095)
Observations	2,096	2,096	2,096	2,096	55,470	66,162	43,620	55,514	66,223	43,647
Cluster Groups	262	2,062	262	2,062	2,017	2,260	41,870	2,017	2,260	41,897
Panel C: Dummy if has Positive Density (Muni.) and if within 5km radius (grid cells)										
Gold Roads	0.724**	0.833***	0.612***	0.728***	0.084	0.010	0.035	0.239	0.244	0.218
	(0.282)	(0.231)	(0.168)	(0.192)	(0.351)	(0.415)	(0.369)	(0.198)	(0.207)	(0.210)
Observations	2,096	2,096	2,096	2,096	55,470	66,162	43,620	55,514	66,223	43,647
Cluster Groups	262	2,062	262	2,062	2,017	2,260	41,870	2,017	2,260	41,897
Control Group	Neighb.	Neighb.	Neighb.	Neighb.	< 40km	< 50km	< 30km	< 40km	< 50km	< 30km
Fixed-Effects:	MCA	State	MCA	State	Muni.	Muni.	Muni.	Muni.	Muni.	Muni.
SE Clustered by	MCA	Conley 30	MCA	Conley 30	Muni.	Muni.	Conley 30	Muni.	Muni.	Conley 30

Notes: Clustered standard errors presented in parentheses. Gold Roads refers to the indicated transformation of either gold road density (municipalities) or the distance to the nearest gold road (grid cells). All specifications remove municipalities that already existed in 1700 and control for geography variables from Table A.1 and a second-order latitude-longitude polynomial. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

Table B.3: Mule roads and population density – Alternative Transformations

	(1)	(2)	(3)	(4)
Dep. Var. Transform	Log(1 +)		IHS	
Dependent Variable	Pop. Den.	Nightlight	Pop. Den.	Nightlight
Panel A - Municipalities				
Mule Roads	0.058***	0.051***	0.189***	0.154***
	(0.013)	(0.012)	(0.043)	(0.039)
Observations	3,301	3,301	3,301	3,301
Cluster Groups	364	364	364	364
Access Transform:	Log(1 +)	Log(1 +)	Has Path	Has Path
Fixed-Effects:	State	State	State	State
Panel B - Grid Cells				
Mule Roads	-0.055***	-0.043***	0.072***	0.076***
	(0.010)	(0.006)	(0.024)	(0.015)
Observations	70,331	70,344	70,331	70,344
Cluster Groups	3,060	3,060	3,060	3,060
Road Transformation	Log(1 +)	Log(1 +)	Within 10km	Within 10km
Fixed-Effects:	Muni.	Muni.	Muni.	Muni.

Notes: Standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. Mule Roads refers to the indicated transformation of either mule road density (municipalities) or the distance to the nearest mule road (grid cells). All columns include geography controls presented in Table A.2, a latitude-longitude second-order polynomial, and remove municipalities that already existed in 1872. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

Table B.4: Mule roads and population density – Alternative specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Municipality				Grid-Cell					
Dependent Variable	Pop. Density		Nightlight Den.		Pop. Density			Nightlight Den.		
Panel A: IHS Transform of Density and Distance										
Mule Roads	0.047^{***}	0.051^{***}	0.038^{***}	0.045^{***}	-0.055^{***}	-0.055^{***}	-0.049^{***}	-0.056^{***}	-0.049^{***}	-0.048^{***}
	(0.013)	(0.010)	(0.011)	(0.010)	(0.011)	(0.012)	(0.007)	(0.012)	(0.007)	(0.008)
Observations	3,301	3,301	3,301	3,301	83,841	95,482	70,331	83,857	95,510	70,344
Cluster Groups	364	3,266	364	3,266	3,306	3,496	67,259	3,306	3,496	67,272
Panel B: Log(1 +) Transform of Density and Distance										
Mule Roads	0.052^{***}	0.058^{***}	0.042^{***}	0.051^{***}	-0.055^{***}	-0.055^{***}	-0.055^{***}	-0.044^{***}	-0.044^{***}	-0.043^{***}
	(0.014)	(0.011)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)	(0.006)	(0.006)	(0.007)
Observations	3,301	3,301	3,301	3,301	83,841	95,482	70,331	83,857	95,510	70,344
Cluster Groups	364	3,266	364	3,266	3,306	3,496	67,259	3,306	3,496	67,272
Panel C: Dummy if has Positive Density (Muni.) and if within 5km radius (grid cells)										
Mule Roads	0.180^{***}	0.189^{***}	0.120^{***}	0.154^{***}	0.075^{***}	0.074^{***}	0.072^{***}	0.080^{***}	0.083^{***}	0.076^{***}
	(0.049)	(0.038)	(0.039)	(0.036)	(0.025)	(0.027)	(0.027)	(0.015)	(0.015)	(0.016)
Observations	3,301	3,301	3,301	3,301	83,841	95,482	83,857	70,331	95,510	70,344
Cluster Groups	364	3,266	364	3,266	3,306	3,496	3,306	67,259	3,496	67,272
Control Group	Neighb.	Neighb.	Neighb.	Neighb.	< 40km	< 50km	< 30km	< 40km	< 50km	< 30km
Fixed-Effects:	MCA	State	MCA	State	Muni.	Muni.	Muni.	Munic.	Munic.	Munic.
SE Clustered by	MCA	Conley 30	MCA	Conley 30	Muni.	Muni.	Conley 30	Muni.	Muni.	Conley 30

Notes: Standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. Mule Roads refers to the indicated transformation of either mule road density (municipalities) or the distance to the nearest mule road (grid cells). All columns include geography controls presented in Table A.2, a latitude-longitude second-order polynomial, and remove municipalities with that already existed in 1872. $^{*}p < 0.1, ^{**} p < 0.05, ^{***} p < 0.01$

C Discussion results for mule roads

In a similar vein to the main text, we ask whether historical pathways in the network sample have created contemporaneous advantages in present-day factor density. The findings are presented in Table C.1. Panel A shows that multe roads are positively correlated with all variables. However, in Panel B, the effects conditional on population density survive only for modern transportation infrastructure, as as the case with gold roads.

