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 old infrastructure had an influence on the current one.

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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 impacts on growth and economic development have been widely discussed in the literature. This study aims to answer three main questions: i) Is material infrastructure denser in those territories that inherited more of it from the past?; ii) Do motorways and railways follow or superimpose old roads?; iii) How much the orography of a territory can explain an overlapping and how much can be, instead, ascribed to economic development, such as the rise and expansion of cities whose development calls for connectedness?

This paper offers a new contribution on this very point, focusing on the Italian case.[1] Italy represents an ideal case: it is where the historical Roman road network, one of the largest investments in infrastructure in history, had its denser presence and where it started its expansion. The Roman Empire had its core in Italy and the entire national territory was endowed with roads. To use an epidemiological terminology, Rome can be thought as 'point source outbreak' of the Roman conquest pattern, which took several centuries to unfold. In 238 B.C. central, southern and part of northern Italy were under Roman dominion, well before the expansion to non-Italic lands started. In 42 B.C. the conquest of the current Italian territory was completed. This aspect introduces an interesting element of analysis to the paper, that has to do with the economic fortunes of Italy today. The Italian economic and social dualism (a high-developed North-Center and a less-developed South) can be attributed to historical episodes and dominations that happened after 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.[2]

[1] To deeply exploit the spatial variation in infrastructure at the greatest possible territorial detail, this paper relies on a meso approach (see Michalopoulos and Papaioannou, 2018).

[2] 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). Indeed, the provincial level represents a good geographical disaggregation to measure differences across Italy.

Though central government has the main influence in determining institutions, the national set of rules work differently in the North and in the South of the country, suggesting that specific local factors affect the institution's functioning. In view of this, the idea at the heart of this work is basically that Roman roads have positively affected current transport systems, regardless of the variety of historical paths which insisted on the Italian territory: the Roman network was widespread in the whole territory and its presence is associated to urban development. As in Wahl (2017), the transmission mechanism, that links past to present, reveals the enduring effect of the Roman road network, fostering city growth and a denser infrastructure.

Following the strand of research that quantifies the long-term effects of historical events on current development (Nunn, 2009), and exploiting the availability of new historical data, the paper follows the line of investigation of Temin (2013), and of the works by Michaels and Rauch (2018), Wahl (2017) and Dalgaard *et al.* (2018). The evidence here provided develops on two dimensions: the persistent effect of history and the mechanism linking past with present.

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 only to labor productivity forces and balances between rural and town areas. Bosker *et al.* (2013) allow for the nature of a city geographical location, where the fact of being connected to a major Roman road or to a Roman hub makes the difference when accounting for the possibility of the smaller cities of 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. Still the above analyses do not focus on the interconnected process of ancient transport endowments, cities' birth and development and the need for new infrastructure.

Historians already reported how Romans built their roads, particularly the major (consular) ones, in order to conduct their military campaigns. During the Roman Empire, in fact, goods mainly moved through the sea while the mobility of people, for reasons different than the military one, was near to null. 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 in order to overcome geographical barriers. This is the first point of the paper. A second result refers to how modern infrastructure has benefited from the existence of the old one. Areas where the Roman network was denser present today more railways and motorways. Nevertheless, third result of this work, the effect played by the Roman infrastructure differentiates between North and South Italy: the presence of Roman roads in the South was fundamental for developing the railway system. Consular roads, instead, traced the expansion of the motorway network only in northern territories; in the South were mainly the minor Roman roads that directed the construction of modern major roads. Interestingly, before the unification, when Italy was divided in several states, each one with its own historical path, Roman roads are associated to the presence of bigger cities (starting from 1300) regardless of the type of domination. This fourth result unfolds the mechanism through which Roman roads have a persistent effect today.

The paper is organized as follows. Next three sections constitute the *mise en place* of the single elements of the problem. Section 2 places the analysis in the 'new economic history' strand of literature (Michalopoulos and Papaioannou, 2017). Section 3 illustrates the available data on Roman roads and how they have been transformed, organized and used in the subsequent analysis. Section 4 provides an overview of the development of modern infrastructure in Italy and analyzes the intersection between the Roman road network and the railway and motorway system. Section 5 discusses the reverse causality problem that may arise when investigating the effects of infrastructure on economic outcomes and offer the empirical validation of historians' argument according to which Romans built their roads without aiming at the connectivity of economic centers. Section 6 is devoted to investigating, from an econometric point of view, the link between old and current infrastructure and the role played by urban dynamics. Section 7 concludes.

2 The persistent effect of history and historical infrastructures

In the last twenty years a new strand of economic literature, focused on the influence of history on various aspects of the economy today, has emerged. As nicely summarised by Nunn (2009) and by the three volumes edited by Michalopoulos and Papaioannou (2017), the 'new economic history' literature - that started by collecting data on specific historical episodes (e.g. colonialism in Engerman and Sokoloff, 1997, La Porta *et al.*, 1997, and Acemoglu *et al.*, 2001) and providing evidence of the long-lasting effect of those historical episodes 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;[3] in a second stage, the focus of 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.

Moving to a topic closely related with the present paper, the focus on historical infrastructures accounts for a large share of the entire literature on the persistent nature of history. Recent research has shown an interest in the effect of great historical transportation infrastructure projects on reducing trade costs, on enhancing productivity and on increasing the level of real income in the trading regions involved.

Starting from the seminal work of Aschauer (1990), the contributions of Donaldson (2018), Donaldson and Hornbeck (2016), Jedwab *et al.* (2017), Berger and Enflo (2017) add novel insights into understanding the effects of large transportation infrastructure projects and their expansion. 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. In particular, Jedwab *et al.* (2017), exploiting the variability in railways constructed by colonizers in Kenya, show how the location of major urban centers is characterized by path-dependence. Although, colonial benefits in terms of physical (i.e. transport infrastructure) and human capital vanished after independence, railway cities kept their developed status until today.[4]

Differently from other episodes in history, the civilization that started from Rome in 753 B.C. 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, in more than seven centuries of history, led recent 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, one specific aspect of the Roman Empire has attracted the attention of researchers: the Roman road infrastructure.

In the paper by Wahl (2017), the presence of ancient Roman roads is instrumental in dividing

[3] The three volumes edited by Michalopoulos and Papaioannou (2017) include works with a global view point, in volume 1, on Africa and Asia, in volume 2, and on Europe and the Americas, in volume 3.

[4] Other works address other means of transport. Volpe Martincus *et al.* (2014) analyze the case of Peruand use the Inca road network (built by the Inca Empire before 1530) as an instrument for the current road infrastructure.

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 in a regression discontinuity design framework to test whether the formerly Roman part of Germany shows greater nighttime luminosity than the non-Roman part. The transmission mechanism, that links past to present, 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 maintainance offers a valid proof of the persistence of infrastructure over time.

3 The Roman road network

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.[5] 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. The earliest strategic consular Roman road[6] was the *Via Appia* (the Appian Way), named after the Roman censor Appius Claudius Caecus and constructed in 312 B.C. in a south-easterly direction from Rome to Capua (close to Naples), to guarantee fresh troops for the war against the Samnites. It was constructed as an assembly of straight segments as the easiest and most convenient way to move troops and supplies. Subsequently, the Appian Way, the *regina viarum*, was extended to reach Beneventum, and Tarentum and finally Brundisium, on the Adriatic coast.

