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FROM THE HISTORICAL ROMAN ROAD NETWORK TO MODERN INFRASTRUCTURE IN ITALY

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WORKING PAPERS

2021/02

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Title: FROM THE HISTORICAL ROMAN ROAD NETWORK TO MODERN INFRASTRUCTURE IN ITALY

Prima Edizione: Agosto 2021

ISBN: 978 88 68513 603

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From the historical Roman road network to modern infrastructure in Italy*

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Abstract

An integrated and widespread road system, like the one built during the Roman Empire in Italy, plays an important role today in facilitating the construction of new infrastructure. It first influenced the growth of cities, regardless of the variety of historical paths after the fall of the Roman Empire and before the unification of the country. Through this channel Roman roads have been the main determinant of both motorways and railways in the country. Even the Italian North-South divide can be ascribed, among other factors, to the way the ancient infrastructure had an influence on the modern one.

Keywords: Roman roads; Long-term effects of history; Railways; Motorways; Italy; Provinces.
Jel Classification: H54, N73, N93, O18.

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* A longer version of this paper has been circulated under the title "The long-term effects of the historical Roman road network: trade costs of Italian provinces", CRENoS wp. 2018-01. The authors thank, among the others, Andrea Ariu, Rinaldo Brau, Alessandro Bucciol, Danilo Cavapozzi, Paola Conconi, Enrico Marvasi, Emanuele Mazzini, Alireza Naghavi, Gianluca Orefice and Luigi Pascali for their insightful comments. The authors are grateful to Adriana Di Liberto and Marco Sideri for generously sharing their data. Vania Licio gratefully acknowledges the Sardinia Regional Government for funding her PhD scholarship (P.O.R. Sardegna F.S.E. Operational Programme, Autonomous Region of Sardinia, European Social Fund 2007-2013 - Axis IV Human Resources, Objective l.3, Line of Activity l.3.1.).

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"*And what was said by Homer, 'The Earth was common to all', you (Rome) have made a reality, by surveying the whole inhabited world, by bridging rivers, by cutting carriage roads through the mountains, by filling deserts with stationes, and by civilising everything with your way of life and good order*" Aelius Aristides Orat.26.101

1 Introduction

Transport infrastructure is of major importance. Its direct and indirect impact on growth and economic development has been widely discussed in the literature. However, there are still some gray areas, like the effect played by historical transport projects on modern physical capital. This study, focusing on Italy, aims to answer two main questions: i) Is material infrastructure lengthier in those territories that inherited more from the past?; ii) To what extent can the relief of a territory explain an overlap and how much can instead be ascribed to economic development, such as the rise and expansion of cities whose development calls for connectedness?

Italy represents an ideal case: it is where the historical Roman road network, one of the largest investments in infrastructure in history, was densest and where its expansion began. The Roman Empire had its core in Italy and roads were built throughout the entire peninsula. Rome can be thought as the 'point source outbreak' of the Roman conquest pattern, which took several centuries to unfold. This aspect introduces an element that has to do with the economic fortunes of Italy today. The Italian economic and social dualism (a highly-developed North-Center and a less-developed South) can be attributed to historical episodes and dominations that occurred following the collapse of the Roman Empire (Carlà-Uhink, 2017). Since the Middle Ages, the peninsula has been ruled by several foreign dominators, who were quite heterogeneous within the current unified territory, both in cultural and administrative terms. Today, the central government has the main influence in determining institutions. However, national regulations work differently in the North and the South of the country, suggesting that specific local factors affect the institution's functioning.[1] The idea at the heart of this work is that Roman roads have positively affected current transport systems, regardless of the variety of historical paths within the Italian territory: the Roman network was widespread and its presence is associated with urban development. As in Wahl (2017), the transmission mechanism reveals the enduring

[1] Crescenzi *et al.* (2016) stress the importance of the quality of regional government for the positive economic returns of transport investments at the local level.

effect of the Roman road network, fostering city growth and a denser infrastructure.

This paper follows the strand of research that quantifies the long-term effects of historical events on current development (Nunn, 2009), and the line of investigation of Temin (2013), Michaels and Rauch (2018), Wahl (2017), Dalgaard *et al.* (2018) and Flueckiger *et al.* (2019). The evidence here provided embraces two dimensions: the persistent effect of history and the mechanism linking past with present. The attention is devoted to the NUTS3 province decomposition to better capture all those geographic, urban and historical factors crucial in determining both old and modern transport networks.

This paper is also related to the literature on the rise, development and growth of Italian cities, that started with Malanima (2005), who describes the long-term urbanization process in Italy referring to labor productivity forces and balances between rural and town areas. Bosker *et al.* (2013) allow for the nature of a city's geographical location, where the fact of being connected to a major Roman road or a Roman hub makes the difference when accounting for the possibility of the smaller cities becoming larger population centers. Percoco (2013) widens the view by using historical city characteristics to instrument firm and employment density and estimating their role on income growth.

Historians have reported how Romans built their roads, particularly the major (consular) ones, in order to conduct their military campaigns. During the Roman Empire goods were transported mainly by sea, while the mobility of people, for purposes other than military, was virtually non existent. This paper provides empirical evidence for this fact: the presence of pre-Roman cities and amenities along with geography have been related to the length of Roman roads. Romans did not use major roads for connecting existing cities rather they were motivated by finding solutions for overcoming geographical barriers. This is the first point of the paper. A second result refers to how the modern infrastructure has benefited from the existence of ancient roads. Areas where the Roman network was denser, today have more railways and motorways. Nevertheless - third result of this work - the effect differentiates between North and South Italy: the presence of consular roads in the South was fundamental for developing the railway system; it traced the expansion of motorways only in northern territories. In the South, instead, minor Roman roads dictated the construction of modern major roads. The fourth result unravels the mechanism through which Roman roads have had a persistent effect: already when Italy was divided into several states, Roman roads were associated with the presence of larger cities (starting from 1300) regardless of the type of domination.

The paper is organized as follows. Section 2 places the analysis in the literature. Section 3 illustrates the available data on Roman roads. Section 4 offers the empirical validation of historians' argument according to which Romans built their roads not intending to connect economic centers. Section 5 investigates the link between ancient and modern infrastructure and the role played by urban dynamics. Section 6 concludes.

2 The persistent effect of historical infrastructures

In the last twenty years a new strand of literature, focused on the influence of history on various aspects of the economy today, has emerged. As summarized by Nunn (2009) and Michalopoulos and Papaioannou (2017), the 'new economic history' literature – started by collecting data on specific historical episodes (e.g. colonialism in La Porta *et al.*, 1997 and Acemoglu *et al.*, 2001) and providing evidence of their long-lasting effect on modern economic development – rapidly evolved in several directions. The historical epochs under scrutiny - from the Neolithic to Nazi Germany – and the geographical expansion were one of the first directions investigated. In a second stage, the research "[...] *moved from asking whether history matters to asking why history matters*" (Nunn, 2009, p.66) and several studies focused on the mechanism linking the past to contemporary outcomes, exploring the channels of causality in identification-based empirical analyses.

The focus on historical infrastructures accounts for a large share of this literature. Recent research has shown an interest in the effect of great historical transportation infrastructure projects and their expansion on reducing trade costs, on enhancing productivity and on increasing the level of real income in the trading regions involved, as in the contributions by Donaldson (2018), Donaldson and Hornbeck (2016), Jedwab *et al.* (2017), Berger and Enflo (2017). The first two papers address railway expansion in colonial India and the U.S. respectively, the first also providing a measure of the share of total welfare gains. The other two papers provide similar evidence for Kenya and Sweden.[2]

Differently from other episodes in history, the civilization that started from Rome in 753 B.C.

[2] Other works address other means of transport. Fajgelbaum and Redding (2014) look at Argentina and the reduction of international transport costs generated in the late nineteenth century by the introduction of large steamships. Volpe Martincus *et al.* (2014) analyze the case of Peru and use the Inca road network (built by the Inca Empire before 1530) as an instrument for the current road infrastructure.

stood out for its prolonged and extended traits. The lasting marks left in terms of performing institutions, urbanization patterns and the development of a market economy led several studies to focus on the positive effect attributable to the Roman domination (Bosker and Buringh, 2017; Buringh *et al.*, 2012; Bosker *et al.*, 2013; Michaels and Rauch, 2018); recently, the Roman road infrastructure attracted the attention of researchers. In the paper by Wahl (2017), the presence of ancient Roman roads is instrumental in dividing the area that corresponds to contemporary Germany into a Roman and a non-Roman part. The *Limes Germanicus wall* is used as a geographical discontinuity to test whether the formerly Roman part of Germany shows greater nighttime luminosity than the non-Roman one. The transmission mechanism is attributed to the enduring effect of the Roman road network, fostering city growth and denser infrastructure. Dalgaard *et al.* (2018), instead, use the network of roads constructed during the Roman Empire to demonstrate the provision of public goods as a channel of persistence of economic development. The result is corroborated by comparing the European region with the Middle-East and North Africa territories. Since in Africa the wheel was substituted by camels, Roman roads were not maintained and cannot explain current economic performance. In Europe, instead, Roman road maintenance offers a valid proof of the persistence of infrastructure over time. Flueckiger *et al.* (2019) document a lasting economic integration in Western Europe due to the ancient Roman transport infrastructure and its effect on the modern connectivity.

3 The Roman road network: data

The Roman road network started to spread simultaneously with the expansion of Romans in the IV century B.C. The main reason for constructing paved suburban roads was purely military: the need to rapidly deploy troops to the insecure borders of the Empire.[3] Of course, Romans built roads also for connecting settlements and cities, but this paper demonstrates how this is not the case for major (consular) roads.

In Italy, the network of Roman roads covers the entire peninsula, including the two main islands (Sicily and Sardinia): it touches every region (NUTS2) and 108 out of the 110 Italian provinces (NUTS3) in Italy. There is no other country or region where the Roman infrastructure is dense and widespread as in Italy.

[3] Consular roads were not built either for trade purposes, largely managed by navigation across the Mediterranean Sea, or for civilian transportation (Chevallier, 1976).

The raw data on the Roman road network was digitized by McCormick *et al.* (2013) on the basis of the Barrington Atlas of the Greek and Roman World (2000).[4] The Digital Atlas of Roman and Medieval Civilizations (DARMC) includes 7,154 segments of ancient Roman roads existing at the peak of the Empire, corresponding with the death of Trajan (117 A.D.). Each segment is uniquely identified and roads are composed of many segments.[5] The network covers 36 countries over Europe, Africa, and Asia, and road segments are classified according to their class of importance (e.g. major and minor) and certainty (e.g. certain and uncertain).[6] Figures A.1 and A.2 - included in Appendix A - Additional figures and tables - provide a representation of Roman roads according to importance and certainty.

The road network covers a total length of 192,861 kilometers. The length of the Roman road network at the Italian NUTS3 level is computed by Licio (2021). Figure 1 shows the old road system for Italy, which comprises 10 percent of the entire network: 1,817 segments for a total of 19,593 kilometers in 108 provinces.[7] 94 have major roads, 88 minor roads: 74 both minor and major, 20 only minor and 14 only major (consular) Roman roads.

[Figure 1]

Figure A.3 in Appendix A - Additional figures and tables shows the cartograms of Roman roads in the Italian peninsula.

4 Roman roads, geography and pre-Roman cities

Even if a direct economic reason driving the construction of the consular roads has been excluded by historians,[8] geography and earlier settlements will be tested as possible factors influencing the construction of the ancient transport infrastructure. Roman roads may have been endogenously built where the morphology of the terrain permitted and/or near important economic centers.

[4] The data, in shape file format, allows spatial analysis for the Roman and medieval worlds using a Geographic Information System (GIS) coding.

[5] As an example, the *Via Appia* is composed of 67 different segments. Roads are not classified as such and have to be reconstructed assembling the different segments. For brevity, from now on, the terms 'road' and 'road segment' will be used interchangeably.

[6] Certainty refers to the path followed by the road segment. All segments are always certain in their existence and in their Roman origin; what makes a road 'uncertain' is the imprecision in the georeferentiation of the path followed by the road: some stretches of roads got destroyed or abandoned through the ages and for some of them there is neither archaeological nor historical evidence.

[7] Pordenone (in the North-East) and Verbano-Cusio-Ossola (in the North-West) are the two Italian provinces not crossed by Roman roads.

[8] See Appendix B - The exogeneity of the Roman road network for a detailed discussion.