We also reproduce the analysis regarding 1920's factor densities. Table C.2 presents the effect of mule roads in variables that proxy infrastructure investment, investment in human capital, and industrial investment. These variables are the same studied in Table 5 and the results are very similar. It is clear from the estimates that historical pathways did not induce more investment in durable capital in 1920. This result is true even not conditioning on population density in 1920. An intriguing result is that pathway density is associated with smaller population density in 1920, which resembles the results in the previous section with smaller standard errors. Still, in Panel C, we test whether these historical factors are confounding our main results. Again, the estimates point to a direct effect of historical pathways independent of any initial advantage created in the form of sunk investment.

Table C.1: Mule roads and current factor densities

	(1) Stations	(2) Rail	(3) Road	(4) Crime	(5) Gov. Spen.	(6) Gov. Empl.
Panel A – Unconditional Effect:						
Mule Roads	0.008***	0.125***	0.081***	0.068**	0.023***	0.037***
	(0.002)	(0.022)	(0.028)	(0.027)	(0.006)	(0.010)
Panel B – Conditional on Population Density:						
Mule Roads	0.005*	0.101***	0.053**	-0.020	-0.002	-0.002
	(0.002)	(0.021)	(0.027)	(0.022)	(0.002)	(0.005)
Log(Pop. Dens. 2010)	0.074***	0.465***	0.531***	1.73***	0.475***	0.756***
	(0.015)	(0.052)	(0.039)	(0.038)	(0.008)	(0.016)
Observations	3,301	3,301	3,301	3,229	3,229	3,229
Cluster Groups	364	364	364	363	363	363

Notes: Clustered standard errors at the MCA level in parentheses. Mule Roads refers to either the inverse hyperbolic sine transformation of mule road density. All columns control for state fixed effects, geography variables presented in Table A.2, a latitude-longitude second-order polynomial, and exclude municipalities that already existed in 1872. $^{*}p < 0.1, ^{**} p < 0.05, ^{***} p < 0.01$

Table C.2: Mule roads and factor densities in 1920

	(1) Pop. Den.	(2) Stations	(3) Rail	(4) Lit. Men	(5) Lit. Men (%)	(6) Teachers PC	(7) Manu /Agr	(8) Manu. (%)	(9) Transp. (%)	(10) HHI
Panel A – Unconditional Effect:										
Mule Roads	-0.026**	0.005	0.075**	-0.012	0.010	0.014	-0.005	0.0004	-0.021	-0.011
	(0.013)	(0.003)	(0.037)	(0.012)	(0.006)	(0.015)	(0.017)	(0.001)	(0.023)	(0.017)
Panel B – Conditional on Population Density:										
Mule roads		0.005	0.073**	0.007	0.009	0.014	-0.004	0.0004	-0.018	-0.010
		(0.003)	(0.037)	(0.006)	(0.006)	(0.014)	(0.017)	(0.001)	(0.023)	(0.017)
Log(Pop. Dens. 1920)		0.007	-0.076	0.728***	-0.040	0.002	0.053	0.0010	0.105	0.018
		(0.009)	(0.167)	(0.097)	(0.030)	(0.057)	(0.067)	(0.005)	(0.095)	(0.129)
Observations	522	522	522	522	522	522	522	522	518	522
Cluster Groups	194	194	194	194	194	194	194	194	193	194
Panel C – Current Population Density Conditional on Factor Density:										
Mule Roads	0.060***	0.053**	0.054**	0.054**	0.061**	0.064**	0.055**	0.059**	0.053**	0.057**
	(0.023)	(0.026)	(0.025)	(0.022)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Factor Density	0.678***	1.11***	0.118***	0.645***	0.213	0.148**	0.241***	2.27**	0.156***	0.291***
	(0.097)	(0.366)	(0.026)	(0.092)	(0.163)	(0.074)	(0.071)	(0.949)	(0.035)	(0.109)
Observations	422	422	422	422	422	422	422	422	416	422

Notes: Clustered standard errors at the MCA level in parentheses in Panels A and B. Robust standard errors in Panel C. Mule Roads refers to either the inverse hyperbolic sine transformation of mule road density. All columns control for state fixed effects, geography variables presented in Table A.2, a latitude-longitude second-order polynomial, and exclude municipalities that already existed in 1872. $^{*}p < 0.1, ^{**} p < 0.05, ^{***} p < 0.01$

D Special case: Caminho Velho

In this section , we study the effects of one specific and well-identified pathway, *caminho velho* (old pathway), linking the city of *Paraty*, in the southwest of the state of *Rio de Janeiro*, to the newly discovered gold mines in the city of *Ouro Preto* in the state of *Minas Gerais*, in the late 17th century. The advantage of this analysis rest in the fact that this was the first route used to extract gold from the mines in Minas Gerais. Therefore, we can argue that this trail is plausibly exogenous.