After the *Via Appia*, miles and miles of roads were built.[7] In Italy, the network of Roman

[5] Consular roads were not built either for trade purposes, largely managed by navigation across the Mediterranean Sea, or for civilian transportation. The cost of mobility was high and Romans were very superstitious. Moreover, moving required a great deal of effort to be realized (Chevallier, 1976).

[6] Twelve are the most important consular roads in Italy: Aurelia, Cassia, Flaminia, Salaria, Tiburtina, Casilina, Appia, Emilia, Postumia, Capua-Regium, Nomentana and Prenestina.

[7] Starting from the city of Rome, the expansion of the road network covered six centuries and three continents (Europe, Africa, Asia), covering at its peak the territories of almost forty of today's nations.

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.

The raw data on the Roman road network, used throughout the analysis, was digitized by McCormick *et al.* (2013) on the basis of the Barrington Atlas of the Greek and Roman World (2000).[8] 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.[9] 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).[10] 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 each segment of the Roman road network is the third trait extracted and included in the dataset used in the following analysis. These data give a good idea of the extent and coverage of the entire infrastructure but its geo-coding does not make any explicit reference to current political boundaries of the geographical territories. To obtain that information Licio (2020) uses the DARMC's shapefile along with GIS tools to create, among the others, two new datasets: a shapefile of the Roman road infrastructure for the Italian territory alone (excluding segments outside Italy's borders) and a measure of Roman roads in kilometers for every Italian province. Figure 1 shows the newly created layer of the old road system for Italy, which comprises 10 percent of the entire network: 1,817 out of 7,154 segments for a total of 19,593 kilometers. As mentioned, 108 out of the 110 Italian provinces have Roman roads,[11] 94 have major roads, 88 minor roads: 74 both minor and major, 20 only minor and 14 only major (consular) Roman roads.

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

[9] 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.

[10] 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 archeological nor historical evidence.

[11] The two Italian provinces where there are no Roman roads are the province of Pordenone (in the North-East) and the province of Verbano-Cusio-Ossola (in the North-West).

[Figure 1]

Figure A.3 in Appendix A - Additional figures and tables shows the cartograms of Roman roads in the Italian peninsula. When considering all roads (major and minor), it is clear how Romans devoted more effort to building roads in the South rather than in the North of the Italian territory. This depends on the way the Roman Empire expanded: firstly towards the southern regions, then to the North. When looking simply at major (consular) roads, this spatial correlation becomes less evident.

4 Railways and modern roads in Italy

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 an unified and connected Empire, modern railways and motorways did not had a similar effect. As observed by Ciccarelli and Fenoaltea (2013), the construction of railways before and after the Italian unification did not play a role in promoting an 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 the insufficient investment in southern regions to overcome the gap.

4.1 Railways

The first railway in Italy was constructed in the South in 1839, 22 years before the Italian unification. It was 7 kilometers long and linked Naples to Portici. At that time, all the southern Italy but 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 rail lines; one of these linked Caserta to Capua.[12]

The aim behind the construction of the first rail lines is not trivial. 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.

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

In a second step they also served for military reasons. 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 used the railways to reach their resort mansions as well. The connection of big ports, instead, was a need that emerged only after the construction of the first lines.

If the South was the first endowed with rail lines the northern states quickly filled the gap. The Kingdom of Lombardy-Venice (under the Austrian crown), the Kingdom of Sardinia (that included Piedmont and Savoy), the Grand Duchy of Tuscany, among the others, were completely devoted in linking their main strategical points, and in 1861, when Italy became an unitary country, Piedmont was endowed with an impressive railway system (Forghieri, 1997). The Kingdom of Sardinia and the House of Savoy were 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.[13] 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 the railway politics, supporting the design and the construction of the main Italian rail trajectories (Guadagno, 1996). He knew that the construction of the railway system was fundamental for the Italian independence and identified the main networks for the rail transport (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) outlining 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 symbol of cohesion and unity.[14]

In 1861, after the proclamation of the Kingdom of Italy, two issues emerged immediately: the construction of new lines in those territories where the railway system was completely absent and the management of all those small and big private firms devoted in constructing the railway (Guadagno, 1996). However, the boost of the railway construction activity drained the government spending funds and this led the ruling class to entrust the railway enlargement to private societies (Jannattoni, 1975).

In 1865 started the second phase of the development of railways in Italy (Schram, 1997). The design and the realization of the new railway links relied totally on the private concessionaires,

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

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

and the new Italian government kept only a monitoring function. However, due to the lack of a central planning and organization, many lines were design and realized not efficiently (Forghieri, 1997; Guadagno, 1996).[15] Nevertheless, the big 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 exchanges.

Due the inefficiencies and the increasing negative returns of the private concessionaires,[16] in 1905 the railway sector was nationalized and the state-owned *Ferrovie dello Stato* was founded. During this fourth and last phase of the Italian railway development, the central government assumed all responsibilities and the management of 10,557 kilometers of rail lines. In later years the network was further enlarged and several issues were the priority of the State: modernization of locomotives and wagons, construction of double binary tracks, train speed, unscheduled delays.

4.2 Motorways

In 1924, less than 100 years after the construction of the first railway in Italy, was inaugurated the first Italian motorway. From Varese to Milan, the one-lane motorway,[17] called *Motorway of Lakes* (*Autostrada dei Laghi*), was a paying road, that had the main aim to connect two locations in the fastest way possible, according to the current definition of motorway. The *Motorway of Lakes* set another record: it was the first European motorways as well (Moraglio, 2017). However, until World War II, the expansion of the network was limited due to the slow development of the motorization in Italy and the incoming economic crises (Benfratello *et al.*, 2006). Indeed, the decision that led the government to invest in the motorways was the big gap in terms of roads existing between Italy and the other western European countries.

During fascism several motorways were opened: Milano-Laghi, Milano-Bergamo, Napoli-Pompei, Brescia-Bergamo, Milano-Torino, Firenze-Mare, Padova-Mestre. A part from Napoli-Pompei, in the South, and Firenze-Mare, in the Center, all other lines were realized in the North of Italy. They were relatively easy to construct because of the flat areas of the North. Just two years later, it was realized the first mountainous motorway from Milano to Genova

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

[16] This is the third phase of the development of railways in Italy.

[17] One lane for each direction.

and, considered the technology of the time, it was a relatively a short time to complete a long road (Greco, 2005).

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

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

During the Italian economic miracle the enlargement of the motorway network experienced an exponential trend. 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, the motorway sector was pushed down. The government decided to stop the construction of new motorways and only already planned line where allowed to be completed. However, the new decision did not had an immediate effect and the network stopped to increase only in 1980.[18]

Starting from 1980 only already planned lines were built or improved. In 2000 with the

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

law 340 the Parliament legislated that the construction of new motorways was allowed only if included in the General Transport Plan and in the three years plan as greatest importance issue.

4.3 Roman roads and modern infrastructure: correspondence

The overlapping or correspondence of the modern transport infrastructure with the old one is strictly linked with the mechanism of persistence of history. Historians have a double view about the maintenance 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 for 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, allowing 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.