Landform can shape both the within-country spatial distribution of road infrastructure and economic activity (Ramcharan, 2009) and, if so, it represents a potential unobserved factor correlated with both road building and economic performance. The development of primordial engineering techniques by the Romans is largely due to the country's orography: 35 percent of the Italian territory is made up of mountains, 42 percent of hills, and 23 percent of plains.[9]

The investigation on the relationship between Roman roads and geography is first discussed using Figure 2 where elevation data at the municipality level have been geo-coded and mapped using the polygon layer of the Italian territory.[10] Then the layer of the Roman network has been superimposed dividing roads into major (consular) and minor. The average altitude of each spatial unit has been classified according to five ordered equiproportional classes: [0 - 407 meters); [407 - 814); [814 - 1221); [1221 - 1628); [1628 - 2035). The distribution of Roman roads among the different elevation classes is fairly homogeneous. The Roman infrastructure is also present in the darker areas, where elevation is higher.[11] In central-southern Italy, there is a high concentration of Roman roads in the Apennines, the second mountain range in Italy. Nevertheless, in the North, the highest concentration of Roman roads is along the Po Valley, where the average elevation is lower.[12]

[Figure 2]

Since the early days of the Roman Republic, Italy was home to several cities and municipal aggregates founded by pre-Roman populations. The Greeks in the South, the Etruscans in the Center, the Celts in the North were only some of the several civilizations that ruled Italy in ancient times when the Romans were still a small tribe settled around the Capitoline Hill. A

[9] The Romans resorted to deviations in roads only when major obstacles could not be overcome by building structures such as bridges, and whenever possible road supports, like embankments or dykes, or tunnels through hills and mountains (Richard, 2010). Their roads in the Alps and the Apennines had sleep slopes and allowed the movement of pedestrians, horses, and wagons.

[10] Table A.1 in Appendix A - Additional figures and tables summarizes all variables and data sources.

[11] The right part of Figure 2 zooms in on an exemplifying area of North-East Italy (i.e. the delimited rectangular area in the left part of the figure). The chosen area includes four different elevation zones, lakes and a stretch of Roman road that passes through lowlands and more elevated areas: the road does not circumnavigate the lake where the altitude is lower, but crosses a more elevated area.

[12] The 10x10 *km* grid level co-variance analysis available in Table A.2 of Appendix A - Additional figures and tables confirms the evidence in Figure 2, adding detail by terrain type. Cells are classified according to three terrain zones: mountainous (if elevation is equal to or more than 700 meters); hilly (if elevation is less than 700 meters, but equal to or more than 300 meters); plain (if elevation is less than 300 meters). Results show that when grid cells are not differentiated by terrain type, the effect played by geography is misleading. The construction of Roman roads is linked to geography but not limited by it: roads are present in all types of terrains.

number of economic centers (e.g. Agrigento, Pisa, Aquileia) were important well before the arrival of the Romans. Others started flourishing with the expansion of the Empire (this is the case of Turin, Piacenza, Ragusa). Others, instead, gained importance during the Middle Ages or later.

The conditional correlation test on the role of both geography and urbanization relies on the following model, with NUTS3 provinces as a unit of analysis:

$$\mathcal{RR}_i = \alpha_0 + \mathbf{G}_i\alpha_1 + \alpha_2\ \texttt{Pre-Roman city}_i + \alpha_3\ \texttt{Pre-Roman amenities}_i + u_i \tag{1}$$

where $\mathcal{RR}_i$ is the log-transformed measure of kilometers of roads (major/consular or all roads); $\mathbf{G}_i$ denotes a matrix of geographical measures in logarithms ($\texttt{Elevation}_i$ and $\texttt{Percentage of mountainous territory}_i$);[13] $\texttt{Pre-Roman city}_i$ takes the value of 1 if the provincial capital was a pre-Roman city center; $\texttt{Pre-Roman amenities}_i$ is 1 if any pre-Roman settlements or any type of civil infrastructure or amenity were present in the province before the Romans; u_i denotes the (heteroskedasticity consistent) error term. Results are presented in Table 1.

[Table 1]

In the first column only the orography of the provincial territory is taken into account: both geographical variables are significantly correlated with major Roman roads. The elasticity of 0.255 of the $\texttt{Elevation}_i$ index discloses how more kilometers of Roman roads are needed to reach more challenging territories. On the other hand, the -0.127 $\texttt{Percentage of mountainous territory}_i$ elasticity confirms that Roman roads are sparser in more impervious areas.[14] Considering all Roman roads (including therefore minor roads), as in specification (4), the elevation of the territory is still positively correlated with Roman infrastructure. However, in this case Roman roads are inelastic to the presence of mountainous areas at given elevations. All in all, the role of geography in explaining the presence of Roman roads at the provincial level is minimal. More than 95 percent of the variability in the data is unrelated to geography.[15]

[13] Elevation here is a continuous variable.

[14] The standard errors for $\texttt{Elevation}_i$ and $\texttt{Percentage of mountainous territory}_i$ increase, 0.134 and 0.074 respectively, when using HC3 robust standard errors formula instead of an HC0 formula, less reliable in finite samples.

[15] Other geographical variables usually used in territorial analyses have been tested at a finer level in Table A.2 of Appendix A - Additional figures and tables. None of the variables has been found relevant.

Integrating the geography of the territory with information on pre-Roman urbanization and settlements provides a test on whether Roman roads were built near larger urban centers or favored the subsequent expansion of earlier settlements. Existing cities could become logistic bases for the organization of troops and military camps providing infrastructure useful in war campaigns. In this design setting, the position of existing settlements and cities may have contributed to determining the trajectory of a road segment or its terminal point, which varied by construction stage. Also, the road may have generated agglomeration effects leading to the subsequent development of cities.

Specification (2) of Table 1 shows that the coefficient of the $\texttt{Pre-Roman city}_i$ dummy is not statistically significant: the Roman road network does not get denser with the presence of cities. The elevation of the territory is still relevant. Results are identical when including also minor roads in specification (5).[16]

Table 1 then tests a measure that looks at the whole province and also takes into account several types of amenities. Exploiting the information from Pleiades: A Gazetteer of Past Places,[17] $\texttt{Pre-Roman amenities}_i$ takes the value of 1 if in the province existed simple settlements or settlements represented by a civil infrastructure (amphitheater, theater, cemetery, sanctuary, bath, bridges, ports, forts). Column (3) of Table 1 shows how these types of settlements do not influence the length of consular Roman roads providing, therefore, a confirmation of their military nature. Only when including minor roads (all Roman roads) as in specification (6) the $\texttt{Pre-Roman amenities}_i$ coefficient turns out to be highly significant. A result indicating the auxiliary role of minor roads by connecting the consular network to the civil infrastructure.

How the quantity of consular roads is somehow related to geography but independent from the presence of economic centers is the first result of this paper and it will be used for investigating the link between old and new infrastructure in the following section.

[16] The provincial capital is, in general, the main urban center of a province and its current administrative importance lies in the historical origin of the city, as it was viewed when Italy became a nation-state in 1861.

[17] For more details see `https://pleiades.stoa.org/help/data-structure`.

5 Old and modern infrastructure

The legacy left by the historical Roman road network on current transport infrastructure - railways and motorways - is investigated by considering the possible factors behind their linkage.[18]

Cultural and landscape conditions determine why the new infrastructure may be related to the ancient one. The fact of having favored the birth and development of economic centers is an important one.[19] On the other hand, city location does not follow a casual process and has been found linked to (among other things) the presence of road infrastructure (Bosker and Buringh, 2017). Besides, the direct effect that geography imposes on the costs of transport infrastructure projects cannot be overlooked. When landform creates construction difficulties, the presence of an old infrastructure facilitates the construction of a new one.[20] For this reason, this paper adopts a measure of major Roman roads orthogonal to geographical factors as the main dependent variable.

Provincial units of analysis allow taking into account how modern infrastructure has been designed at the national level with an integrated view of the whole country's geography.[21] The needs expressed by the local administrative authorities (regions and provinces) have been taken into account by using a composite approach of the singularities of the North-Center and southern regions of the country. Also, provinces allow the highest within-country variance and pinpoint control for those historical legacies which followed the collapse of the Roman Empire.[22]

In Equation (2), measures of modern infrastructures are regressed on the measure of Roman roads, as the residuals of Equation (1) resulting from specification (1) in Table 1:

$$\mathcal{I}_i = \beta_0 + \beta_1 \tilde{\mathcal{RR}}_i + \beta_2 \mathcal{M}_i + \beta_3 \texttt{ Roman city}_i + \beta_4 \texttt{ Post-Roman city}_i + \mathbf{G}_i \beta_5 + \mathbf{H}_i \beta_6 + \phi_r + u_i \tag{2}$$

The dependent variable $\mathcal{I}_i$, is the log transformation of two measures in kilometers of current

[18] For an analysis on the intersection between the Roman road network and the Italian railway and motorway system see Appendix C - Railways, motorways, and Roman roads: correspondence.

[19] Several contributions (see Garcia-Lopez *et al.* (2015) among others) stress that motorways are not located at random and argue in favor of the location of cities as the main driver of modern road infrastructure.

[20] As for Roman roads, Table A.3 in Appendix A - Additional figures and tables provides a more detailed analysis at the grid level for a finer understanding of the role of geography.

[21] An analysis at the grid level is provided in Table A.4 of Appendix A - Additional figures and tables.

[22] An interesting strand of the literature focuses on the role of the social capital in Italy, exploiting the heterogeneity that originated from the events that followed the collapse of the Roman Empire (Guiso *et al.*, 2004).

infrastructure: railways and motorways.[23] Considering two different transport systems derives from how transport infrastructure developed in Italy: railways from 1839, motorways from 1924 on.[24] The set of additional controls is aimed at capturing the recursive effect from the old infrastructure to the birth and growth of cities and then back to the new transport infrastructure provision: $\mathcal{M}_i$ accounts for the number of current municipalities (over 50,000 inhabitants) in every province i, crossed by a major (consular) Roman road; $\texttt{Roman city}_i$ is a dummy variable that takes the value of 1 if the provincial capital of the NUTS3 region was a Roman city center; $\texttt{Post-Roman city}_i$ is a dummy variable that takes the value of 1 if the provincial capital became an important city center after the Roman domination;[25] $\mathbf{G}_i$ is the matrix of the above discussed geographical measures ($\texttt{Elevation}_i$ and $\texttt{Percentage of mountainous territory}_i$) taken in logarithms and tested on railways and motorways regardless of how they determined the number of Romans roads; $\mathbf{H}_i$ denotes a matrix of count variables on past dominations after the Roman collapse. NUTS2 regional fixed effects ϕ_r complete the model specification and u_i denotes the error term.

The role played by historical evolution after the Roman Empire, captured by matrix $\mathbf{H}_i$, includes the data collected and examined in Di Liberto and Sideri (2015), and consists of the length of the dominations that ruled Italy between the twelfth and eighteenth century. This set of information allows controlling for the political, institutional, and social changes occurring since the Middle Ages and that is at the root of the observed differences in productivity and income since the foundation of the country as a nation-state in 1861.[26]

Table 2 presents the results. The model of Equation (2) is estimated in its complete form in column (6) and (12). Specifications (1) and (7) focus on isolating the effect of geography on railways and motorways, respectively. $\texttt{Elevation}_i$ has a positive impact on both infrastructure

[23] Data on kilometers of railways by province are from Istat and refer to 2005. The information is provided for 103 out of 110 provinces, since the missing provinces were established or became operational after 2005. Data on the current road network are from Automobile Club d'Italia (ACI) and are updated to 2011. Data on motorways comes from AISCAT (`http://www.aiscat.it`) and ANAS (`http://stradeanas.it/it`).

[24] See Appendix C - Railways, motorways, and Roman roads: correspondence.

[25] The nature of the three variables is different: $\mathcal{M}_i$, constructed using GIS methods, relates more to the birth and development of cities along with the old infrastructure, $\texttt{Roman city}_i$ and $\texttt{Post-Roman city}_i$, relate more instead to the historical development of urban centers in nearby areas.

[26] Since the collapse of the Roman Empire, Italy became a vibrant territory, characterized by several realms, local conflicts and alliances, and a large number of foreign influences and diverse cultural links with the noble European dynasties. Di Liberto and Sideri (2015) assign to each province the number of years during which each regime ruled. Between 1100 and 1700 nine dominations occurred: the Normans, the Swabians, the Anjou, the Spanish, the Bourbons, the Papal State, the Savoy, the Austrians, and the Republic of Venice.

systems, $\texttt{Percentage of mountainous territory}_i$, instead, shows a negative effect only on the railway infrastructure. In specifications (2) and (8), regional fixed effects capture most of the effect.