In the latter half of the 17th century, as the sugar industry declined, the Portuguese Crown incentivized the discovery of precious metals in Brazil by offering rewards and honors. This paved the way for a systematic search for gold and other minerals. The discovery of gold mines in Minas Gerais, Goiás, and Mato Grosso was a pivotal event in the economic history of the country. The shift in production focus from sugar cane plantations along the Northeast coast to the mining provinces in the countryside led to the creation of various pathways that connected the mines to Rio de Janeiro and Bahia on the coast. In this context, ground transportation became indispensable for collecting taxes on merchandise circulation and controlling the flow of gold (Morais, 2010, p. 22).

The *bandeiras* were small military forces launched in the state of São Paulo with the objective of exploring the country's hinterlands in search of valuable metals. Equipped with basic tools, these expeditions faced harsh conditions since the unsettled hinterlands of the country were largely uncharted. To navigate the unknown terrain, the *bandeiras* relied on existing indigenous paths and river routes and used the sun as their primary point of reference (Santos, 2001).

In the late 17th century, Fernão Dias led a renowned expedition that discovered the first minerals in the province of Minas Gerais. The route taken by the expedition, known as the *caminho velho*, took over seven years to complete and eventually became the primary route used by miners to transport their goods. The pathway connected the gold mines to Paraty, located in the southwest of Rio de Janeiro state. From there, the gold

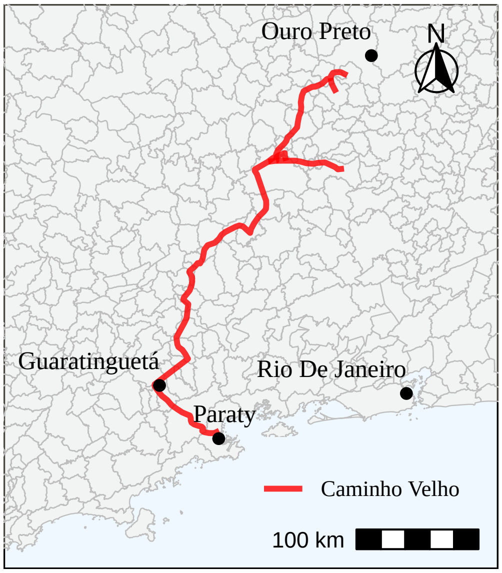


Figure D.1: Caminho Velho

was shipped by sea to Rio de Janeiro. Initially, the *caminho velho* intersected with the São Paulo pathway in Taubaté. However, the junction point later moved to Pindamonhangaba and then Guaratinguetá.

After the news of the discovery reached other regions of Brazil and the European continent, the influx of settlers arrived at Rio de Janeiro and then traveled through *Sepetiba* bay by land and then *Paraty* by sea, until reaching the São Paulo path in Taubaté, defined the last portion of what became known as the *caminho velho* (see map in Figure D.1).[2]

It is worth noting that the *caminho velho* was far from ideal. It was created by explorers who ventured into Brazil's hinterlands in search of gold, and they prioritized favorable geography over minimizing travel time to reach the ports in Rio. Consequently, in the early 18th century, a new route called the *caminho novo* was established.

The historical episode detailed above provides us with a unique setting to estimate the long-run causal effect of historical pathways and local economic development, as the discovery of the mines happened fortuitously (Palma, 2022) and the treated units

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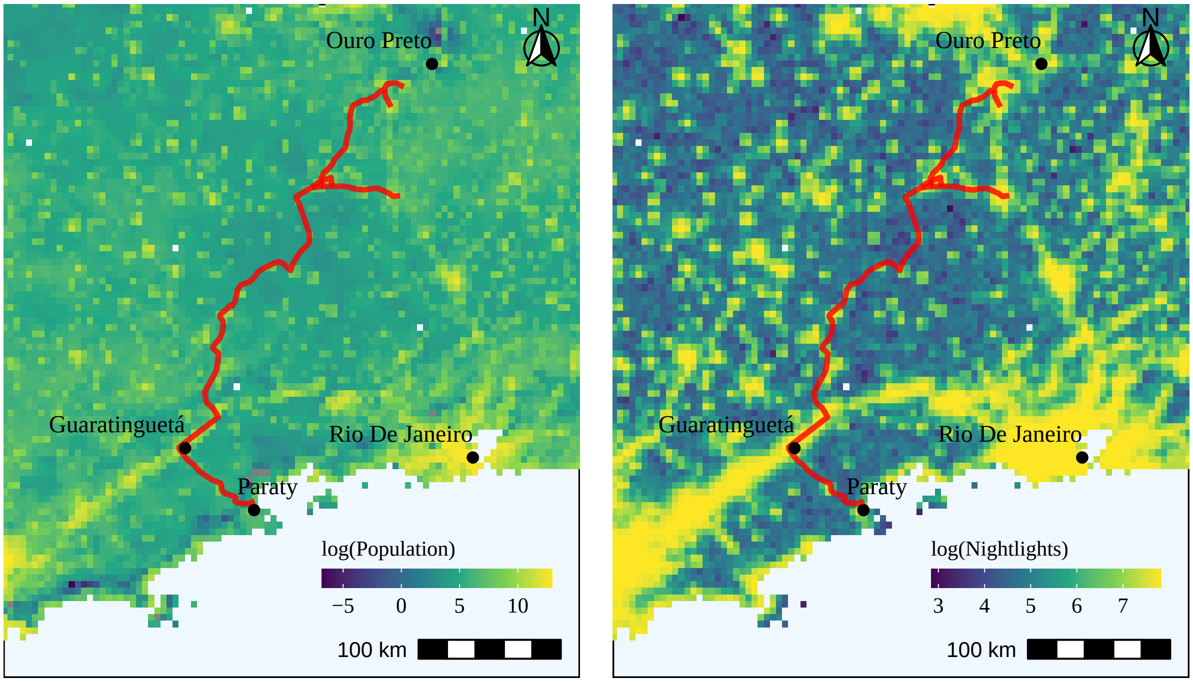
[2] Afterwards, to shorten the path connecting Rio de Janeiro and São Paulo, the junction point between the Rio de Janeiro and São Paulo paths changed to Pindamonhangaba, and then, Guaratinguetá.