Consistently with Wahl (2017), this section adopts a GIS method to understand which is the degree of overlapping between the old and modern infrastructure. Figure 2 and Figure 3 map together the Roman road network and the modern transport infrastructure, and show three different buffer areas traced around the Roman road network: 500 meters, 1 kilometer and 2 kilometers. The width of the chosen buffer zones can be considered relatively narrow. 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 areas of 5 km. However, because of the geography of the Italian territory, mainly composed by hills and mountains, the choice of narrower buffer areas is more suitable and allows to provide a more precise analysis. The left part of Figure 2 shows modern railways together with the whole Italian Roman roads (both major and minor).[19] The right part, instead, zooms on a specific part of the map showing the three buffer zones with a track of railways and a segment of Roman road. Figure 3 focuses on motorways and consular Roman roads.[20] 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 have the aim to connect both large and smaller urban centers; motorways, instead, have the main purpose to make the movement of

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

[20] The linear shapefile of the Italian motorways comes from OpenStreetMap.

people and goods fastest, linking only the main cities.

[Figure 2]

[Figure 3]

Results emerging from the overlapping analysis are interesting. When considering a very narrow buffer area around the layout of the old Roman road network (500 meters), almost 20% of Italian railways overlap the Roman segment lines; 12% when looking at the correspondence between motorways and consular roads. Allowing a wider buffer area (1 kilometer large), the overlapping between Roman road and railways and between major Roman roads and motorways is 39% and 25%, respectively.[21] When taking into account a buffer zone of 2 kilometers, instead, that is the largest that this analysis considers but can be considered relatively narrow, the degree of overlapping 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 Roman roads have been used as trace to construct the new transport infrastructure and the degree of correspondence can be even higher if larger areas are accommodated. The GIS descriptive introduces the main result of the paper: the existence of previous road lines (in use or abandoned) facilitated the building of the modern transport networks, representing a starting track to realize railways first and motorways then.

5 The exogeneity of the Roman road network

As generally applies, the exogeneity of the Roman road infrastructure must be placed under scrutiny. The endogeneity drawback in the use of infrastructure in empirical models[22] is a serious matter also in the present case.

[21] 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 overlapping 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.

[22] This has been widely discussed in the literature, in conjunction with the econometric solutions used to deal with the problem. As highlighted by Brooks and Hummels (2009), a considerable amount of time elapses between planning a road and its actual completion. 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.

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. Understanding why and how Roman roads were built, distinguishing between major (consular) roads and minor roads connecting the backbone of the consular road structure, and providing detailed historical reasoning, is therefore important.[23]

5.1 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.[24]

The construction of the *Via Appia* over the centuries is a clear and concrete example of its military purpose and how the ultimate aim to reach some strategic territories resulted in a long

[23] 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*". Moreover, Bosker *et al.* (2013) support the view that the reverse causality issue is not present 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.

[24] 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 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).

road that passed through areas of absolutely no interest to Romans, but that, nonetheless, benefited from the presence of the road (see Berechman (2003) for a recent and in-depth description of the economics of the *Via Appia*). If the construction of the Appian Way, the *regina viarum*, explains the absence of an economic objective by its direction (the Romans decided to build their first road south-easterly, although the economic development of the time was concentrated in the southern-western part of Italy), the *Via Annia*, constructed south-westerly two centuries after the *Via Appia*, represents a good example for its position: it strictly follows the western coast of Campania and Calabria, completely disregarding the part of the coast where the main economic centers of the time were located, since the objective of the road was simply to reach Regium (modern Reggio Calabria) in the easiest and fastest way.[25]

5.2 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. In fact, 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.[26]

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*[27] *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

[25] See Appendix B - The *Via Appia* and *Via Annia*.

[26] 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 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.

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

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.[28] Giving credit to historians' arguments, it is possible to evaluate the proposition that the straightness of the roads[29] is the best rule for drawing an old historical infrastructure by looking at how the presence of Roman roads is linked with the geographical characteristics of the territory it travels across. The following subsection discusses the point.

5.3 Roman roads, geography and pre-Roman cities

Even excluding a direct economic reason driving the construction of the consular roads, geography and earlier settlements will be tested as possible factors that influenced the construction of the old transport infrastructure. Roman roads may have been endogenously built where the morphology of the terrain permitted and/or near important economic centers.

In an insightful paper, Ramcharan (2009) argues that landform can shape both the within-country spatial distribution of road infrastructure and economic activity, and, if so, it represents a potential unobserved factor correlated with both road building and economic performance.[30] The Romans resorted to deviations in roads only when major obstacles could not be overcome by building structures such as bridges. Also, whenever possible, the Romans built road supports, like embankments or dykes, or tunnels to cross hills, mountains, and marshlands (Richard, 2010).[31] Moreover, the development of primordial engineering techniques by the Romans is

[28] 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 not a geometric outline behind the planning of the network, but rather a preference to follow the shape of nature.

[29] The straightness of the road and, more specifically, 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). According to 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). On these bases, the empirical strategy examines the correlation between the distance to the nearest straight line and economic performance.

[30] Moreover, Ramcharan (2009, pp. 559-560) argues that "*[...]countries with rougher surfaces also have less dense surface transport networks: a 1% increase in roughness is associated with about a 1% decline in the number of kilometers of roadway within a country*". This evidence is consistent with the road construction literature.

[31] In Italy, their roads in the Alps and the Apennines had steep slopes and can be defined as ancient motorways

largely due to the orography of the country: 35 percent of the Italian territory is made up of mountains, 42 percent of hills and 23 percent of plains.[32]

Table 1 summarizes the data adopted throughout the coming analysis and data sources.

[Table 1]

The investigation on the relationship between Roman roads and geography is first discussed using the map in Figure 4. Here data provided by Istat on the elevation at the Italian municipality level have been geo-coded and mapped using the polygon layer of the Italian territory. 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 Italian map has been completed with the information on lakes and rivers using Corine Land Cover (CLC) data in order to control for watercourses and basins. The layer of the Roman road network at the Italian level has been then superimposed on the polygon one and the Roman roads were divided into major (consular) and minor. The distribution of Roman roads among the different elevation classes is fairly homogeneous. Roman infrastructure is not absent in the darker areas, where elevation is higher.[33] 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, clearly, average elevation is lower.

[Figure 4]

A proper conditional correlation test on the role of geography and urbanization is based on the following model applied to the raw Roman road variable:

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

since they allowed the movement of pedestrians, horses and wagons.

[32] In geographical terms, landforms can be measured by elevation or by the percentage of mountainous territory. Data on the percentage of mountainous territory at the provincial level are provided by the Istituto Tagliacarne; three statistics can be found: percentage of mountainous, hilly and flat terrain. The sum of these three percentages gives the total provincial land, 100. Data on elevation by municipality is drawn from Istat. The information by province has been obtained as the average elevation of all its municipalities.

[33] The right part of Figure 4 zooms in on an exemplificative 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. It is possible to observe how the course of the Roman road 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.

where $\mathcal{RR}_i$ denotes the dependent variable, the log-transformed measure of Roman roads (major/consular or all roads); $\mathbf{G}_i$ denotes a matrix of geographical measures in logarithms (`Elevation` and `Percentage of mountainous territory`).[34] Selecting the most appropriate geographical measure is not trivial. For instance, elevation does not distinguish territories that are mainly mountainous from territories that are mostly hilly but with some mountainous peaks.[35] $\texttt{Pre-Roman city}_i$ is a dummy variable that takes the value of 1 if the provincial capital of the NUTS3 region was a pre-Roman city center; $\texttt{Pre-Roman amenities}_i$ is a dummy variable that accounts whether some pre-Roman settlements or any type of civic infrastructure or amenity were present in the territory of the province before the Romans; u_i denotes the (heteroskedasticity consistent) error term. All variables are measured at the provincial level. Results are presented in Table 2.