Moving forward on specifications in Table 2, columns (3) and (9) test $\mathcal{RR}_i$, i.e. the raw Roman road measure where the effect of geography has not been partialled out. Specifications (4) and (10), instead, exploit $\tilde{\mathcal{RR}}_i$, i.e. the residuals of Equation (1) as in specification (1) of Table 1, which allows better control for confounding factors from geography to infrastructure. Regardless of the measure adopted, major (consular) roads are positively correlated with current infrastructure, more so in the case of motorways and when using $\tilde{\mathcal{RR}}_i$: the elasticity of $\mathcal{I}_i$ to $\tilde{\mathcal{RR}}_i$ is 0.63 for railways and 0.67 for motorways.[27] In columns (5) for railways and (11) for motorways covariates associated with urban development are included in the estimation, and in specification (6) and (12) historical dominations complete the model. Fixed effects accounting for regional differences are present in all specifications. The increase in the number of municipalities within close distance from consular Roman roads has a positive effect only on motorways, while other covariates associated with urban development and geography are not statistically significant. In any case, conditional correlation between $\tilde{\mathcal{RR}}_i$ and $\mathcal{I}_i$ (i.e. between old and modern infrastructure) is strongly positive, also when taking into account regional heterogeneity, historical dominations, geography, and urban dynamics. The R-squared shows a valuable goodness-of-fit, confirming how important is the relationship between old and new infrastructure, second and main result of this paper.

[Table 2]

In Table 3 the extent to which the Roman road network affected modern-day infrastructure is analyzed referring to the Italian North-South divide. This is measured interacting $\tilde{\mathcal{RR}}_i$ with the `North` dummy, equal to one for all northern NUTS3 provinces, and `South` dummy, equal to one for all southern NUTS3 provinces.[28] Geography, urban development, historical dominations and regional fixed effects complete the model.

[27] Table A.4 in Appendix A - Additional figures and tables measures the effect of the Roman infrastructure on the modern one by terrain geography. Results do not change the evidence hereby presented. The legacy of Roman roads has been more important in hilly zones than in mountainous ones for railways, while consular roads represented a starting point to construct modern roads in territories with higher altitudes.

[28] Northern NUTS3 provinces are those that are included in the NUTS2 regions of Piemonte, Valle d'Aosta, Lombardia, Trentino Alto-Adige, Veneto, Friuli-Venezia Giulia, Liguria, Emilia Romagna, Toscana, Umbria, Marche, Lazio. Southern NUTS3 provinces are those included in the NUTS2 regions of Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia, Sardegna.

Estimations show that when focusing only on the railway system, Roman roads have, *ceteris paribus*, a stronger positive effect in the South than in North, suggesting the greater impact the Roman road network had on the construction of railways in the southern regions. In the case of motorways, estimation outputs are less trivial. Major Roman roads are positively correlated with motorways only in the northern NUTS3 provinces; $\texttt{South}^*\tilde{\mathcal{RR}}_i$, instead, is not linked to a statistically significant coefficient. These results are in line with expectations: the geography in northern Italy is characterized by extensive plains that facilitated the construction of an intricate system of straight Roman roads and subsequently motorways. If the Alps represent the geographic boundary between northern Italy and the rest of Europe that can be overcome with the construction of more kilometers of roads, in the South, instead, the Mediterranean Sea represents a geographic discontinuity that separates Italy from Africa and Middle-East, and that impedes the continuity of the transport system. In Italy, the main mean of transport for moving goods in space is through the use of roads.[29] In these terms, the Italian North-South divide can be ascribed, among other factors, to the influence the historical Roman road network had on the construction of new infrastructure, third result of this work.

[Table 3]

5.1 The medium-term effect of Roman roads

Among the main mechanisms that can explain the link between old and new transport infrastructure, this paper draws attention to the agglomeration forces involved in the birth and development of cities.[30] If settlements can drive the construction of new roads, also transport infrastructure can determine the development of new urban centers, in a sequence of recursive events. As emphasized by Bosker *et al.* (2013), the existence of Roman roads allowed small cities to grow earlier and faster. Notwithstanding the decline of the Roman Empire, many Roman urban centers remained important as they were connected by Roman roads. In Wahl (2017), new settlements benefited from the Roman network, as being located near a road allowed them

[29] In 2016, 18 percent of the value of extra-EU28 exports in goods was by road. In Italy, it was 21 percent (Source: `http://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_in_goods_by_mode_of_transport`). Within Europe, road freight transport is predominant and represents approximately three-quarters of the total. In Italy, this share is even greater.

[30] The birth and development of urban centers is one of the investigated channel. Also whether the presence of Roman roads determined the probability of being under the rule of a given medieval dominator has been analyzed. Results suggest that this mechanism is not relevant.

to develop and to become trade nodes. In this sense, the persistence of the Roman road network passes through cities in two separate moments. In a first step Roman roads favored the birth and development of new settlements. Then, the fact of becoming crucial nodes, favored by the proximity to a transport infrastructure, facilitated their maintenance and preservation.

To test the city development channel, this paper looks at the urbanization Italy underwent during the Middle Ages. Data come from Malanima (2015) and include the urban population of the Italian cities with more than 5,000 inhabitants in the six centuries between 1300 and 1800 and in 1861, the year of Italian unification.[31]

Table 4 shows the results of a regression model that tests the effect of the major Roman roads on urban development, using covariates of Equation (2) as a set of controls. The dependent variable in the first six specifications is the city population in three different periods: 1300, 1600 and 1861. Columns from (7) to (12), instead, refer to the number of cities with a population of over 5,000 inhabitants in the same three periods. They are two distinct measures of urbanization: the first quantifies the size of a city, while the second captures the density of urbanization. For each period the regression has been run with and without historical domination controls to check the effect of different realms.[32] Regression results from (1) to (6) show that major Roman roads are positively correlated with the urban population of the Middle Ages. Statistically significant coefficients persist after controlling for the different regimes that governed during that century. Moreover, the importance of the major Roman road measure ($\tilde{\mathcal{RR}}_i$) is confirmed by the inclusion of the different variables accounting for urbanization. The most important one is the presence of a major Roman road passing through today's metropolitan areas. When considering the number of cities (specifications from (7) to (12)), however, the impact peters out with controls for medieval dominations.

[Table 4]

This is the fourth and last result of this paper: Roman roads are associated with the presence of larger cities and this unravels one of the mechanisms through which Roman roads have a persistent effect today.

[31] The database includes 193 cities in the six centuries between 1300 and 1800 and 556 cities in 1861. If in a given period the city's population was under 5,000 inhabitants, the urban center is assigned 0 (Malanima, 2015).

[32] Historical controls change according to whether the domination ruled in that century or not.

5.2 Robustness checks

Robustness checks have a twofold purpose: to confirm the relevance of the Roman road index and to provide further controls for path dependency in the Roman road network expansion.

The first set of robustness checks concerns the use of a different measure of Roman road infrastructure: all Roman roads. The aim is to generalize the findings of the analysis to include those minor roads constructed for the purpose of enhancing the connectedness of the major roads network by linking pre-Roman settlements or amenities. All provinces but two are crossed by the Roman road network when minor roads are considered.

Table 5 adopts a measure of all Roman roads orthogonal to both geography and pre-Roman amenities ($\tilde{\mathcal{RR}}_i$), obtained as the residuals of Equation (1) resulting from specification (6) of Table 1. The measure is interacted with the `North` and `South` dummies to gain insight into the country's territorial divide. Results suggest that when also minor Roman roads are considered, the positive correlation between old and current infrastructure holds for both railway and motorway systems, in contrast to the results reported in Table 3. Moreover, it clearly emerges that all Roman roads have, *ceteris paribus*, a stronger positive effect in the southern provinces than in northern ones, suggesting that the Roman domination and the road network exerted significant influence in southern Italy. Results are robust to any control included in the regression and the goodness-of-fit confirms the appropriateness of the estimated model.

[Table 5]

The second set of robustness checks concerns the historical evolution of the Roman Empire and the dynamics of the Roman road network construction. This issue is relevant since it further qualifies the elements of the debate on the endogeneity of Roman roads discussed in Section 4 and Appendix B - The exogeneity of the Roman road network. Segments of a transportation and mobility network are not created at random and the process of network formation follows a preferential attachment rule requiring new segments to be connected to previously existing ones (Barthélemy, 2011). The existence of a given segment and its length are, therefore, not independent of the existence and length of previously existing ones. This sequentiality in network formation implies that the location of new segments is endogenous, and this has to be taken into account in identification.

In order to account for this effect, the development of the Roman road network has been decomposed into nine historical periods, from 800 B.C. to 1 A.D., and the Roman Empire expansion and the construction of the corresponding Roman road network has been subdivided and mapped using GIS techniques.[33] Figure 3 maps the expansion of both Roman Empire and Roman road network for the nine periods in a single map. Figure A.4 in Appendix A - Additional figures and tables shows separate maps. For each of the nine historical periods, s=[1,9], the measures of Roman roads have been computed at the province level.

[Figure 3]

Spatial path dependency has been modeled as in Equation (3), where Roman roads at their maximum expansion, $\tilde{\mathcal{RR}}_{i,s=9}$, are a function of the previous stages of network development.

$$\tilde{\mathcal{RR}}_{i,9} = \alpha_0 + \alpha_1 \tilde{\mathcal{RR}}_{i,8} + ... + \alpha_7 \tilde{\mathcal{RR}}_{i,2} + \alpha_8 \mathcal{RR}_{i,1} + \epsilon_i \tag{3}$$

For each period, except for the first one, the Roman road measure is the result of the variance left over from an OLS regression where $\mathbf{G}_i$, $\texttt{Pre-Roman city}_i$ and $\texttt{Pre-Roman amenities}_i$ have been controlled for, as in the analysis performed in Section 4.[34]

Table 6 replicates columns (6) and (12) of Table 2 using $\tilde{\mathcal{RR}}_i$ as a time series process. Coefficients' signs, magnitude and significance of Roman roads as a determinant of railways and motorways are confirmed in both specifications. Geographic, urban development, and historical controls complete the model, although only the old infrastructure measure shows an effect on current transport measures. As in all previous models, regional fixed effects account for the heterogeneity within the Italian territory.

[Table 6]

6 Concluding remarks

This paper provides novel evidence on the long-term effect of the Roman Empire. It shows how the Roman road network has had a persistent effect on the present-day road and railway system in Italy and how this represents one of the mechanisms of influence on modern economy.

[33] The analysis has been facilitated by the use of the digital history repository and desktop app Running Reality (`http://www.runningreality.org`), which is freely available online. The division into nine periods is the default one in Running Reality.

[34] Because of the low number of observations, it has not been possible to remove the influence of geography and archaic cities from the Roman road measure of period 1.

The case of Italian provinces is interesting for several reasons: historically Italy is characterized by a duality between the developed North-Center and a less-developed South, although the central government is responsible for the maintenance of the current infrastructure. The history of Italy after the fall of the Roman Empire is a collection of several dominations whose influence differed in different parts of the country. In all but two Italian provinces (NUTS3) there exist roads built during the Roman Empire. At the same time, however, the measure of Roman roads shows a remarkable variability, the result of the needs of the military campaigns conducted by the Romans during the expansion of the Empire.

The legacy left by Roman roads on modern infrastructure has been investigated adopting a measure of major Roman roads orthogonal to geographical factors, since pre-Roman settlements did not affect the construction of the consular roads. A second measure including both major and minor roads, and cleaned from the effect of both geography and pre-Roman amenities, instead, has been tested in the robustness checks. The econometric analysis reveals a meaningful and significant positive effect of the integrated ancient Roman road network on current infrastructure. This issue is especially significant from the perspective of the Italian North-South divide. Consular roads have been particularly important in determining the motorway network in northern provinces. For the railway system, instead, major Roman roads have influenced today's infrastructure more so in the South than in the North. Indeed, when considering both major and minor Roman roads, southern provinces have benefited more from the existence of Roman roads in terms of both railways and motorways.

As far as the mechanism driving the result, areas with a denser Roman road infrastructure are more likely to have a denser road and railway infrastructure today since Roman roads shaped the Italian landscape making the construction of current roads less costly. Today's roads simply followed the same path traced by the Romans. Reasons for this are quite diverse: in Bosker and Buringh (2017) Roman roads are a proxy for favorable land-based accessibility locations and an important determinant for the founding of a city. In Bosker *et al.* (2013) Roman roads are taken as elements favoring subsequent urban expansion, differently from current roads, built for connecting already existing urban centers. Also, Michaels and Rauch (2018) discuss how the presence of the old Roman road infrastructure contributes to path dependency in historical urban structuring. This paper investigates the urban development mechanism using data from Malanima (2015), confirming that the maintenance and preservation of the network favored the growth of important cities along it.

To summarizing, the legacy of the Roman road network in Italy acted in two ways. On the one hand, it formed the basis for today's infrastructure by shaping the Italian landscape. On the other, in a first step, it favored the birth of new settlements; in a second step it enabled the development of urban centers simply because roads linking cities were maintained and preserved.