along the pathway connecting São Paulo, formerly an underdeveloped village with only 3,000 inhabitants, and the gold region in Minas Gerais are arguably exogenous, given the somewhat arbitrary nature of the paths trailed by the explorers following the initial expedition of Fernão Dias, in 1674 (Santos, 2001).

Data. Historical maps are utilized to estimate distances to the historical pathways, as well as distances to and densities of modern transportation infrastructures. The geographic location of the *caminho velho*, which serves as the primary source of data for this experiment, is obtained from historical maps compiled by Costa (2005), as illustrated in Figure D.1.

To ensure that the argument developed above holds, our main estimation considers only two sections of the *caminho velho*: the one connecting Paraty to Guaratinguetá and the one connecting Guaratinguetá to Ouro Preto. We also exclude Paraty and Guaratinguetá, given that these areas were previously developed, and Ouro Preto as the presence of gold mines may have prompted a specific path of development. None of these choices alter the main results significantly. Figure D.1 depicts the resulting georeferenced pathway together with municipalities in 2010 and four important seats highlighted: Paraty, Guaratinguetá, Ouro Preto and Rio de Janeiro. The *caminho velho* extends over 522.37 kilometers crossing three of the richest states in Brazil: São Paulo, Rio de Janeiro, and Minas Gerais.

The logarithm of the population (Panel a) and nightlights (Panel b) by 25km^2 grids are displayed in Figure D.2 along with the *caminho velho*. The images demonstrate a clear association between the *caminho velho* and higher population and nightlight density. Notably, in the stretch between Guaratinguetá and Ouro Preto, we observe areas with high economic development surrounded by areas with low development. It is worth mentioning the difference in variance between nightlights and population measures. The



(a) Population Density

(b) Nightlight Density

Figure D.2: Population Density and Nightlight Incidence in 25km^2 grid cells

limited range of nightlights, between 0 and 100 per 1km^2 grids, results in less precision when comparing high-density areas.

The analysis is focused on municipalities touched by the pathway and their neighbors. At the grid-cell level, we keep observation within a 30-kilometer radius from the *caminho velho* and excludes municipalities that existed before 1700. Descriptive statistics for the variables mentioned earlier at the municipality and 25km^2 grid level are presented in Table D.1. Within this radius, there are 105 municipalities where population density ranges from 5.4 to 2,200 individuals per square kilometer, and the average density is 17%. At the grid level, there are 1,438 observations, and the values are more diverse with population density ranging from grids with almost no individuals to 2,835 individuals per squared kilometer.

Table D.1: Descriptive Statistics – *Caminho Velho*

Variables	Count	Mean	Std. Dev.	Min	Max
Panel A - Municipality:					
Pop. Density	105	83.38	230.6	5.42	2200.29
IHS(Pop. Density)	105	4.26	1.07	2.39	8.39
IHS(Nightlights)	105	2.82	0.77	1.86	5.29
Caminho Velho Density	105	0.17	0.27	0	1
IHS(Caminho Velho Density)	105	1.65	2.08	0	5.3
Ruggedness	105	79.78	29.93	11.1	176.25
Elevation	105	982.72	213.84	309.7	1640.35
Precipitation	105	1516.07	104.5	1279.4	1856.02
Temperature	105	18.85	1.35	13.75	22.01
Area	105	374.59	292.28	3.57	1464.5
Dist. to River	105	59818.15	35408.55	2208.4	187295.58
Dist. to Coast	105	150159.12	75775.94	0	292321.48
Panel B - Grid Cell:					
Pop. Density	1438	52.73	214.62	0.03	2835.7
IHS(Pop. Density)	1438	6.16	1.49	0.65	11.86
IHS(Nightlights)	1438	2.76	1.05	0	5.3
HIS(Dist. to Caminho Velho)	1438	9.99	0.99	4.66	11
Ruggedness	1438	79.12	37.06	4.77	295.18
Elevation	1438	1028.94	223.69	186.33	2276.49
Precipitation	1438	1535.71	119.98	1317.2	2251.99
Temperature	1438	18.61	1.49	11.84	22.75
Dist. to River	1438	56016.02	33448.14	0	149722.84
Dist. to Coast	1438	151183.77	75316.54	0	291584.56

OLS Estimates The historical event described above offers a distinctive opportunity to gauge the lasting impact of past pathways on local economic development. We establish a linear association between the distance to the *caminho velho* and current development indicators. In particular,

$$y_i = \alpha_s + \beta \text{Distance}_i + \mathbf{X}_i' \boldsymbol{\gamma} + \epsilon_i, \tag{D.1}$$

where y_i denotes the development metric at the geographical location i in 2010, Distance_i represents the distance from i to the *caminho velho*, $\mathbf{X}_i$ is a column vector containing covariates, α_s denotes the fixed effect of the state s, and ϵ_i is the error term.