[Table 2]

Geography

The first column considers a simple specification of Equation (1) where only the orography of the territory is taken into account. Specification (1) shows that both geographical variables are significantly correlated with major Roman roads. The elasticity of 0.255 of the `Elevation` index discloses how more kilometers of Roman roads are needed to reach more challenging territories. On the other hand, the -0.127 `Percentage of mountainous territory` elasticity is confirming that Roman roads are sparser in more impervious areas.[36] 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, as mentioned, the role of geography in explaining the presence of Roman roads is minimal. More that 95% of the variability in the data is unrelated to geography.

[34] Here the data on elevation is considered as a continuous variable rather than as a categorical one as in Figure 4.

[35] Ramcharan (2009) argues that rougher territories have less kilometers of roads. This view implies that in rougher territories roads are sparse. However, more kilometers of roads are needed to reach those territories. From this perspective, the relationship between kilometers of roads and geography of the territory is an open question.

[36] The standard errors for `Elevation` and `Percentage of mountainous territory` become larger, 0.134 and 0.074 respectively, when using HC3 robust standard errors formula instead of a HC0 formula, less reliable in finite samples.

To better understand the coefficients' signs emerging from Table 2, Table 3 divides the Italian territory in 10*10 km grid cells and analyzes how the effect played by elevation on Roman roads changes according to the degree of mountainous territory.[37]

[Table 3]

Specifications (1) and (5) of Table 3 show that `Elevation` has no impact on the quantity of major and all Roman roads when the effect of is assessed without distinction for the three terrain types. In only mountainous territory (Specifications (2) and (6)) the coefficient is negative for all Roman roads, but not significant for major Roman roads: being the main trajectories, major roads were less likely constructed in mountainous territory. Minor roads, instead, had a connectedness aim in impervious zones as well, however the higher the elevation, the sparser the network. In hilly grids, elevation is negatively correlated with both types of Roman infrastructure (as in Specifications (3) and (7)). In plain terrains, instead, a positive coefficient on `Elevation` (Specifications (4) and (8)), confirms how longer roads are constructed in geographically easier territories.

Pre-Roman cities

Since the early days of the Roman Republic, the Italian territory 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 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 (it is the case of Turin, Piacenza, Ragusa). Others, instead, gained importance during Middle Ages or after.

Integrating the geography of the territory with information on pre-Roman urbanization and settlements provides a test on weather Roman roads were built near larger urban centers or favored the subsequent expansion of earlier settlements. In fact, 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

[37] Italy is composed by 5,111 10*10 km grid cells. For each cell the elevation in meters is computed using geotiff data from Jarvis *et al.* (2008), `http://srtm.csi.cgiar.org`. According to Istat, grid cells are then categorized in three terrain zones: mountainous (if elevation is equal to or more than 700 meters); hilly (if elevation if less than 700 meters, but equal to or more than 300 meters); plain (if elevation is less than 300 meters).

have contributed to determine the trajectory of a road segment or its terminal point, which varied by construction stage. Also, the road may have generated agglomeration effects leading the subsequent development of cities.

The role of preexisting cities and settlements is captured by two variables. The first one is a dummy that looks at each provincial capital of the 110 Italian NUTS3 provinces[38] and takes the value of 1 if the city was an important urban agglomeration before the Romans arrived and conquered the territory. Small villages or irrelevant settlements have been classified as not being a `Pre-Roman city` and the dummy variable takes the value of 0. Augmenting the Specification in column (1), Specification (2) of Table 2 shows that the coefficient of the `Pre-Roman city` variable 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).

The second variable is a dummy that looks at the whole province and takes into account also several types of amenities. Exploiting the information from Pleiades: A Gazetteer of Past Places,[39] the variable `Pre-Roman amenities` 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), proving the existence of pre-Roman agglomerations in the region. Column (3) of Table 2 shows how these types of settlements do not influence the length of consular Roman roads providing therefore a confirm of their military nature. Only when including minor roads (all Roman roads) as in Specification (6) the `Pre-Roman amenities` coefficient turns to be highly significant. A result stating the auxiliary role of minor roads by connecting the consular network to the civic infrastructure.

How the quantity of consular roads is 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 from old to new infrastructure in Italy in the following Section.

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

[39] Pleiades is a geographical index and map of geo-coded ancient locations. It is built by volunteer contributors and is continuously updated. It is organized into three types of information: *places, names, locations.* The variable constructed in this paper uses the information derived and elaborated from *places.* For more details see `https://pleiades.stoa.org/help/data-structure`.

6 Old and modern infrastructure

This section aims investigating what is the heritage left by the the historical Roman road network on the modern Italian transport infrastructure: railways and motorways. Cultural and landscape conditions determine why the new infrastructure may be related to the old one. The fact of having favored the rise and development of economic centers is an important one.[40] On the other hand, also cities location does not follow a casual process and has been found linked to (among other things) the presence of a road infrastructure (Bosker and Buringh, 2017). Therefore when investigating on the link from old to modern infrastructure the presence of recursive forces in the historical dynamics between cities and infrastructure have to be taken in due account. Besides, the direct effect that geography imposes on the costs of transport infrastructure projects cannot be left out. When the morphology of a territory imposes construction difficulties, the presence of an old infrastructure constitutes a technical facilitation for the construction of a new one.

The estimates of the coefficients of Equation 1, summarized in Table 2, will therefore be used along these lines. The main variable used throughout the empirical analysis is a measure of major Roman roads orthogonal to geographical factors.[41] This allows to exclude from the Roman road measure every potentially confounding effect correlated to the measure of modern transport infrastructure.

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 2:

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

The dependent variable $\mathcal{I}_i$, is the log transformation of two measures of current infrastructure, railways and motorways.[42] Considering two different transport systems derives, as argued in Section 4, from how transport infrastructure developed in Italy: railways from 1839, motorways

[40] Several contributions (see Garcia-Lopez *et al.* (2015) among the 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.

[41] A measure of all Roman roads, orthogonal to both geography and pre-Roman amenities, will be tested for robustness checks in Section 6.2.

[42] Sources and descriptions of all variables used in the analysis are provided in Table 1. 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. Until 2011 there was a lack of data on the provision of road infrastructure in the different and comprehensive territorial levels. ACI fulfilled the need for more detailed data, collecting information from different sources. Data on motorways comes from AISCAT (http://www.aiscat.it) and ANAS (http://stradeanas.it/it).

from 1924 on. The set of further controls is aimed at capturing the recursive effect from the old infrastructure to the rise 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) 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;[43] $\mathbf{G}_i$ 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 railroads and motorways independently from how they determined the quantity of Romans roads; $\mathbf{H}_i$ denotes a matrix of count variables referring to the number of years the province was ruled by past dominations during the Middle Ages. NUTS2 regional fixed effect ϕ_r complete the model specification and u_i denotes the error term.