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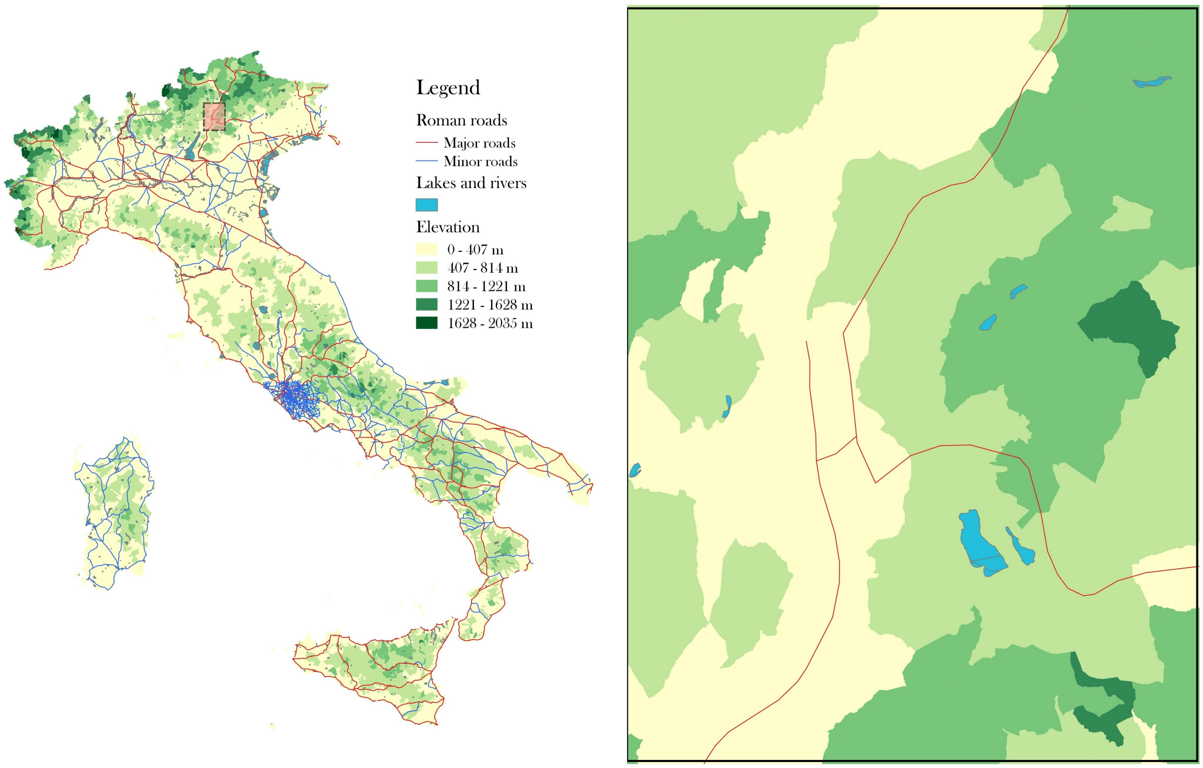
Figures and tables

Figure 1: Roman road layer and Italian provinces

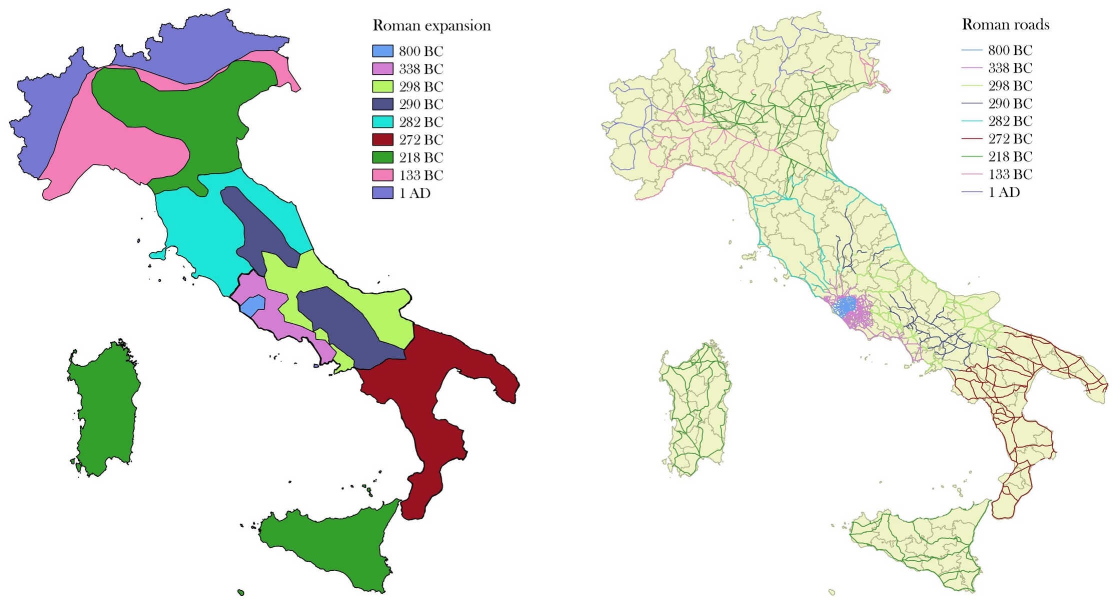
Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5 and from Istat data (2011)

Figure 2: Roman roads and geography: position by elevation



Source: Authors' drawing from Istat data, Corine Land Cover data, McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5

Figure 3: Roman Empire and road network expansion: combined view



Source: Authors' elaborations

Table 1: Roman roads, geography and pre-Romanity

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Roman roads in km (log)		*Major*			*All*	
`Elevation` (log)	0.255*	0.244*	0.173	0.181*	0.171*	0.064
	(0.134)	(0.138)	(0.173)	(0.104)	(0.104)	(0.117)
`% of mountainous territory` (log)	-0.127*	-0.120	-0.091	-0.098	-0.093	-0.052
	(0.074)	(0.078)	(0.093)	(0.063)	(0.063)	(0.067)
`Pre-Roman city`		0.205	0.125		0.264	0.129
		(0.218)	(0.214)		(0.191)	(0.199)
`Pre-Roman amenities`			0.285			0.481**
			(0.260)			(0.208)
Intercept	3.287***	3.198***	3.432***	4.052***	3.933***	4.280***
	(0.623)	(0.580)	(0.683)	(0.448)	(0.412)	(0.458)
Observations	94	94	94	108	108	108
R^2	0.045	0.055	0.073	0.025	0.046	0.107
Adjusted R^2	0.023	0.024	0.032	0.006	0.019	0.072

Note: All log-transformed variables are indicated with (log). Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Robust standard errors are reported in parentheses and computed using HC3 robust standard errors formula.

Table 2: Major Roman roads and current transport infrastructure

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Current infrastructure in km (log)	*Railways*						*Motorways*					
$\mathcal{RR}_i$ (log)			0.387***						0.404***			
			(0.141)						(0.118)			
$\tilde{\mathcal{RR}}_i$ (residuals of (1) Table 1)				0.625***	0.583***	0.535**				0.674***	0.589***	0.691***
				(0.224)	(0.229)	(0.233)				(0.232)	(0.224)	(0.262)
`Elevation` (log)	1.015***	0.168	0.110	0.319**	0.239	0.220	0.554***	-0.250	-0.283	-0.072	-0.222	-0.146
	(0.035)	(0.116)	(0.102)	(0.161)	(0.176)	(0.206)	(0.069)	(0.207)	(0.190)	(0.243)	(0.247)	(0.302)
`% of mountainous territory` (log)	-0.364***	-0.158*	-0.090	-0.233**	-0.184*	-0.176	0.084	0.149	0.199*	0.057	0.137	0.140
	(0.074)	(0.090)	(0.072)	(0.106)	(0.106)	(0.109)	(0.119)	(0.124)	(0.118)	(0.142)	(0.133)	(0.156)
$\mathcal{M}_i$					0.127	0.118					0.286*	0.266
					(0.114)	(0.121)					(0.160)	(0.171)
`Roman city` (dummy)					-0.075	-0.008					-0.238	-0.088
					(0.340)	(0.399)					(0.459)	(0.556)
`Post-Roman city` (dummy)					-0.403	-0.763					-0.865*	-1.081
					(0.529)	(0.542)					(0.531)	(0.688)
$\mathbf{H}_i$	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	YES
ϕ_r	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES
Observations	103	103	103	103	103	103	110	110	110	110	110	103
Adjusted R^2	0.935	0.949	0.958	0.959	0.959	0.961	0.762	0.849	0.865	0.868	0.878	0.880

Note: All log-transformed variables are indicated with (log). ϕ_r represents NUTS2 region fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. For Specification (1), (2), (3), (7), (8) and (9) standard errors are reported in parentheses and clustered at the province (NUTS3) level. For Specification (4), (5), (6), (10), (11), (12) bootstrap standard errors (10,000 replications) are reported in parentheses.

Table 3: North-South divide: major Roman roads and current transport infrastructure

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Current infrastructure in km (log)		*Railways*			*Motorways*	
`North` $* \tilde{\mathcal{RR}}_i$ (residuals of (1) Table 1)	0.609^{**}	0.565^{**}	0.511^{*}	0.628^{***}	0.525^{**}	0.606^{***}
	(0.262)	(0.266)	(0.300)	(0.252)	(0.238)	(0.227)
`South` $* \tilde{\mathcal{RR}}_i$ (residuals of (1) Table 1)	0.689^{***}	0.655^{***}	0.613^{**}	0.858	0.840	0.966
	(0.213)	(0.230)	(0.272)	(0.675)	(0.649)	(0.737)
`Elevation` (log)	0.323^{**}	0.243	0.228	-0.066	-0.217	-0.120
	(0.154)	(0.169)	(0.201)	(0.240)	(0.249)	(0.290)
`% of mountainous territory` (log)	-0.238^{**}	-0.190^{*}	-0.185	0.045	0.123	0.109
	(0.106)	(0.106)	(0.119)	(0.137)	(0.131)	(0.155)
$\mathcal{M}_i$		0.128	0.118		0.293^{**}	0.269
		(0.110)	(0.126)		(0.151)	(0.187)
`Roman city` (dummy)		-0.067	-0.001		-0.221	-0.062
		(0.338)	(0.430)		(0.441)	(0.601)
`Post-Roman city` (dummy)		-0.399	-0.761		-0.862^{*}	-1.074
		(0.501)	(0.513)		(0.506)	(0.667)
$\mathbf{H}_i$	NO	NO	YES	NO	NO	YES
ϕ_r	YES	YES	YES	YES	YES	YES
`North` (dummy)	YES	YES	YES	YES	YES	YES
Observations	103	103	103	110	110	103
Adjusted R^2	0.959	0.959	0.960	0.867	0.877	0.879

Note: All log-transformed variables are indicated with (log). ϕ_r represents NUTS2 region fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10,000 replications) are reported in parentheses.

Table 4: Medium-term effect: major Roman roads and urbanization

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Population (log) and			*Population*						*Numer of cities > 5,000 inhabitants*			
number of cities	*in 1300*	*in 1300*	*in 1600*	*in 1600*	*in 1861*	*in 1861*	*in 1300*	*in 1300*	*in 1600*	*in 1600*	*in 1861*	*in 1861*
$\tilde{\mathcal{RR}}_i$ (residuals of (1) Table 1)	0.298***	0.302**	0.284***	0.277**	0.334***	0.288*	0.443*	0.428	0.481**	0.459	0.531	0.748
	(0.108)	(0.130)	(0.110)	(0.144)	(0.112)	(0.155)	(0.230)	(0.271)	(0.236)	(0.329)	(0.532)	(0.859)
$\mathcal{M}_i$	0.232**	0.231**	0.390***	0.391***	0.339***	0.331***	0.309	0.325	0.354	0.371	1.673**	1.723**
	(0.098)	(0.102)	(0.088)	(0.089)	(0.068)	(0.072)	(0.274)	(0.297)	(0.329)	(0.372)	(0.729)	(0.873)
`Roman city` (dummy)	-0.691***	-0.663**	-0.451*	-0.349	-0.593***	-0.448	-0.614	-0.617	-0.824*	-0.795	-1.953*	-1.768
	(0.264)	(0.288)	(0.244)	(0.300)	(0.239)	(0.297)	(0.518)	(0.632)	(0.446)	(0.568)	(1.148)	(1.699)
`Post-Roman city` (dummy)	-0.295	-0.258	-0.646	-0.962	-0.240	-0.281	-0.500	-0.568	-0.996	-1.205	1.058	0.997
	(0.309)	(0.359)	(0.415)	(4.447)	(0.272)	(0.374)	(0.485)	(0.555)	(0.716)	(0.918)	(1.280)	(1.754)
`Elevation` (log)	-0.032	-0.022	-0.438***	-0.415**	-0.091	-0.105	0.127	0.133	-0.300	-0.283	-0.535	-0.551
	(0.200)	(0.241)	(0.141)	(0.177)	(0.119)	(0.146)	(0.319)	(0.372)	(0.354)	(0.429)	(0.842)	(1.086)
`% of mountainous territory` (log)	0.029	0.045	0.155**	0.151	0.024	0.021	0.015	0.014	0.190	0.205	0.663	0.778
	(0.095)	(0.102)	(0.070)	(0.075)	(0.078)	(0.086)	(0.170)	(0.182)	(0.189)	(0.219)	(0.542)	(0.676)
$\mathbf{H}_i$	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
ϕ_r	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	82	82	81	81	95	95	96	96	96	96	96	96
Adjusted R^2	0.962	0.961	0.966	0.967	0.971	0.969	0.714	0.697	0.723	0.704	0.761	0.734

Note: All log-transformed variables are indicated with (log). ϕ_r represents NUTS2 region fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10,000 replications) are reported in parentheses.