Our identification assumption is based on the premise that, given the covariates $\mathbf{X}_i$ and state-invariant unobserved factors, the error term is uncorrelated with the distance to the *caminho velho*. This assumption is reasonable, even without conditioning on any specific factors, as the discovery of the mines was a chance occurrence, resulting from the explorers following a somewhat arbitrary path set by Fernão Dias in 1674 (Palma, 2022). Therefore, municipalities were treated based on their location between a port (Paraty) and a random point in space rather than any specific characteristic that could have caused long-term development. Nevertheless, our estimates account for geographical factors to address the possibility that the expedition may have traversed areas with "favorable" geography, such as proximity to rivers. The covariate vector $\mathbf{X}$ includes the logarithm of median elevation, median precipitation, median temperature, distance to the coast, distance to rivers, area, and median terrain ruggedness index (TRI).

The main results are presented in Table D.2. Panel A shows estimates where population density is the variable of interest, while Panel B shows estimates with nightlight incidence as the dependent variable. Column (1) shows a simple OLS with no covariates or fixed effects, while Column (2) adds state-fixed effects. Column (3) includes the geography variables listed in Table D.1 as covariates, and Column (4) adds a second-order polynomial of latitude and longitude. Column (5) shows within-municipality effects

Table D.2: *Caminho Velho* access and current population density

	(1)	(2)	(3)	(4)	(5)
		Municipality			Grid-Cells
Panel A - Dep. Var.: Population Density:					
Caminho Velho Access	0.225***	0.239***	0.208***	0.234***	-0.442***
	(0.044)	(0.042)	(0.031)	(0.036)	(0.111)
Observations	105	105	105	105	1,438
Cluster Groups	27	27	27	27	113
Panel B - Dep. Var.: Nightlights:					
Caminho Velho Access	0.156***	0.161***	0.118***	0.130***	-0.318***
	(0.036)	(0.035)	(0.032)	(0.041)	(0.072)
Observations	105	105	105	105	1,438
Cluster Groups	27	27	27	27	113
Fixed-Effects:	No	State	State	State	Muni.
Controls: Geography	No	No	Yes	Yes	Yes
Lat-Long Polynomial	No	No	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. *Caminho Velho* Access refers to the inverse hyperbolic sine transformation of either *Caminho Velho* density (municipalities) or the distance to *Caminho Velho* (grid cells). Geography variables are the ones present in Table D.1 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1700. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

with 25km² grids as the unit of observation. Municipalities that existed before 1700 are excluded from the sample in all specifications. They are *Paraty*, *Guaratinguetá*, *Taubaté*, and *Ubatuba*. Standard errors are clustered at the level of 1872 minimum comparable areas (MCAs) to account for spatial correlation between units.

The results indicate that an increase in pathway access is ssociated with population density and nightlight incidence. Specifically, a ten-percent increase in *caminho velho* density is associated with a 2.25% increase in population density and a 1.56% increase in nightlights, according to the simple OLS estimate. The coefficients experience only minimal changes with the inclusion of geography variables as covariates. Within mu-

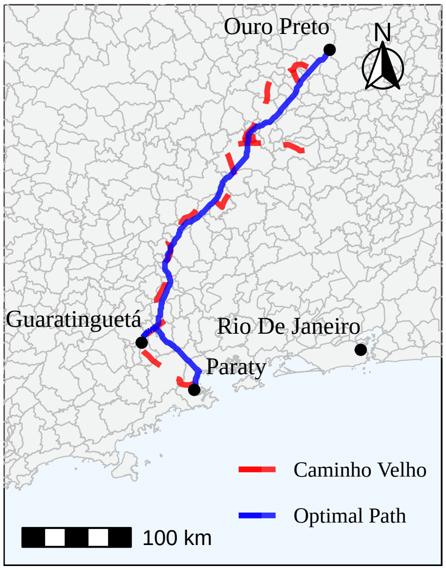


Figure D.3: Least-cost path between *Paraty* and *Guaratinguetá* and then to *Ouro Preto* using TRI as cost of moving

nicipalities, a ten-percent increase in distance is associated with a 4.42% decrease in population density and a 3.18% decrease in nightlight incidence.

2SLS Estimates To account for potential bias stemming from unobservable factors that may be associated with favorable geographic features of certain municipalities, we employ an instrumental variable approach. Specifically, we use the least-cost path between *Paraty* and *Guaratinguetá*, and then to *Ouro Preto*, as an instrument for the actual path taken by the *caminho velho*. The least-cost path is calculated by using the reciprocal of the terrain ruggedness index (TRI) as the transition matrix and employing Dijkstra's method to allow connections through all eight adjacent cells. The resulting path is displayed in Figure D.3.