The role played by the 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 in the length (i.e. number of years) of the dominations that ruled Italy between the twelfth and eighteenth century. The set of information allows to control for the political, institutional and social changes occurring since the Middle Ages. 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 linkages with the noble European dynasties. $\mathbf{H}_i$ also allows to capture crucial differences in the level of local institutional quality and social capital which are at the root of the observed differences in productivity and income since the foundation of the country as a nation state in 1861.[44]

Table 5 presents results. Specifications from (1) to (6) refer to railways, those from (7) to (12) to motorways. The model of Equation (2) is estimated in its complete form in column (6)

[43] The corresponding nature of the three variables above is therefore different. $\mathcal{M}_i$, constructed using GIS methods, is more related to the rise and development of cities along the old infrastructure. $\texttt{Roman city}_i$ and $\texttt{Post-Roman city}_i$, are instead more related to the historical development of urban centers in nearby areas.

[44] Di Liberto and Sideri (2015) follow two approaches to measure past dominations. On the one hand, they use a set of binary variables that identify, for each province, the administration that ruled from the mid sixteenth century to the mid seventeenth century, namely, the period from 1560 to 1659. In that period, the Italian peninsula had five different governments and one independent area, thus generating six binary variables: the Spanish Kingdom, the Republic of Venice, the Duchy of Savoy, the Papal State, the Austrians, the independent area. On the other hand, they measure the different administrations that governed Italy over seven centuries before the creation of the unified Italian State (1861), namely, the period from about 1100 to 1700, assigning to each province the number of years during which each regime ruled. During these 700 years, 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. This second set of variables is included in Equation (2).

and (12). Specifications (1) and (7) focus on isolating the effect of geography on railways and motorways, respectively. $\texttt{Elevation}_i$ plays a positive impact on both infrastructure systems, $\texttt{Percentage of mountainous territory}_i$, instead, shows a negative effect only on the railway infrastructure. In Specification (2) and Specification (8), regional fixed effect capture most of the effect. To better understand the findings, Table 4 provides a higher detailed analysis at the grid level. As for Roman roads, Table 4 reveals that if the effect of `Elevation` is assessed without controlling for the terrain type (Specification (1) and Specification (5)), there is no impact of geography on the quantity of current infrastructure, the effect of different territories balance-out. For motorways the coefficient linked to `Elevation` is statistically significant, with the expected positive sign, only for plain terrains (Specification (4)), confirming how motorways are less likely to be constructed in impervious territories. Columns (6), (7) and (8), instead, show that the railway system expands throughout different terrain types: meters of railways decrease when elevation increases in mountainous or hilly terrains, but increase with increasing elevation in plains.

[Table 4]

Moving forward on specifications in Table 5, columns (3) and (4) for railways and (9) and (10) for motorways introduce Roman roads. In particular, the measure adopted in Specification (3) and Specification (9) is $\mathcal{RR}_i$, where the effect of geography has not been partied out. Columns (4) and (10), instead, exploit $\tilde{\mathcal{RR}}_i$, i.e. the residuals of Equation 1 as in Specification (1) in Table 2 (the preferred measure of Roman roads which allows a better control for confounding factors from geography to infrastructure). Regardless of the variant of major Roman roads adopted, all four columns show that major (consular) roads are positively correlated to 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. In columns (5) for railways and (11) for motorways covariates associated with urban development are included in the estimation, and in Specification (6) and Specification (12) historical dominations complete the model. Fixed effects accounting for regional differences are present in all specifications. The increase in the number of municipalities at a close distance with respect to 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 worthy is the relationship between old and new infrastructure, the second and main result of this paper.

[Table 5]

In Table 6 the effect played by the Roman road infrastructure on the current one 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.[45] Geographical, urban development, historical dominations and regional fixed effects complete the model. Estimations show that when focusing only on the railway system, Roman roads play, ceteris paribus, a stronger positive effect in the South than in North, suggesting the greater importance the Roman road network had in the construction of the rail lines in the southern territories. In the case of motorways estimation outputs are less trivial. Major Roman roads are positively correlated with motorways only in the northern NUTS3 provinces; $South{*}\tilde{\mathcal{RR}}_i$, instead, is not linked to a statistically significant coefficient. These results are in line with expectations: the geography in northern Italy is characterized by an extended plain territory that allowed the construction of an intricate system of straight Roman roads first and motorways then. If the Alps represent the geographical boundary of northern Italy with 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 geographical discontinuity that separates Italy from Africa and Middle-East, and that impedes the continuity of the transport system. Moreover, the entire Center and South Italy is crossed by a mountain range (the Apennines) that makes particularly hard the construction of the transport infrastructure and that represents a further natural obstacle for a dense network system. In these terms, the Italian North-South divide can be ascribed, among other factors, to the influence the historical Roman road network had in the construction of the new infrastructure, third result of this work.

[Table 6]

[45] 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.

6.1 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 the attention to the line of the terrain and to the agglomeration forces linked to the rise and development of cities. 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 *et al.* (2013), the existence of Roman roads allowed small cities to grow earlier and faster. Although the decline of the Roman Empire, many Roman urban centers remained important because connected by Roman roads. In Wahl (2017), new settlements took advantage from the Roman network, since being located nearby a road allowed them to develop and to became trade nodes. In this sense, the persistence of the Roman road network pass 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 its maintenance and preservation.

To test the city development channel, this paper looks at the urbanization Italy experienced 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, year corresponding with the Italian unification.[46]

Table 7 displays the results of a regression model that texts the effect of the major Roman roads on the urban development, by using covariates of Equation (2) as 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 higher than 5,000 inhabitants in the same three periods. They are two distinct measures of urbanization: the first one quantifies the size of a city, while the second one captures the density of urbanization. For each period the regression has been run with and without historical domination controls to check the effect played by the different realms.[47] 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

[46] The database include 193 cties 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, a 0 is attributed to the urban center (Malanima, 2015).

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

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 our-days metropolitan areas crossed by a major Roman road. When considering the number of cities (specifications from (7) to (12)), however, the impact fades away with controls for medieval dominations.

[Table 7]

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

6.2 Robustness checks

Robustness checks have a twofold purpose. First, to confirm the relevance and significance of the Roman road measure considering all roads instead of only major (consular) roads; second, to provide further controls for the 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 also to those minor roads whose aim was to increase 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 allowed.

Table 8 adopts the all Roman roads measure orthogonal to both geography and pre-Roman amenities ($\tilde{\mathcal{RR}}_i$), obtained as the residuals of Equation (1) resulting from Specification (6) in Table 2. The measure is interacted with the `North` and `South` dummies to gain insight on the country territorial divide. Results suggests that when considering also minor Roman roads the positive correlation between old and current infrastructure is valid for both railway and motorway systems, differently from what reported in Table 6. Moreover, it clearly emerges that all Roman roads play, ceteris paribus, a stronger positive effect in the southern provinces than in northern ones, suggesting that the Roman domination and the road network exerted a relevant influence in southern Italy. Results are robust to any control included in the regression and the valuable goodness-of-fit confirms the appropriateness of the estimated model.

[Table 8]

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 5. 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. The Roman Empire expansion and the construction of the corresponding Roman road network has been subdivided and mapped using GIS techniques.[48] Figure 5 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 at the province level have been computed.

[Figure 5]

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 the development of the network.

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

For each period, except for the first one, the Roman road measure is the result of the variance left by an OLS regression where $\mathbf{G}_i$, `Pre-Roman city` and `Pre-Roman amenities` have been controlled for, as in the analysis performed in Subsection 5.3.[49]

Table 9 replicates column (6) and column (12) of Tables 5 using $\mathcal{RR}_i$ 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. Geographical, urban development, historical

[48] 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.