Table 5: North-South divide: all Roman roads and current transport infrastructure

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Current infrastructure in km (log)		*Railways*			*Motorways*	
`North` $*\tilde{\mathcal{RR}}_i$ (residuals of (6) Table 1)	0.647***	0.588**	0.497	0.677***	0.498*	0.517*
	(0.255)	(0.276)	(0.340)	(0.254)	(0.276)	(0.303)
`South` $*\tilde{\mathcal{RR}}_i$ (residuals of (6) Table 1)	1.018***	1.060***	1.066***	1.065***	1.070**	1.955***
	(0.181)	(0.235)	(0.266)	(0.475)	(0.237)	(0.774)
`Elevation` (log)	0.295**	0.223	0.217	-0.115	-0.270	-0.148
	(0.136)	(0.159)	(0.190)	(0.243)	(0.237)	(0.282)
`% of mountainous territory` (log)	-0.235**	-0.198**	-0.201*	0.047	0.124	0.082
	(0.102)	(0.097)	(0.111)	(0.143)	(0.128)	(0.162)
$\mathcal{M}_i$		0.087	0.083		0.269*	0.234
		(0.111)	(0.116)		(0.156)	(0.205)
`Roman city` (dummy)		-0.164	-0.092		-0.342	-0.253
		(0.319)	(0.392)		(0.428)	(0.524)
`Post-Roman city` (dummy)		-0.467	-0.851		-0.849	-1.285**
		(0.541)	(0.556)		(0.527)	(0.653)
$\mathbf{H}_i$	NO	NO	YES	NO	NO	YES
ϕ_r	YES	YES	YES	YES	YES	YES
`North` (dummy)	YES	YES	YES	YES	YES	YES
Observations	103	103	103	110	110	103
Adjusted R^2	0.959	0.959	0.961	0.870	0.878	0.889

Note: All log-transformed variables are indicated with (log). ϕ_r represents NUTS2 region fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10,000 replications) are reported in parentheses.

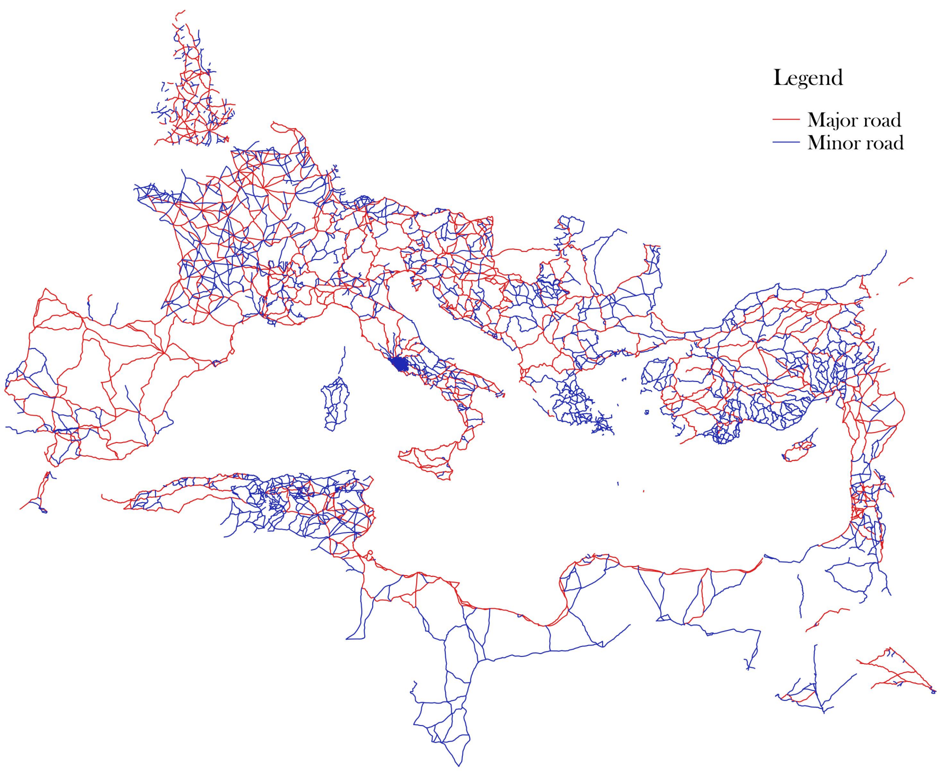
Table 6: Historical dynamics of major Roman roads

Dependent variable:	(1)	(2)
Current infrastructure in km (log)	*Railways*	*Motorways*
Historical dynamics of major $\mathcal{RR}_i$ (fitted values of Equation (3))	0.657***	0.803***
	(0.222)	(0.289)
`Elevation` (log)	0.236	-0.137
	(0.202)	(0.300)
`% of mountainous territory` (log)	-0.208*	-0.106
	(0.109)	(0.150)
$\mathcal{M}_i$	0.112	0.265
	(0.111)	(0.168)
`Roman city` (dummy)	-0.132	-0.240
	(0.393)	(0.566)
`Post-Roman city` (dummy)	-0.782	-1.106
	(0.567)	(0.709)
$\mathbf{H}_i$	YES	YES
ϕ_r	YES	YES
Observations	103	103
Adjusted R^2	0.962	0.880

Note: All log transformed variables are indicated with (log). ϕ_r represents NUTS2 region fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors are reported in parentheses (10,000 replications).

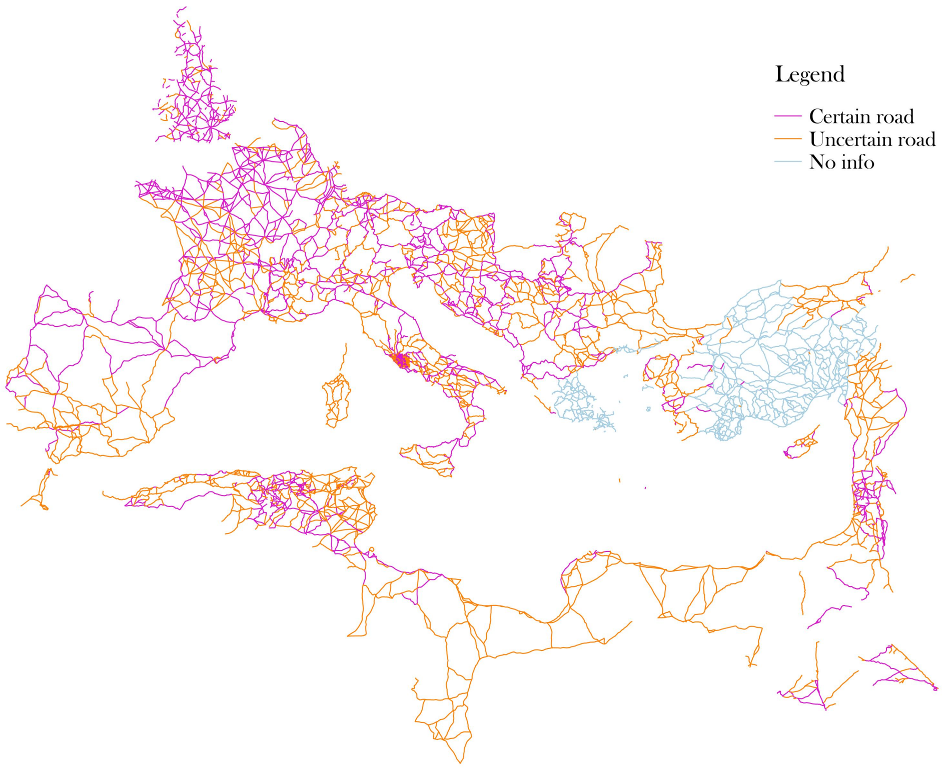
Appendix A - Additional figures and tables

Figure A.1: Roman roads by importance: major and minor roads



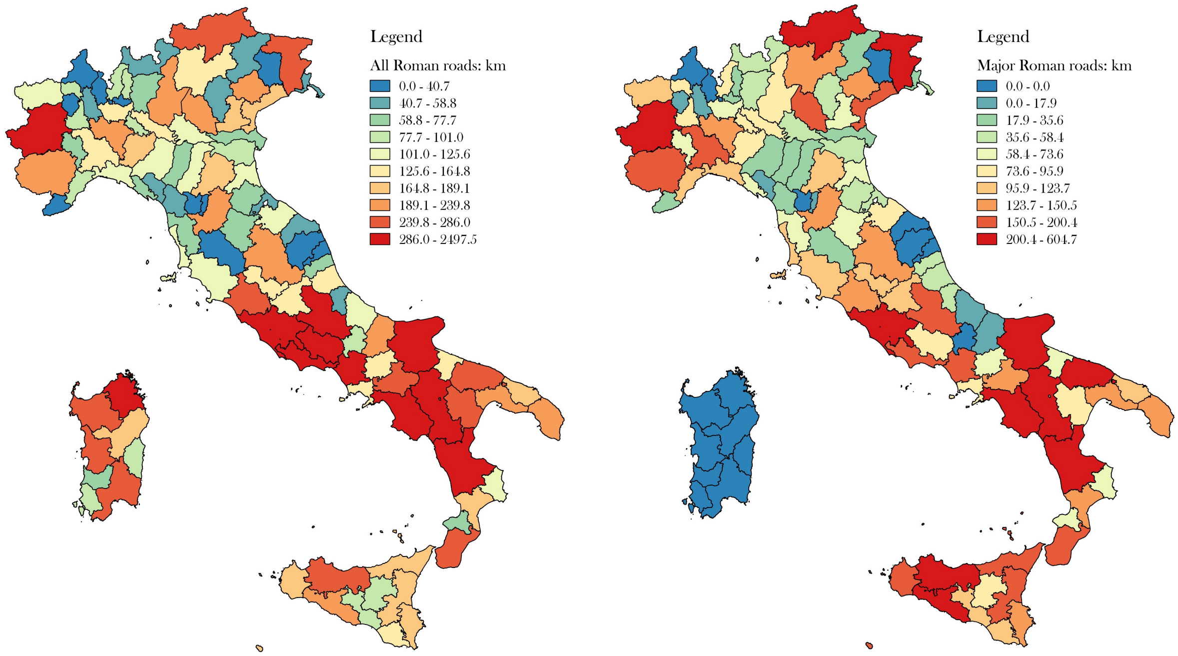
Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5

Figure A.2: Roman roads by certainty: certain and uncertain roads



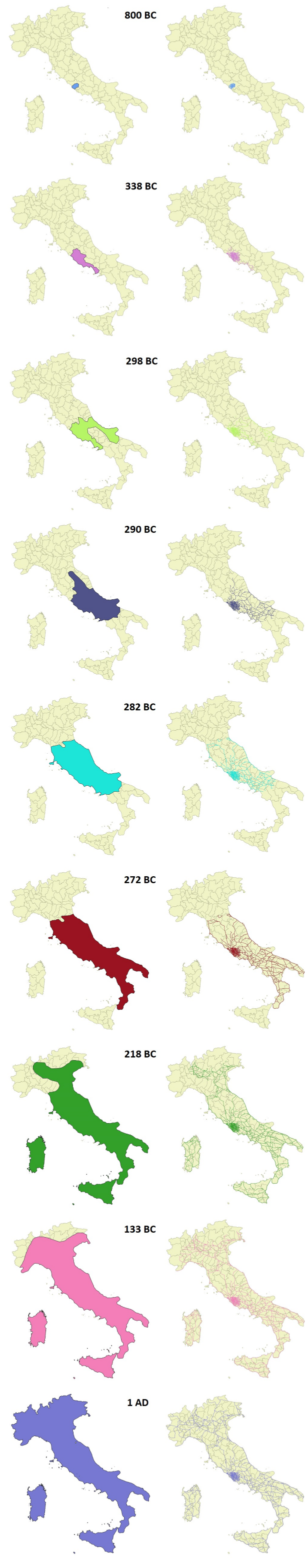
Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5

Figure A.3: Roman roads in length by Italian province



Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5 and from Istat (2011)