The findings of the two-stage least squares (2SLS) estimation, which are similar to specifications in columns (2), (4), and (5) of Table D.2, are presented in Table D.3. The first-stage F statistics indicate a somewhat strong relationship between the distance to the least-cost path and the distance to the *caminho velho*, ranging from 8.72 to 41.9. The coefficients of the 2SLS estimates, using municipalities as the unit of observation, are

Table D.3: 2SLS – *Caminho Velho* access and current population density

	(1)	(2)	(3)	(4)	(5)	(6)
	Pop. Density			Nightlights		
	Municipality		Grid	Municipality		Grid
Caminho Velho Access	0.211**	0.212*	-1.46***	0.150**	0.125*	-0.871**
	(0.092)	(0.108)	(0.544)	(0.062)	(0.062)	(0.338)
Observations	105	105	1,438	105	105	1,438
Cluster Groups	27	27	113	27	27	113
Kleibergen-Paap F	41.952	12.201	8.7261	41.952	12.201	8.7261
Fixed-Effects:	State	State	Munic.	State	State	Munic.
Controls: Geography	No	Yes	Yes	No	Yes	Yes
Lati-Longi Polynomial	No	Yes	Yes	No	Yes	Yes

Notes: Clustered standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. *Caminho Velho* Access refers to the inverse hyperbolic sine transformation of either *Caminho Velho* density (municipalities) or the distance to *Caminho Velho* (grid cells). *Caminho Velho* Access is instrumented using the equivalent access to a least-cost paths from *Paraty* to *Guaratinguetá*, then to *Ouro Preto*. Geography variables are the ones present in Table D.1 and a latitude-longitude second-order polynomial. The sample excludes municipalities that already existed in 1700. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

similar in magnitude and significance to those in Table D.2, suggesting that omitted variables in the OLS estimates might not be a first order factor. However, focusing on the within-municipality estimations, we observe significant discrepancies between the OLS and the 2SLS estimates. The 2SLS estimates are stronger but less precise when using the least-cost path as an instrument for the *caminho velho*.

Robustness The previously discussed marginal effects indicate that being close to the *caminho velho* conferred economic benefits on municipalities today. These findings withstand various alternative transformation of the dependent variable presented in Table D.4 and alternative specifications, which are presented in Table D.5.

Table D.4: *Caminho Velho* access and current population density – Alternative Transformations

	(1)	(2)	(3)	(4)
Dep. Var. Transform	Log(1 +)		IHS	
Dependent Variable	Pop. Den.	Nightlight	Pop. Den.	Nightlight
Panel A - Municipalities				
Caminho Velho Access	0.269***	0.144***	0.703***	0.415**
	(0.042)	(0.045)	(0.165)	(0.153)
Observations	105	105	105	105
Cluster Groups	27	27	27	27
Access Transform:	Log(1 +)	Log(1 +)	Has Path	Has Path
Fixed-Effects:	State	State	State	State
Panel B - Grid Cells				
Caminho Velho Access	-0.440***	-0.293***	0.473***	0.393***
	(0.111)	(0.066)	(0.167)	(0.127)
Observations	1,438	1,438	1,438	1,438
Cluster Groups	113	113	113	113
Access Transform	Log(1 +)	Log(1 +)	Within 10km	Within 10km
Fixed-Effects:	Muni.	Muni.	Muni.	Muni.

Notes: Standard errors in parentheses. They are clustered at the MCA level when the unit of observation is the municipality and at the municipality level when the unit of observation is the grid cell. *Caminho Velho* Access refers to either the indicated transformation of either *Caminho Velho* density (municipalities) or the distance to *Caminho Velho* (grid cells). All columns include geography controls presented in Table A.1, a latitude-longitude second-order polynomial, and remove municipalities that already existed in 1700. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table D.5: *Caminho Velho* access and current population density – Alternative specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Municipality				Grid-Cell					
Dependent Variable	Pop. Density		Nightlight Den.		Pop. Density			Nightlight Den.		
Panel A: IHS Transform of Density and Distance										
Caminho Velho Access	0.239^{***}	0.234^{***}	0.133^{**}	0.130^{***}	-0.433^{***}	-0.424^{***}	-0.442^{***}	-0.303^{***}	-0.287^{***}	-0.318^{***}
	(0.042)	(0.039)	(0.056)	(0.037)	(0.119)	(0.120)	(0.122)	(0.076)	(0.077)	(0.079)
Observations	105	105	105	105	1,909	2,379	1,438	1,909	2,380	1,438
Cluster Groups	27	89	27	89	142	170	1,313	142	170	1,313
Panel B: Log(1 +) Transform of Density and Distance										
Caminho Velho Access	0.274^{***}	0.269^{***}	0.147^{**}	0.144^{***}	-0.429^{***}	-0.419^{***}	-0.440^{***}	-0.279^{***}	-0.265^{***}	-0.293^{***}
	(0.050)	(0.045)	(0.062)	(0.041)	(0.118)	(0.119)	(0.122)	(0.070)	(0.070)	(0.071)
Observations	105	105	105	105	1,909	2,379	1,438	1,909	2,380	1,438
Cluster Groups	27	89	27	89	142	170	1,313	142	170	1,313
Panel C: Dummy if has Positive Density (Munic.) and if within 10km radius (grid cells)										
Caminho Velho Access	0.662^{***}	0.703^{***}	0.399^{**}	0.415^{***}	0.442^{**}	0.429^{**}	0.473^{**}	0.397^{***}	0.387^{***}	0.393^{***}
	(0.225)	(0.161)	(0.194)	(0.143)	(0.180)	(0.181)	(0.205)	(0.130)	(0.129)	(0.150)
Observations	105	105	105	105	1,909	2,379	1,438	1,909	2,380	1,438
Cluster Groups	27	89	27	89	142	170	1,313	142	170	1,313
Control Group	Neighb.	Neighb.	Neighb.	Neighb.	< 40km	< 50km	< 30km	< 40km	< 50km	< 30km
Fixed-Effects:	MCA	State	MCA	State	Munic.	Muni.	Muni.	Muni.	Muni.	Muni.
SE Clustered by	MCA	Conley 30	MCA	Conley 30	Muni.	Muni.	Conley 30	Muni.	Muni.	Conley 30