[49] 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.

controls complete the model, although only the old infrastructure measure show an effect on current transport measures. As in all previous models, regional fixed effects account for the heterogeneity within the Italian territory.

[Table 9]

7 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.

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 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 who had distinct influence in various 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, being the result of the needs of the military campaigns conducted by the Romans during the expansion of the Empire.

This paper presents a detailed investigation of historical sources, narrations and facts in order to understand why and how Roman roads were constructed. It also discusses the relationship between geography and extent of the major (consular) Roman road network and the correspondence between the historical and modern transport infrastructure.

The mark left by Roman roads on current infrastructure has been investigated adopting a measure of major Roman roads orthogonal to geographical factors, since pre-Roman settlements did not affected the construction of the consular roads. A second measure including both major and minor roads, and cleaned by 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 assumes a particular importance in the view of the Italian North-South divide. Consular roads have been particularly relevant in determining the motorway network in northern provinces. For the railway system, instead, major Roman roads exerted their effect mainly in the South than in the North. Indeed, when considering both major and minor Roman roads, southern provinces benefited more of the existence of Roman roads for both railways and motorways.

As far as the mechanism at work is concerned, areas with a denser Roman road infrastructure are more likely to have a denser present road and railway infrastructure, since Roman roads shaped the Italian landscape making the construction of later roads less costly. Current roads simply followed the same route traced by the Romans. Reasons for this to happen are quite diverse: Bosker and Buringh (2017) in their study on the determinants of city locations in Europe include direct access to the former Roman road network in the group of first geography factors. Roman roads are a proxy for favorable land-based accessibility locations, and are 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 urban historical structuring. Even in Britain, where persistence of city locations after the Roman Empire collapse has been much lower than in France, the presence of Roman roads, fortifications, durable masonry make Britain's observed persistence more similar to France's. This paper investigates the urban development mechanism by using data from Malanima (2015), confirming that the maintenance and preservation of the network favored the growth of important cities along it.

Summarizing, the contribution of this research to the economic literature is to present novel results on the persistent effect of history on contemporary economy. The heritage of the Roman road network in Italy acted in two ways. On the one hand, it acted as a trace for the new 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 allowed the development of urban centers simply because roads linking cities were maintained and preserved.

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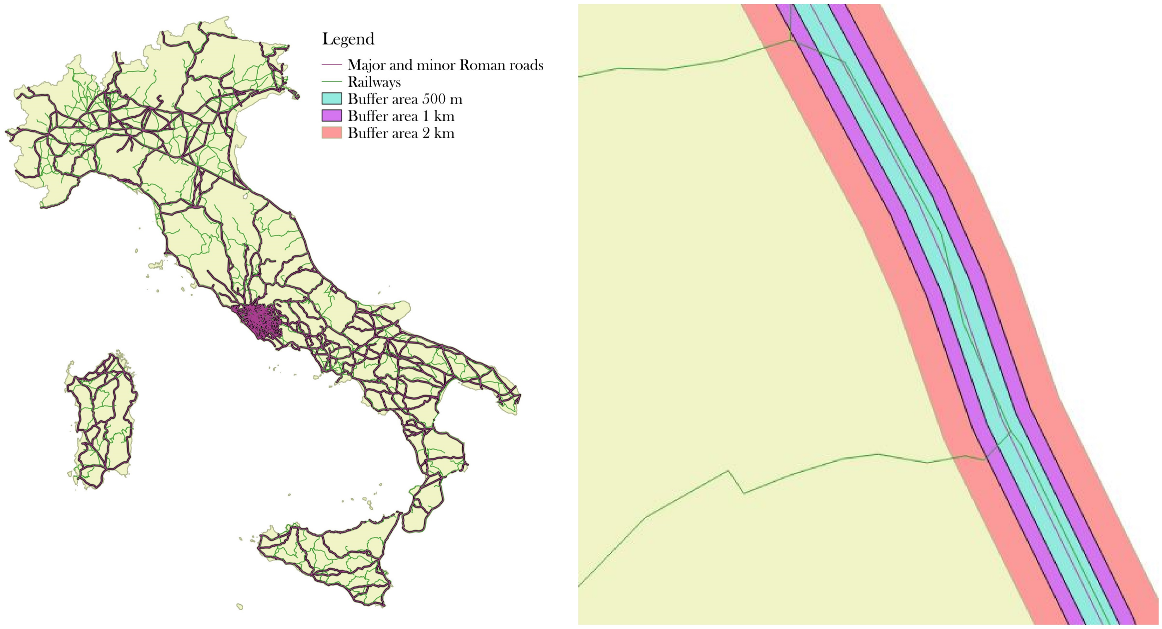
Figures and tables

Figure 1: Roman road layer and Italian provinces

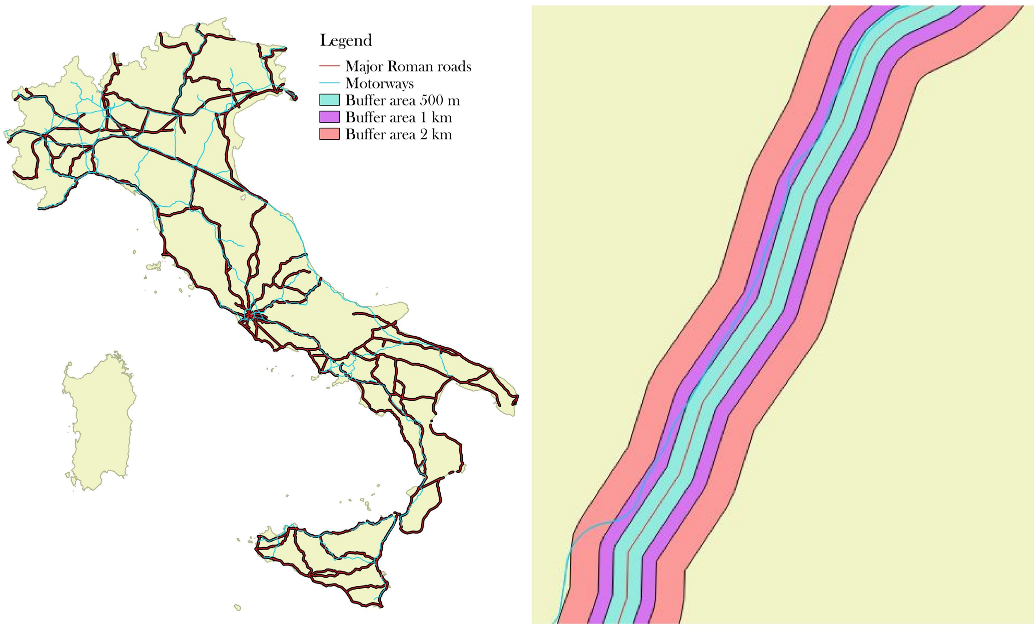
Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5 and from Istat data (2011)