Figure A.4: Roman Empire and road network expansion: by period view



Source: Authors' elaborations

Table A.1: Data and sources

Variables	*Definition*	*Years*	*Source*	*Available for*
Major Roman roads (km)	Kilometers of major Roman roads	117 A.D.	Licio's (2021) creation from McCormick *et al.* (2013) shape file	110 provinces
All Roman roads (km)	Kilometers of all Roman roads	117 A.D.	Licio's (2021) creation from McCormick *et al.* (2013) shape file	110 provinces
Major Roman roads historical dynamic	Major Roman roads as a simple result of Roman Empire enlargement in 9 periods/steps	117 A.D.	Authors' creation from McCormick *et al.* (2013) shape file and from Running Reality	110 provinces
Railways (km)	Kilometers of current railways	2005	Istat	110 provinces
Railways (shape file)	Linear shape file of Italian railways	Modern	Diva-GIS	Italy
Motorways (km)	Kilometers of current motorways	2011	Automobile Club d'Italia (ACI)	110 provinces
Motorways (shape file)	Linear shape file of Italian motorways	2009	OpenStreetMap	Italy
% of mountainous territory	Percentage of mountainous territory	Time invariant	Istituto Tagliacarne	110 provinces
Mountain	Dummy variable: 1 if the mean elevation of the grid cell is ≥ 700	Time invariant	Authors' creation from Jarvis *et al.* "Hole-filled seamless SRTM data V4" , International Centre for Tropical Agriculture (CIAT)	10x10 km grid cells
Hill	Dummy variable: 1 if the mean elevation of the grid cell is ≥ 300, but <700	Time invariant	Authors' creation from Jarvis *et al.* "Hole-filled seamless SRTM data V4" , International Centre for Tropical Agriculture (CIAT)	10x10 km grid cells
Plain	Dummy variable: 1 if the mean elevation of the grid cell is <300	Time invariant	Authors' creation from Jarvis *et al.*"Hole-filled seamless SRTM data V4" , International Centre for Tropical Agriculture (CIAT)	10x10 km grid cells
Elevation	Elevation in meters	Time invariant	Istat	110 provinces
Elevation	Elevation in meters	Time invariant	Authors' creation from Jarvis *et al.* "Hole-filled seamless SRTM data V4" , International Centre for Tropical Agriculture (CIAT)	10x10 km grid cells
(Mediterranean) Sea	Dummy variable: 1 if at least one segment of the transport infrastructure inside the grid cell is within 2 km from the seacoast	Time invariant	Authors' creation	10x10 km grid cells
River	Dummy variable: 1 if at least one segment of the transport infrastructure inside the grid cell has a river within 2 km	Time invariant	Authors' creation from OpenStreetMap	10x10 km grid cells
Pre 1500 relative cropland suitability	Mean cropland suitability of the grid cell relative to the average of the mean cropland suitability of all grid cells belonging to the same province	Pre 1500 C.E	Authors' creation from Galor and Özak (2016)	10x10 km grid cells
Post 1500 relative cropland suitability	Mean cropland suitability of the grid cell relative to the average of the mean cropland suitability of all grid cells belonging to the same province	Post 1500 C.E	Authors' creation from Galor and Özak (2016)	10x10 km grid cells
Lakes and rivers	Watercourses and basins	Time invariant	Corine Land Cover	Italy
Pre-Roman city	Dummy variable: 1 if the provincial capital was important before the Romans	Before Roman Empire	Authors' creation from Wikipedia	110 provinces
Roman city	Dummy variable: 1 if the provincial capital was made important by the Romans	During Roman Empire	Authors' creation from Wikipedia	110 provinces
Post-Roman city	Dummy variable: 1 if the provincial capital became important after the Romans	After Roman Empire	Authors' creation from Wikipedia	110 provinces
Pre-Roman amenities	Dummy variable: 1 if in the provinces were present settlements or settlements equipped by civil infrastructures before the Romans	Before 30 B.C.	Authors' creation from Pleiades	110 provinces
Municipalities on Roman roads	Number of municipalities on a major Roman road and with a population over 50,000 inhabitants	2011	Authors' creation from Istat	110 provinces
Urban population in 1300	Total population of urban centers with over 5,000 inhabitants	1300	Malanima (2015)	96 provinces
Urban population in 1600	Total population of urban centers with over 5,000 inhabitants	1600	Malanima (2015)	96 provinces
Urban population in 1861	Total population of urban centers with over 5,000 inhabitants	1861	Malanima (2015)	96 provinces
Number of cities in 1300	Number of urban centers with over 5,000 inhabitants	1300	Malanima (2015)	96 provinces
Number of cities in 1600	Number of urban centers with over 5,000 inhabitants	1600	Malanima (2015)	96 provinces
Number of cities in 1861	Number of urban centers with over 5,000 inhabitants	1861	Malanima (2015)	96 provinces
Normans	Number of years of the Norman domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Swabians	Number of years of the Swabian domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Anjou	Number of years of the Anjou domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Spain	Number of years of the Spanish domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Bourbons	Number of years of the Bourbon domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Papal State	Number of years of the Papal domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Venice	Number of years of the Venetian domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Austria	Number of years of the Austrian domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces
Savoy	Number of years of the Savoy domination	1100-1700	Di Liberto and Sideri (2015)	110 provinces

Source: Authors' elaborations

Table A.2: Roman roads and geography: 10x10 km grid cell analysis

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Roman roads in km (log)		*Major*				*All*		
Grid cells	All	Mountain	Hill	Plain	All	Mountain	Hill	Plain
`Elevation` (log)	0.100***	-0.748	-0.980***	0.169***	0.069**	-0.735**	-0.796***	0.217***
	(0.037)	(0.513)	(0.358)	(0.047)	(0.031)	(0.366)	(0.287)	(0.036)
`Sea` (dummy)	0.139	-	-0.238	0.182	0.127	-	-0.104	0.184*
	(0.108)	-	(0.216)	(0.133)	(0.086)	-	(0.193)	(0.096)
`River` (dummy)	0.399***	-0.202	0.294	0.497***	0.449***	0.163	0.425**	0.479***
	(0.085)	(0.360)	(0.189)	(0.105)	(0.073)	(0.281)	(0.177)	(0.088)
`Cropland suitability` (log)	-0.057	-0.217	1.685*	-0.634**	-0.159	-0.168	1.164	-0.438*
	(0.188)	(0.366)	(0.958)	(0.328)	(0.173)	(0.301)	(0.962)	(0.268)
ϕ_p	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,310	173	301	836	2,043	275	524	1,244
R^2	0.708	0.725	0.779	0.730	0.712	0.764	0.738	0.754
Adjusted R^2	0.685	0.662	0.722	0.698	0.695	0.715	0.690	0.731

Note: All log-transformed variables are indicated with (log). `Elevation` is the elevation in the 10x10 *km* grid cell. For each cell the elevation in meters is computed using geotiff data from Jarvis *et al.* (2008), `http://srtm.csi.cgiar.org`. Sea is a dummy that takes the value of 1 if at least one segment of the Roman road infrastructure inside the grid cell is within 2 *km* from the Mediterranean seacoast. River is a dummy that takes the value of 1 if at least one segment of the Roman road infrastructure inside the grid cell is constructed within 2 *km* from a river. `Cropland suitability` measures the mean cropland suitability of the 10x10 *km* grid cell (according to the geotiff data of the Caloric Suitability Index by Galor and Özak (2016), `https://ozak.github.io/Caloric-Suitability-Index/`) relative to the average cropland suitability of all grid cells included in the same province. ϕ_p represents NUTS3 province fixed effects. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Robust standard errors are reported in parentheses.

Table A.3: Current transport infrastructure and geography: 10x10 km grid cell analysis

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Current infrastructure in km (log)		*Motorways*				*Railways*		
Grid cells	All	Mountain	Hill	Plain	All	Mountain	Hill	Plain
`Elevation` (log)	0.005	-2.114*	-0.385	0.169**	0.064**	-2.137***	-0.203	0.208***
	(0.057)	(1.174)	(0.469)	(0.078)	(0.027)	(0.391)	(0.249)	(0.038)
Sea (dummy)	0.281*	-	0.181	0.340**	0.145*	-	0.032	0.183*
	(0.160)	-	(0.455)	(0.172)	(0.087)	-	(0.319)	(0.096)
River (dummy)	0.364***	-0.373	0.190	0.478***	0.366***	0.273	0.389***	0.344***
	(0.106)	(0.657)	(0.425)	(0.118)	(0.062)	(0.202)	(0.142)	(0.079)
`Cropland suitability` (log)	0.122	-0.428	4.490*	-0.497	0.050	-0.735***	-0.790	-0.814***
	(0.394)	(0.691)	(2.614)	(0.542)	(0.127)	(0.220)	(0.745)	(0.322)
ϕ_p	YES	YES	YES	YES	YES	YES	YES	YES
Observations	897	98	178	621	2,202	297	570	1,335
R^2	0.779	0.817	0.805	0.804	0.736	0.806	0.771	0.749

Note: All log-transformed variables are indicated with (log). All variables as previously described. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Robust standard errors are reported in parentheses.
Results are confirmed if NUTS2 region rather NUTS3 province fixed effects are included. Since both motorway and railway planning usually occurs at the regional level, the use of region fixed effect is more suitable in analyses about the current infrastructure.

Table A.4: Major Roman roads and current transport infrastructure: 10x10 km grid cell analysis

Dependent variable:	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
Current infrastructure (dummy)			*Railways*					*Motorways*		
Grid cells	All		Mountain	Hill	Plain	All		Mountain	Hill	Plain
`Major Roman roads` (dummy)	0.408***		0.357***	0.262***	0.387***	0.283***		0.247***	0.224***	0.285***
	(0.012)		(0.028)	(0.032)	(0.017)	(0.010)		(0.023)	(0.024)	(0.019)
`Mountain` * `Major Roman roads` (dummy)		0.295***					0.254***			
		(0.034)					(0.027)			
`Hill` * `Major Roman roads` (dummy)		0.310***					0.241***			
		(0.026)					(0.021)			
`Plain` * `Major Roman roads` (dummy)		0.475***					0.303***			
		(0.016)					(0.012)			
Intercept	0.437***	-	0.256***	0.468***	0.565***	0.217***	-	0.141***	0.210***	0.333***
	(0.006)	-	(0.012)	(0.013)	(0.009)	(0.006)	-	(0.011)	(0.012)	(0.010)
ϕ_p	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	5,111	5,111	1,154	1,213	2,410	4,197	4,197	739	840	1,889

Note: Probit estimates; marginal effects presented in the table. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Robust standard errors are reported in parentheses.

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Appendix B - The exogeneity of the Roman road network

As generally applies, the exogeneity of the Roman road infrastructure must be placed under scrutiny.[1] Roman roads might have been constructed for military purposes (major roads) but it cannot be ruled out that some of them and some minor roads were built to reach economically prosperous and flourishing territories, and that these conditions could well have lasted up to the present day.[2]

B.1 - Why did Romans build roads? The 'military reason'

As reported in the Dictionary of Greek and Roman Antiquities, "*The public road-system of the Romans was thoroughly military in its aims and spirit: it was designed to unite and consolidate the conquests of the Roman people, whether within or without the limits of Italy proper*" (Smith, 1890). Even after construction, it had no significant immediate economic impact, since the cheaper modes of goods' transport in that historical epoch were by river or sea (Finley, 1973). More specifically, as Laurence (1999) clearly explains, roads were planned and designed to provide troops with the essential means in terms of subsistence and support, to guarantee an efficient repositioning and to facilitate armies' movements. Because of this original purpose, roads were straight, as level as possible, often stone-paved, cambered for drainage, equipped with safe stops along the way.[3]

[1] A considerable amount of time elapses between planning a road and its actual completion (Brooks and Hummels, 2009). From this perspective, road infrastructure can be considered as an exogenous variable. The case of old infrastructure would appear to be different. Donaldson (2018) argues that the effect of historical transportation infrastructure is characterized by a potential simultaneity problem: roads and railways are often constructed to connect regions already active in trade, while inter-regional trade relations are often forged after the construction of infrastructure or road improvements.

[2] Chevallier (1976, p. 116) points out that "*As a rule, earlier sites were avoided by Roman roads, especially the great Imperial highways, which were unconcerned with local interests and small settlements. [...] The road often attracted the village, but when the ancient road itineraries name a civitas, it does not mean that the route went through the town itself: occasionally it simply skirts its territory*". Bosker *et al.* (2013) support the view that the reverse causality is not an issue in the case of Roman roads, since they favored the subsequent expansion of urban centers in those territories where roads passed through, rather than being constructed for already existing settlements.