Notes: Clustered standard errors presented in parentheses. *Caminho Velho* Access refers to the indicated transformation of either *Caminho Velho* density (municipalities) or the distance to the *Caminho Velho* (grid cells). All specifications remove municipalities that already existed in 1700 and control for geography variables from Table A.1 and a second-order latitude-longitude polynomial. $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

References

Abreu, J. C. d. (1963). Capítulos de história colonial (1500-1800) & os caminhos antigos e o povoamento do brasil. *Brasília: UnB*.

Ahmad, Z. and Chicoine, L. (2021). Silk roads to riches: Persistence along an ancient trade network. Available at SSRN: `https://ssrn.com/abstract=3760490`.

Allen, T. and Donaldson, D. (2020). Persistence and path dependence in the spatial economy. Working Paper 28059, National Bureau of Economic Research.

Allen, T. and Donaldson, D. (2022). Persistence and path dependence: A primer. *Regional Science and Urban Economics*, 94:103724.

Andrews, I., Stock, J. H., and Sun, L. (2019). Weak instruments in instrumental variables regression: Theory and practice. *Annual Review of Economics*, 11(1):727–753.

Austregésilo, M. E. (1950). Estudo sobre alguns tipos de transporte no brasil colonial. *Revista de História*, 1(4):495–516.

Bakker, J. D., Parsons, C., and Rauch, F. (2019). Migration and Urbanization in Post-Apartheid South Africa. *The World Bank Economic Review*, 34(2):509–532.

Barsanetti, B. (2021). Cities on pre-columbian paths. *Journal of Urban Economics*, 122:103317.

Bellemare, M. F. and Wichman, C. J. (2020). Elasticities and the inverse hyperbolic sine transformation. *Oxford Bulletin of Economics and Statistics*, 82(1):50–61.

Bertazzini, M. C. (2021). The long-term impact of Italian colonial roads in the Horn of Africa, 1935–2015. *Journal of Economic Geography*, 22(1):181–214.

Bleakley, H. and Lin, J. (2012). Portage and path dependence. *The quarterly journal of economics*, 127(2):587–644.

Bleakley, H. and Lin, J. (2015). History and the sizes of cities. *American Economic Review*, 105(5):558–63.

Borges, L. A. (2016). Mulas em movimento: o mercado interno brasileiro e o negócio de tropas, primeira metade do século xix. *Anos 90*, 23(44):207–230.

Bosker, M., Buringh, E., and van Zanden, J. L. (2013). From Baghdad to London: Unraveling Urban Development in Europe, the Middle East, and North Africa, 800–1800. *The Review of Economics and Statistics*, 95(4):1418–1437.

Bottasso, A., Conti, M., Robbiano, S., and Santagata, M. (2022). Roads to innovation: Evidence from italy. *Journal of Regional Science*, 62(4):981–1005.

Brown, J. C. and Cuberes, D. (2022). The birth and persistence of cities: Evidence from the oklahoma's first fifty years of urban growth. Available at: `https://sites.google.com/site/davcuberes/research`.

Combes, P.-P. and Gobillon, L. (2015). The empirics of agglomeration economies. In Duranton, G., Henderson, J. V., and Strange, W. C., editors, *Handbook of Regional and Urban Economics*, volume 5 of *Handbook of Regional and Urban Economics*, pages 247–348. Elsevier.

Conley, T. G. (1999). Gmm estimation with cross sectional dependence. *Journal of econometrics*, 92(1):1–45.

Conley, T. G. (2010). Spatial econometrics. In *Microeconometrics*, pages 303–313. Springer.

Costa, A. G., editor (2005). *Os Caminhos do Ouro e a Estrada Real*. Editora UFMG.

Dalgaard, C.-J., Kaarsen, N., Olsson, O., and Selaya, P. (2022). Roman roads to prosperity: Persistence and non-persistence of public infrastructure. *Journal of Comparative Economics*, 50(4):896–916.

Davis, D. R. and Weinstein, D. E. (2002). Bones, bombs, and break points: The geography of economic activity. *American Economic Review*, 92(5):1269–1289.

De Abreu, J. C. (1998). *Chapters of Brazil's Colonial History 1500-1800*. Oxford University Press.

Deffontaines, P. (1938). The origin and growth of the brazilian network of towns. *Geographical Review*, 28(3):379–399.

Elizalde, A., Kampanelis, S., and Ioannides, Y. (2023). How local knowledge fuelled colonial expansion and long-run economic activity: Evidence from australia.

Ellis Jr, A. (1950). O café e a paulistânia. *Universidade de São Paulo: USP*.

Flückiger, M., Hornung, E., Larch, M., Ludwig, M., and Mees, A. (2021). Roman Transport Network Connectivity and Economic Integration. *The Review of Economic Studies*, 89(2):774–810.

Franco, A. P., Galiani, S., and Lavado, P. (2021). Long-term effects of the inca road. Working Paper 28979, National Bureau of Economic Research.