Figure 2: Roman roads and railways intersection: buffer analysis



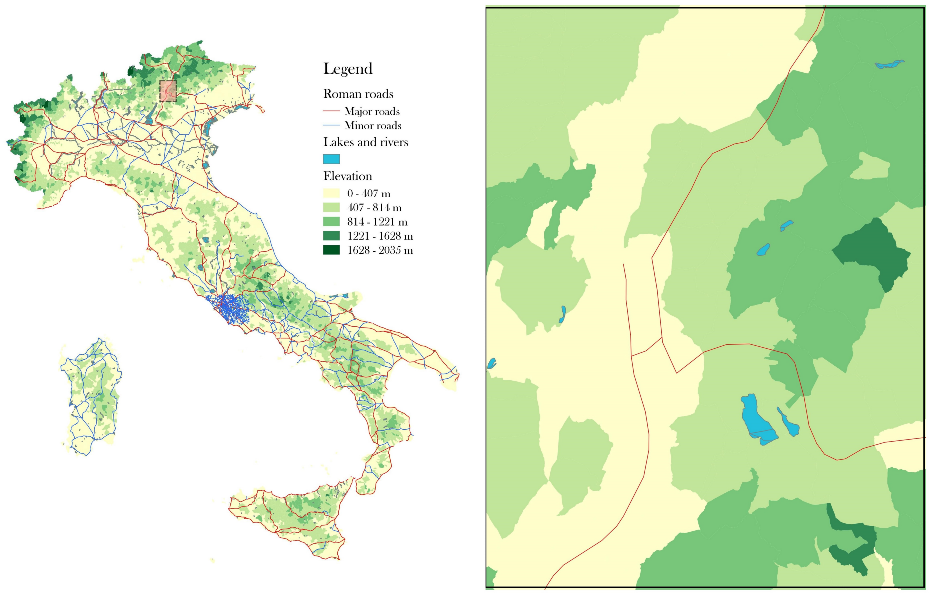
Source: Authors' drawing from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5, Diva-GIS and from Istat data (2011)

Figure 3:   Major Roman roads and motorways intersection: buffer analysis



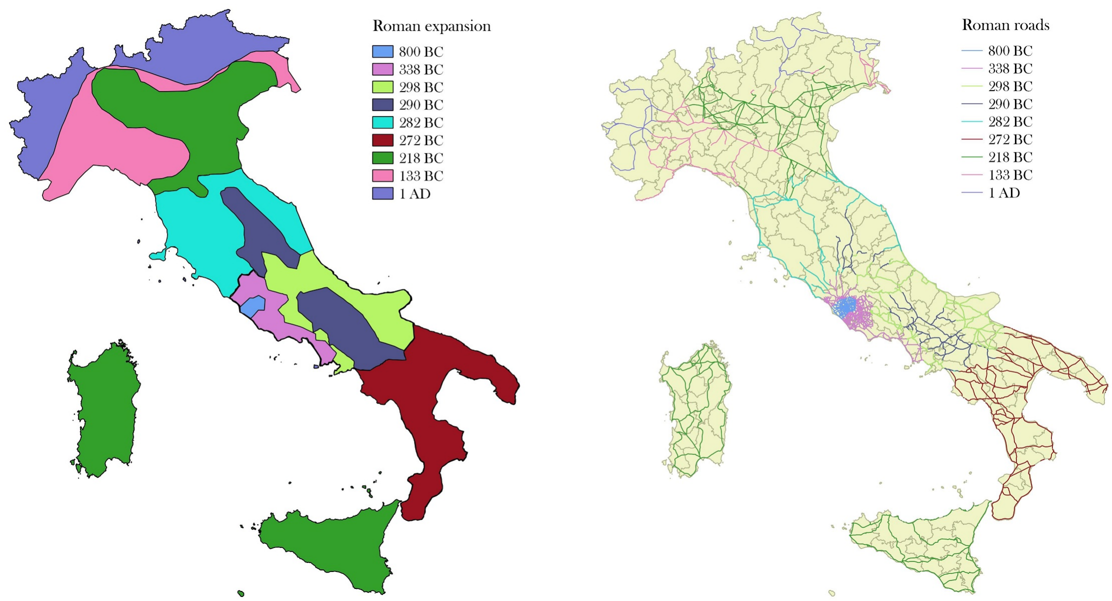
Source: Authors' drawing from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5, Open Street Map and from Istat data (2011)

Figure 4: Roman roads and geography: locationing by elevation area



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 5: Roman Empire and road network expansion: jointly view



Source: Authors' elaborations

Table 1: Data and sources

Variables	*Definition*	*Years*	*Source*	*Available for*
Major Roman roads (km)	Kilometers of major Roman roads	117 A.D.	Licio's (2020) creation from McCormick *et al.* (2013) shape file	110 provinces
All Roman roads (km)	Kilometers of all Roman roads	117 A.D.	Licio's (2020) creation from McCormick *et al.* (2013) shape file	110 provinces
Major Roman roads simple 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 (shapefile)	Linear shapefile of Italian railways	Modern	Diva-GIS	Italy
Motorways (km)	Kilometers of current motorways	2011	Automobile Club d'Italia (ACI)	110 provinces
Motorways (shapefile)	Linear shapefile of Italian motorways	2009	OpenStreetMap	Italy
Mountain	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)	10*10 km grid cells
Hill	Dummy variable: 1 if the mean elevation of the grid cell is $\geq$300, but <700	Time invariant	Authors' creation from Jarvis *et al.* "Hole-filled seamless SRTM data V4" , International Centre for Tropical Agriculture (CIAT)	10*10 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)	10*10 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)	10*10 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 2: Roman roads, geography and pre-Romanity

Dependent variable: *Roman roads in km (log)*	*(1)*	*(2)* *Major*	*(3)*	*(4)*	*(5)* *All*	*(6)*
`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). `Elevation` is the mean of municipalities' elevation in the province. `% of mountainous territory` is the percentage of mountainous territory in the province. `Pre-Roman city` is a dummy variable equal to 1 if the provincial capital was a settlement before the Romans. `Pre-Roman amenities` is a dummy variable equal to 1 if in the province were present settlements equipped by one ore more kinds of civic infrastructure (e.g. amphitheater, bath, sanctuary or temple, mine, cemetery) before the Romans. 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 3: Roman roads and geography: 10*10 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)	0.054	-0.545	-0.687**	0.121***	0.027	-0.597**	-0.462*	0.188***
	(0.035)	(0.428)	(0.323)	(0.047)	(0.028)	(0.279)	(0.245)	(0.033)
Intercept	-0.312	3.301	7.050***	1.290***	1.958***	3.670	5.613***	1.062
	(1.771)	(3.680)	(2.320)	(0.403)	(0.154)	(3.239)	(1.651)	(15.278)
ϕ_p	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,326	186	301	839	2,029	285	515	1,229
R^2	0.062	0.212	0.194	0.139	0.084	0.350	0.201	0.165

Note: All log-transformed variables are indicated with (log). `Elevation` is the elevation in the 10*10 km grid cell. ϕ_p represents provincial fixed effects. 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 4: Current transport infrastructure and geography: 10*10 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)	-0.017	-1.097	-0.498	0.122**	0.013	-0.981***	-0.356*	0.114***
	(0.043)	(0.739)	(0.447)	(0.059)	(0.021)	(0.280)	(0.213)	(0.033)
Intercept	1.452	10.189**	2.206	1.287***	1.375***	8.259***	4.167***	1.255***
	(1.080)	(4.886)	(4.031)	(0.501)	(0.302)	(1.921)	(1.326)	(0.343)
ϕ_r	YES	YES	YES	YES	YES	YES	YES	YES
Observations	905	104	178	623	2,209	302	570	1,337
R^2	0.015	0.172	0.112	0.027	0.007	0.118	0.034	0.022

Note: All log-transformed variables are indicated with (log). `Elevation` is the elevation in the 10*10 km grid cell. ϕ_r represents regional fixed effects. 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 5: 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 2)				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). $\mathcal{RR}_i$ refers to major/consular Roman roads; $\tilde{\mathcal{RR}}_i$ refers instead to the residuals of a regression according to Equation 1 and to Specification (1) of Table 2. $\mathcal{M}_i$ measure the number of provincial municipalities crossed by major/consular Roman roads. All other variables as previously described. 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 (10000 replications) are reported in parentheses.