[3] The 'military reason' is also strongly supported by the Latin literature. "*After having pacified Liguria, Aemelius had his army build a road from Piacenza to Rimini to join the via Flaminia*" (Livy, 59 B.C.-17 A.D.). In his 'Encyclopedia of antiquities, and elements of archaeology, classical and medieval,' Fosbroke (1843) reports that the Anglo-Saxon ancestors named the Roman roads 'military ways' and that they thought the construction of small roads had more military utility than large ones. Chevallier emphasizes the importance of the army's role in the case of main roads. He remarks that "*[...] the majority of main roads were pioneered by military operations. For example, on its return from the first Samnite war (343-40), the Roman army did not come back along the via Latina, but followed the coast through the territory of Aurunci, thus blazing the trail of the Appia on a line that had already been known to traders, at least since the hegemony of Etruria. In the early third century, operations*

The direction of the *Via Appia*[4] is a concrete example of its military purpose and how the ultimate aim to reach some strategic territories resulted in a long road that passed through areas of absolutely no interest to Romans, but that, nonetheless, benefited from the presence of the road.[5]

B.1.1 - The case of the *Via Appia* and the Greek target

The *Via Appia* was the first large strategic consular road. It connected Rome to Brundisium (modern Brindisi, Apulia). Started in 312 B.C, the road had the original tactical purpose to allow troops to be deployed outside the region of Rome during the Samnite Wars.[6] It was constructed in segments, following the progress of military campaigns, and was completed in 191 B.C., when it reached Brindisi (Berechman, 2003).

[Figure B.1]

During that time, the Roman Empire was comprised, as shown in the upper part of Figure B.1, in those territories belonging to the Latine League[7] and corresponding, today, to the provinces of Rome and Latina. Between 500 and 400 B.C. the Romans had already defeated their neighbors in central Italy (the Etruscans, Latins, Sabines, Lavinii, Tusculi, Aequi, Volsci, Aurunci and the Veientes), where a small area was under their control. At the end of the fifth century B.C. the Italian peninsula was under the control of the Celts and the Gauls in the North, the Romans in the central-western part, the Samnites and the Greek colonies (Magna Graecia) in the South. It was precisely at that time, that the Romans decided to build the first section of the *Via Appia* (lower part of Figure B.1) and started to show an interest in the southern part of Italy. Also the Samnites, an Italic population living in southern-central Italy, were interested in those territories. At first, the Romans and the Samnites concluded a non-aggression pact,

against the Umbrians of Mevania and Narnia and against the Senones took into account the route that became the Flaminia. Great strategic roads were built by the military in Gaul under Agrippa from BC 16-13 in Dalmatia and Pannonia under Tiberius from AD 6-9, in the Rhineland and the Danube valley under Claudius, and in Asia Minor under Flavians" (Chevallier, 1976, p. 85).

[4] See Berechman (2003) for a recent and in-depth description of the economics of the *Via Appia*.

[5] The Romans decided to build their first road south-easterly, although the economic development of the time was concentrated in the southwestern part of Italy in those territories corresponding today to the NUTS2 regions of Campania, Calabria and Sicily.

[6] Chambers's Encyclopedia, Vol. 1, p. 490.

[7] The Latine League is a term coined by modern historians, that identifies a coalition of villages and tribes settled in central Italy, surrounding Rome and that had the primary role in guaranteeing the mutual protection against external enemies (Cornell, 1995).

agreeing to expand their possessions in different directions, but this treaty was irremediably broken when these directions clashed. The Romans' intention was, first, to expand their territories in southern Italy (upper part of Figure B.2), to obtain new lands for the growing Roman population and to enter into commercial relationships with the Greek merchants (Musti, 1990), but, later, the ultimate challenge was the conquest of the Magna Graecia and extending their control over the Mediterranean Sea, where most of the trade occurred (Figure B.3).

[Figure B.2]

[Figure B.3]

In 238 B.C., the Romans controlled the entire central and southern parts of the Italian peninsula (upper part of Figure B.2), including the three main Mediterranean islands (Sicily, Sardinia and Corsica); at the same time, the *Via Appia* (lower part of Figure B.2) was extended southeastwards, reaching Brindisi. The Romans aimed to expand northwards (in those territories under the control of the Celts), into Gaul, Spain, North Africa and into Greece (upper part of Figure B.3). The stepwise extension of the *Via Appia* to Brindisi meant that the troops could sail from this port when they later conquested Epirus, landing on the Macedonian coast thanks to ally ports along the opposite coastline, like Durres. The lower part of Figure B.3 shows how the *Via Appia* facilitated the conquest of Greece.

Three facts emerge from the above description: 1) the instrumental role of roads in the military conquest of new territories; 2) the development and expansion of roads by strategic points: the Romans built new road segments starting from tactical cities or outposts (*Stationes*); 3) the stepwise construction of roads, with a view to future expansion. This suggests that some territories were crossed by Roman roads although the Romans themselves had no economic, military or tactical interest in those areas. In other terms, those territories benefited from the presence of Roman roads merely by chance, because they were situated midway between the origin of a road's segment and its strategic destination.

B.2 - How did Romans build roads? The 'engineering reason'

One remarkable engineering feature of the Roman network was its straight roads: the Romans drew straight lines between two strategic locations and built the road as segments connected to one another. Cornell and Matthews (1982) point out that the first step in road construction consisted of marking as straight as possible a path with stakes and furrows, employing sightlines as measuring tools.[8]

The rule that guided Romans in building roads is clearly explained by Lopez (1956, p. 17) who describes "*That the network of roads should be convenient and economic was none of their*[9] *business. That is why the Romans built narrow, precipitous roads along the mountain crests rather than the valley bottoms, sometimes driving straight for their goal over gradients of one in five*". Also Margary (1973) remarks that, in order to achieve as straight a line as possible, Romans built roads with steep slopes or passing through mountainous terrains. Bishop (2014), referring to Britain, quoting Hindle (1998) and Welfare and Swan (1995), emphasizes that long straight sections were a typical feature of the major Roman roads. However, even where variations in terrain morphology existed, the roads were still built in straight lines. Most of the non-major Roman roads exhibit some deviations from the main path. These variations in the course of the road were typically short and, rather than being curvy, they were subject to a change in the degree of the layout. This represents the typical feature that distinguishes Roman infrastructure from modern infrastructure.[10] Giving credit to historians' arguments, the straightness of the roads[11] is the best rule for drawing an old historical infrastructure.

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[8] The Romans preferred direct and straight roads, because with that outline it was easier to avoid ambuscades and human settlements. Moreover, straight roads were easier to secure (Gleason, 2013). As suggested by Poulter (2010) and as remarked by Bishop (2014), the Romans often did guard the beginning and end of the road; garrisons were typically placed at the top of a hill, and the road came along as the segment of a paved route connecting two garrisons. Von Hagen (1967), on the constitution of a mobile civilization throughout the continent, argues how this has been possible thanks to well-engineered and straight roads.

[9] Lopez (1956) refers to the Romans.

[10] In light of this, Bishop (2014) refers to the Roman roads as '*surveyed roads*' which originate from a geometric-linear perspective in conceiving the network. Current roads are, instead, in the words of Bishop (2014), more linked to the '*line of desire,*' since there is no geometric outline behind the planning of the network, but rather a preference to follow the shape of nature.

[11] The lines connecting two points in space, such as two main cities, are the focal point of the identification strategy of a strand of economic literature that started with the work of Banerjee *et al.* (2012). Straight lines capture the way the first modern transportation infrastructure was constructed, which by definition cannot be influenced by the actual level of development, whereas the infrastructure developed afterwards was built along historical routes. According to this reasoning, straight lines can be used as the optimal tool for guaranteeing access to infrastructure and to disentangle the areas that benefited from the infrastructure, due to their proximity to the line (treated areas), from those that did not, because of the distance (non-treated areas).

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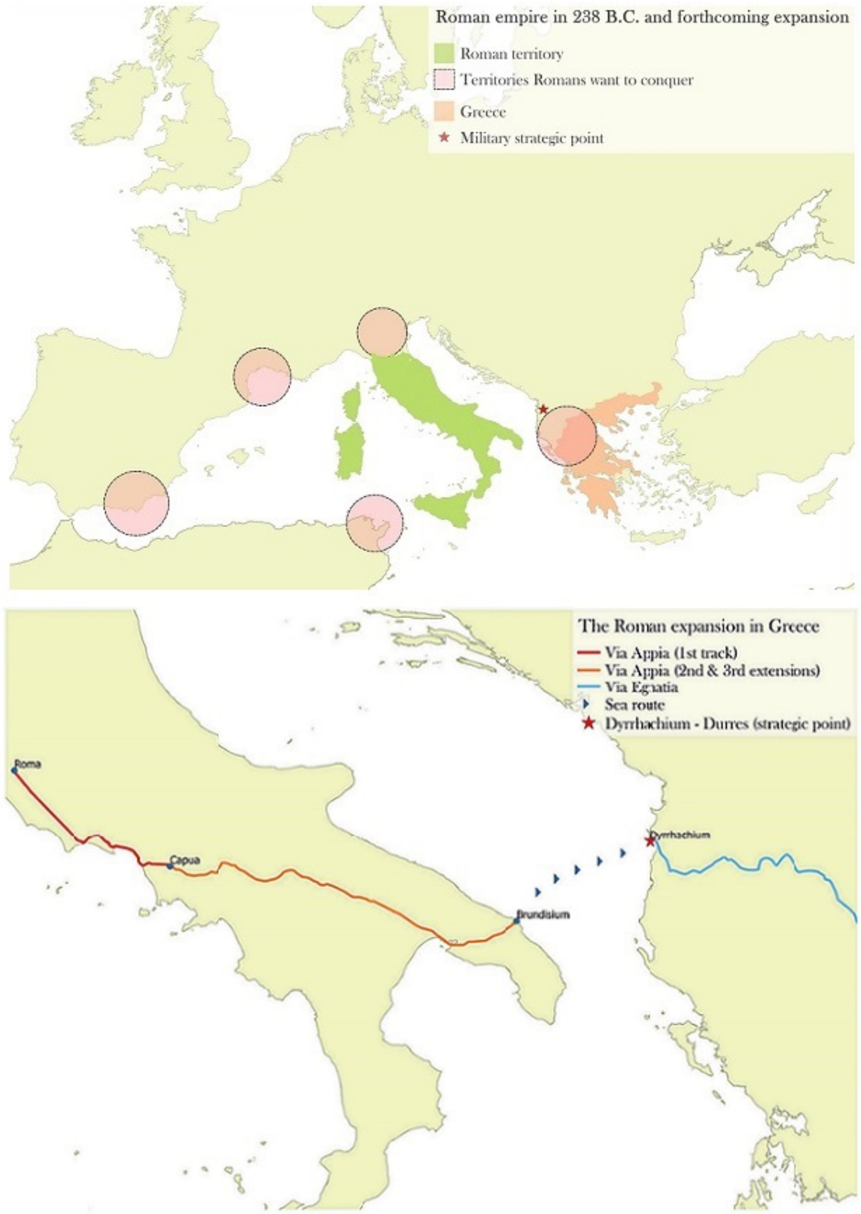
Figure B.1: Roman Empire and Via Appia in 312 B.C.

Source: Authors' drawing

Figure B.2: Roman Empire and Via Appia in 238 B.C.

Source: Authors' drawing

Figure B.3: Romans' expansionist objectives and the conquest of Greece



Source: Authors' drawing

Appendix C - Railways, motorways, and Roman roads: correspondence

The Italian North-South divide has been widely investigated by the economic literature, highlighting the strong cultural, economic, and social differences. This gap also pertains to the modern transport infrastructure. If the Roman road network was beneficial in creating a unified and connected Empire, modern railways and motorways did not have a similar effect. As observed by Ciccarelli and Fenoaltea (2013), the construction of railways before and after Italian unification did not play a role in promoting a homogeneous internal economy. When looking at roads, Cosci and Mirra (2018) find that the construction of motorways in Italy resulted in a polarization between North and South due to the insufficient investment in southern regions to overcome the gap.

C.1 - Railways

The first railway in Italy was constructed in the South in 1839, 22 years before Italian unification. It was 7 kilometers long and linked Naples to Portici. At the time, all of southern Italy, except for Sardinia, was under the realm of the Bourbons in what was called the Kingdom of the Two Sicilies. The king, Ferdinand II, promoted and ordered the construction of different railway lines; one of these linked Caserta to Capua.[1]

Jannattoni (1975) highlights that, in the small pre-unitary states, railways were not developed for economic or social purposes, but they served to allow the movement of the royal family and of the aristocracy. In a second step, they also served for military purposes. Indeed, the origins and destinations of the first railways in Italy were mainly royal palaces or military fortresses, and in the North and in the Center, the monarchy of the pre-unitary states also used the railways to reach their resort mansions. The need for connection with major ports only emerged after the construction of the first railways.