Galvão, O. J. d. (1996). Desenvolvimento dos transportes e integração regional no Brasil – uma perspectiva histórica. *Planejamento e políticas públicas*, (13).

Goulart, J. A. (1959). *Transportes nos engenhos de açúar*. Impr. Gráfica Taveira.

Holanda, S. B. (1975). Caminhos e fronteiras. *São Paulo: Companhia das Letras*.

Jedwab, R., Kerby, E., and Moradi, A. (2017). History, Path Dependence and Development: Evidence from Colonial Railways, Settlers and Cities in Kenya. *Economic Journal*, 127(603):1467–1494.

Klein, H. S. (1989). A oferta de muares no brasil central. *Estudos Econômicos (São Paulo)*, 19(2):347–372.

Kok, G. (2009). Vestígios indígenas na cartografia do sertão da américa portuguesa. *Anais do Museu Paulista: História e Cultura Material*, 17:91–109.

Lin, J. and Rauch, F. (2022). What future for history dependence in spatial economics? *Regional Science and Urban Economics*, 94:103628.

Martincus, C. V., Carballo, J., and Cusolito, A. (2013). Routes, exports, and employment in developing countries: Following the trace of the inca roads.

Michaels, G. and Rauch, F. (2017). Resetting the Urban Network: 117–2012. *The Economic Journal*, 128(608):378–412.

Milet, H. A. (1881). *A lavoura da canna de assucar*. Typ. do Jornal do Recife.

Momsen Jr, R. P. (1963). Routes over the serra do mar: The evolution of transportation in the highlands of rio de janeiro and são paulo. *Revista Geográfica*, pages 5–167.

Monteiro, J. M. (1994). Negros da terra. *São Paulo: Companhia das Letras*.

Montiel-Olea, J. L. and Pflueger, C. (2013). A robust test for weak instruments. *Journal of Business & Economic Statistics*, 31(3):358–369.

Morais, V. A. (2010). Estradas interprovinciais no Brasil central: Mato Grosso, Goiás, Minas Gerais (1834-1870). Master's thesis, Universidade de São Paulo.

Morten, M. and Oliveira, J. (2023). The effects of roads on trade and migration: Evidence from a planned capital city. *American Economic Journal: Applied Economics*.

Netto, F. F. (1974). *150 anos de transporte no Brasil – 1822-1972*. Centro de Documentação e Publicações do Ministério dos Transportes.

Paik, C. and Shahi, K. (2022). Ancient nomadic corridors and long-run development in the highlands of asia. *Explorations in Economic History*, page 101482.

Palma, N. (2022). The real effects of monetary expansions: evidence from a large-scale historical experiment. *The Review of Economic Studies*, 89(3):1593–1627.

Pebesma, E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal*, 10(1):439–446.

Pereira, R., Goncalves, C., Carabetta, J., and Furtado, B. (2019). Geobr: Loads Shapefiles of Official Spatial Data Sets of Brazil.

Portugal, A. and Barsanetti, B. (2022). Paths that led to gold: Historical roads, trade, and persistence. Available at SSRN: `https://ssrn.com/abstract=4390634`.

Prado Júnior, C. (1987). Formação do brasil contemporâneo. *São Paulo: Brasiliense*, 23.

Redding, S. J. and Rossi-Hansberg, E. (2017). Quantitative Spatial Economics. *Annual Review of Economics*, 9:21–58.

Reis, E. (2023). Non-tradables in brazilian economic history. *EconomiA*.

Reis, E., Pimentel, M., Alvarenga, A. I., and Santos, M. d. C. H. (2011). Áreas mínimas comparáveis para os períodos intercensitários de 1872 a 2000. In *Anais do I Simpósio Brasileiro de Cartografia Histórica*, Paraty.

Rosenthal, S. S. and Strange, W. C. (2004). Evidence on the nature and sources of agglomeration economies. In Henderson, J. V. and Thisse, J.-F., editors, *Cities and Geography*, volume 4 of *Handbook of Regional and Urban Economics*, pages 2119–2171.

Santos, M. (2001). *Estradas Reais: introdução ao estudo dos caminhos do ouro e do diamante no Brasil*. Estrada Real.

Silva, M. M. F. (1947). Expansão dos transportes interiores. *Revista Brasileira de Geografia. Rio de Janeiro: IBGE*, 9(03):57–102.

Silva, M. M. F. (1949). *Geografia dos transportes no Brasil*. Number 7. Instituto Brasileiro de Geografia e Estatística.

Simonsen, R. C. (1977). *História Econômica do Brasil: 1500–1820*. São Paulo: Companhia Editora Nacional, 7 edition.

Summerhill, W. (1997). Transport improvements and economic growth in brazil and mexico. *How Latin America Fell Behind*, pages 93–117.

Summerhill, W. R. (2005). Big social savings in a small laggard economy: Railroad-led growth in brazil. *The Journal of Economic History*, 65(1):72–102.

Suprinyak, C. E., Restitutti, C. C., et al. (2006). Os muares e as minas: relações entre a demanda mineira e o mercado de animais de carga nos séculos xviii e xix. *IN: Anais do XII Seminário sobre a Economia Mineira. Diamantina: CEDEPLAR/FaCE/UFMG*.

Takeda, K. and Yamagishi, A. (2023). History versus expectations in the spatial economy: Lessons from hiroshima.