While the first railways were built in the South, the northern states quickly filled the gap. The Kingdom of Lombardy-Venice (under Austrian rule), the Kingdom of Sardinia (that included Piedmont and Savoy), the Grand Duchy of Tuscany, among others, were entirely devoted in linking their main strategical points, and in 1861, when Italy became a unified country, an

[1] In the same geographical area more than 2,000 years before, the first and most important consular Roman road, the *Via Appia*, was constructed: the first portion of the Appian Way linked Rome to Capua.

impressive railway system was developed in Piedmont (Forghieri, 1997). The Kingdom of Sardinia and the House of Savoy represented the efficient government and the strong monarchy under which the unification process consolidated. And this was possible thanks to the active leadership and well-planned administration of its Prime Minister.[2] Indeed, Camillo Benso Count of Cavour, Prime Minister of the Kingdom of Piedmont-Sardinia from 1852 to 1859, can be considered the main creator of railway politics, supporting the design and construction of the main Italian railway routes (Guadagno, 1996). He knew that the construction of the railway system was fundamental for Italian independence and identified the main rail transport networks (the West-East route, from the port of Genova to Venice, and the North-South line that linked the northern regions with Rome and the port of Taranto) delineating in this way the "T-shape" of the current Italian railway system. In this sense, in the Italian unification process, railways had a fundamental role as a symbol of cohesion and unity.[3]

In 1861, after the proclamation of the Kingdom of Italy, two issues emerged immediately: the construction of new lines in those regions where no railway system existed and the management of all the private firms, small and large, involved in constructing the railway (Guadagno, 1996).

The design and the construction of the new railway links relied totally on private concessionaires, with the new Italian government simply maintaining the role of monitoring. However, due to the lack of central planning and organization, many lines were designed and constructed in a way that was far from being efficient (Forghieri, 1997; Guadagno, 1996).[4] Nevertheless, the major political and economic effort devoted to the project led to a significant expansion of the rail network: from 2,169 kilometers in 1860 to 6,183 in 1870 (Guadagno, 1996). In 1885 the network reached 10,602 kilometers: Italy was connected via tunnel to the rest of Europe and this boosted its trade.

Due to the inefficiencies and increasingly negative returns of the private concessionaires, in 1905 the railway sector was nationalized and the state-owned *Ferrovie dello Stato* was founded. During this last phase of the Italian railway development, the central government assumed all responsibilities and the management of 10,600 kilometers of railways. In later years the network

[2] Dincecco *et al.* (2011) suggest that the investment in the railway system by the Savoy government was mainly driven by the unification military campaign.

[3] Rebagliati and Dell'Amico (2011).

[4] As highlighted by Guadagno (1996), the irregular and uncontrolled development of the railways during the nineteenth century was mainly due to the strong relationship between war spending and public spending: the construction of new railways was driven by military requirements rather than economic or development reasons.

was further expanded and several issues became the priority of the State: modernization of locomotives and carriages, construction of double-track railway lines, train speed, unscheduled delays.

C.2 - Motorways

In 1924, less than 100 years after the construction of the first railway in Italy, the first Italian motorway was inaugurated. From Varese to Milan, the one-lane motorway,[5] called *Motorway of Lakes* (*Autostrada dei Laghi*), was a toll road, built for the primary purpose of connecting two locations in the fastest way possible, according to the current definition of motorway. The *Motorway of Lakes* set another record: it was also the first European motorway (Moraglio, 2017). However, until World War II, expansion of the network was limited due to the slow development of motorization in Italy and the upcoming economic crises (Benfratello *et al.*, 2006). Indeed, the decision that led the government to invest in motorways was the big gap existing in terms of roads between Italy and the other western European countries.

During fascism, several motorways were opened. Apart from Napoli-Pompei, in the South, and Firenze-Mare, in central Italy, all the others were constructed in the North. They were relatively easy to construct because of the flat areas in northern Italy.

It was in 1948 with the establishment of the National Autonomous Roads Corporation (ANAS, *Azienda Nazionale Autonoma delle Strade Statali*) and with the so-called Romita law of 1955, that set up the first national program for motorways, that the motorway expansion gained new impetus. This was essentially driven by the need to support the economic development, occupation and inequality in the country. Indeed, post-war politics was strongly committed to developing and improving the Italian transport network, making the construction of new motorway routes the focal point of the administration (Cosci and Mirra, 2018). Moreover, during World War II the road infrastructure was destroyed and damaged and the need to restore the network was a compelling challenge for the country. At that time, motorways only covered 311 kilometers (Greco, 2005), but in just twenty years, the network increased from about 500 kilometers in 1955 to 5,500 kilometers in 1975.

The first impressive challenge for Italian engineering was, however, the planning and construction of the so-called *Autostrada del Sole*. Started in 1956 and completed in 1964, the "Sun

[5] One lane for each direction.

Motorway", from Milan to Naples, had a strategical role for the peninsula. It connected the North to the South, linking the major cities: Bologna, Florence, Rome. Its role was not trivial. As observed by Iuzzolino *et al.* (2011), the North-South divide and the strong differences in regional development are the consequence of the impact played by the infrastructure in shaping human geography and economic activity. Moreover, Cosci and Mirra (2018) highlight that the limited trade within the southern regions is the result of the lack of transport infrastructure and unfavorable geography.

During the Italian economic miracle, the motorway network underwent exponential expansion. However, as clearly explained by Greco (2005), in the early Seventies, due to the oil crisis, the financial problems faced by some companies and other internal factors, motorway industry slumped. The government decided to halt the construction of new motorways and only already planned routes were allowed to be completed. However, the new decision did not had an immediate effect and network expansion only stopped in 1980.[6] From 1980 onwards only planned lines were built or improved.

C.3 - Correspondence

The overlap or correspondence of the modern transport infrastructure with the ancient one is linked with the mechanism of persistence of history. Historians have a twofold view about the maintenance of Roman roads after the fall of the Western Roman Empire. According to Bairoch (1988) or Lopez (1956) Roman roads did not play a central role in medieval trade and, therefore, most of them were not preserved to allow the passage of carts. On the other hand, Glick (1979) or Hitchener (2012) argue that Roman roads in Europe were maintained during the Middle Ages for horse-drawn carriages. This is consistent with the results emerging from Wahl (2017) that confirm that both German primary roads and motorways follow the course of Roman roads.

Starting from these views, Figure C.1 and Figure C.2 adopt GIS methods to understand the degree of overlap between old and modern infrastructure, using three different buffer zones traced around the Roman road network: 500 meters, 1 kilometer and 2 kilometers. In his analysis, Wahl (2017) considers grids of 10 and 5 kilometers. Accordingly, Dalgaard *et al.* (2018), in documenting the positive correlation between modern and Roman roads, exploit buffer zones of

[6] In 1978 the political class realized that the improvement of the motorway system could not be disregarded, but investment in transport infrastructure had lost its priority and its anti-recession role, resulting in delays in the completion of new motorway sections (Greco, 2005).

5 kilometers. However, because of the geography of the Italian territory, mainly composed of hills and mountains, the choice of narrower buffer areas is more suitable as it provides a more precise analysis. The left part of Figure C.1 shows modern railways together with all Italian Roman roads (both major and minor).[7] The right part, instead, zooms on a specific part of the map showing the three buffer zones with a railway track and a segment of Roman road. Figure C.2 focuses on motorways and consular Roman roads.[8] The choice of comparing all Roman roads with railways and only major Roman roads with motorways, respectively, lies in the features of the two transport systems: railways connect both large and smaller urban centers; motorways, instead, ensure the movement of people and goods in the fastest way possible, linking only the main cities.

[Figure C.1]

[Figure C.2]

Interesting results emerge. Almost 20% of Italian railways overlap the Roman segment lines in a very narrow buffer zone (500 *m*); 12% when looking at the correspondence between motorways and consular roads. For a wider buffer area (1 *km*), the overlap between Roman roads and railways and between major Roman roads and motorways is 39% and 25%, respectively.[9] When taking into account a buffer zone of 2 *km*, instead, the degree of overlap between the old and the modern transport infrastructure is 74% for railways and 48% for motorways. Consistently with the results of Wahl (2017) and Dalgaard *et al.* (2018), these percentages confirm that also in Italy modern transport infrastructure is often laid out on old Roman roads and the degree of correspondence can be even greater when larger areas are accommodated. The existence of previous road routes (in use or abandoned) facilitated the building of modern transport networks, representing a starting point for constructing first railways and then motorways.

[7] The linear shape file of the Italian railways comes from Diva-Gis (`https://www.diva-gis.org/gdata`).

[8] The linear shape file of the Italian motorways comes from OpenStreetMap.

[9] Percentages are rounded to the nearest full point since the linear shape file of motorways from OpenStreetMap includes for almost all segments both lanes of traffic. In computing the degree of overlap this aspect has been correctly taken into account; however, in order to provide a result that is as fair as possible, percentages are reported without decimals.

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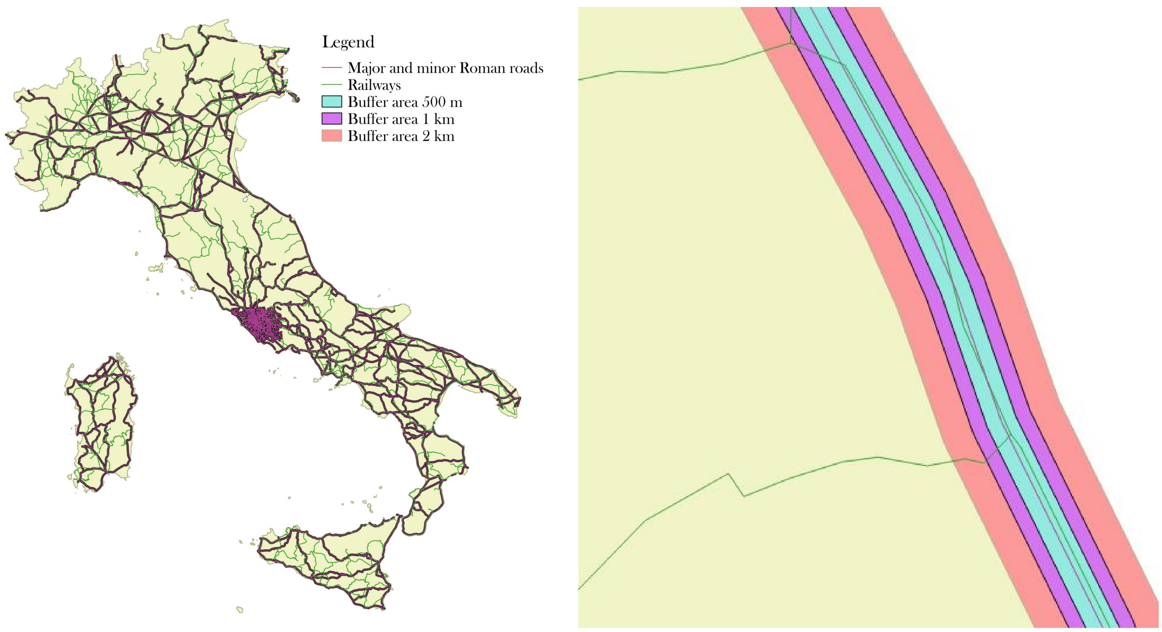
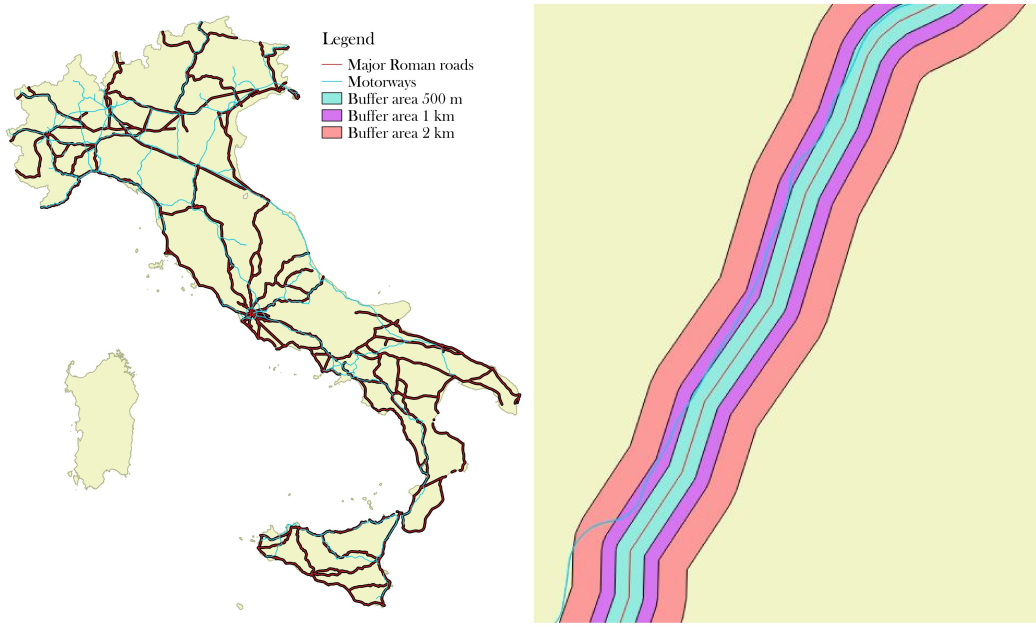
Figure C.1: Roman roads and railways intersection: buffer analysis



Source: Authors' drawing from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5, Diva-GIS and from Istat data (2011)

Figure C.2: Major Roman roads and motorways intersection: buffer analysis



Source: Authors' drawing from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5, Open Street Map and from Istat data (2011)

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