Table 6: 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 2)	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 2)	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). $\tilde{\mathcal{RR}}_i$ refers instead to the residuals of a regression according to Equation 1 and to Specification (1) of Table 2. $\mathcal{M}_i$ measure the number of provincial municipalities crossed by major/consular Roman roads. All other variables as previously described. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10000 replications) are reported in parentheses.

Table 7: Medium-term effect: major Roman roads and urbanization

Dependent variable: Population (log) and number of cities	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
			Population					*Numer of cities > 5,000 inhabitants*				
	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 2)	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). $\mathcal{RR}_i$ refers to major/consular Roman roads; $\tilde{\mathcal{RR}}_i$ refers instead to the residuals of a regression according to Equation 1 and to Specification (1) and (2) of Table 2. $\mathcal{M}_i$ measures the number of provincial municipalities crossed by major/consular Roman roads. All other variables as previously described. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10000 replications) are reported in parentheses.

Table 8: 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 2)	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 2)	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). $\tilde{\mathcal{RR}}_i$ refers instead to the residuals of a regression according to Equation 1 and to Specification (6) of Table 2. $\mathcal{M}_i$ measure the number of provincial municipalities crossed by major/consular Roman roads. All other variables as previously described. Asterisks denote significance levels; * p<0.10, ** p<0.05 and *** p<0.01. Bootstrap standard errors (10000 replications) are reported in parentheses.

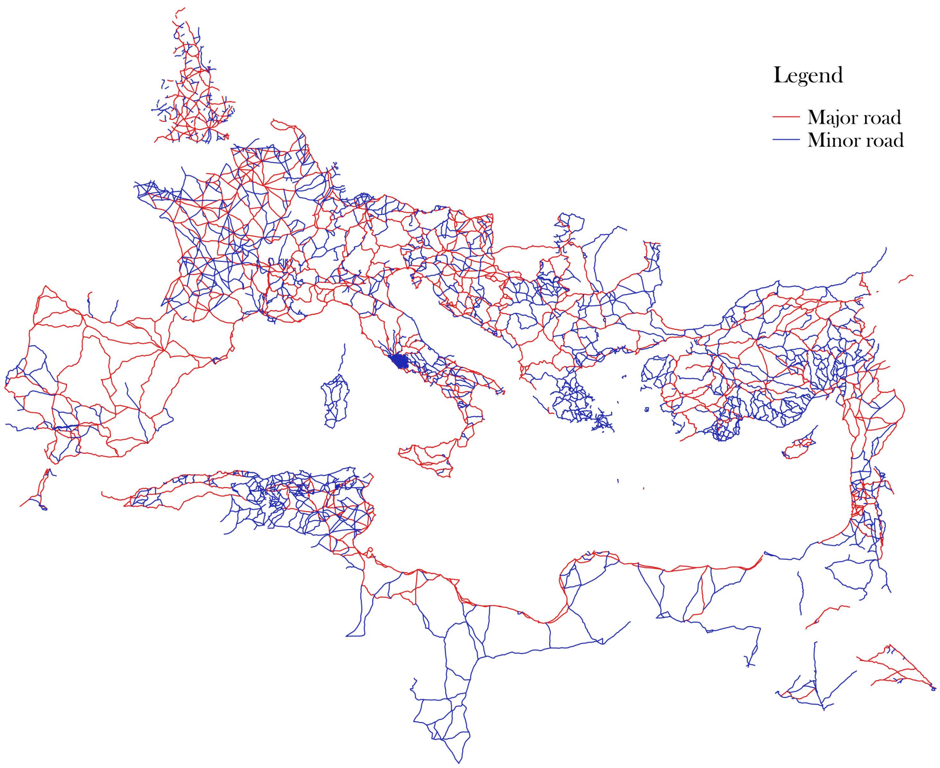
Table 9: Historical dynamic of major Roman roads

Dependent variable: *Current infrastructure in km (log)*	*Railways*	*Motorways*
Historical dynamic 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:The historical dynamic of major Roman roads is represented by the fitted values of a regression where the dependent variable is represented by the residuals of major Roman roads in last period (period 9), obtained partialling out the effect of geography, and the residuals of major Roman roads in remaining periods (from 8 to 2),computed as for residuals referring to period 9, and the logarithm of major Roman roads in period 1 are the independent variables. Since the low number of observations, it has not been possible to partial out the effect of geography for major Roman roads in period 1. All log transformed variables are indicated with (log). Asterisks denote significance levels; * $p<0.10$, ** $p<0.05$ and *** $p<0.01$. Bootstrap standard errors are reported in parentheses (10000 replications).

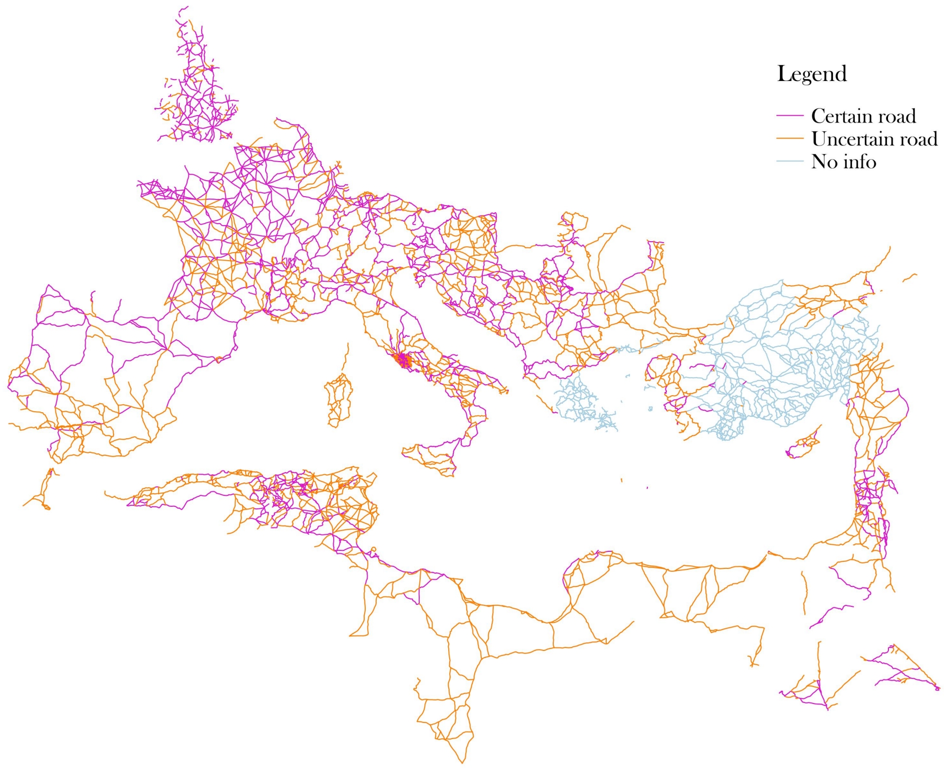
Appendix A - Additional figures and tables

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



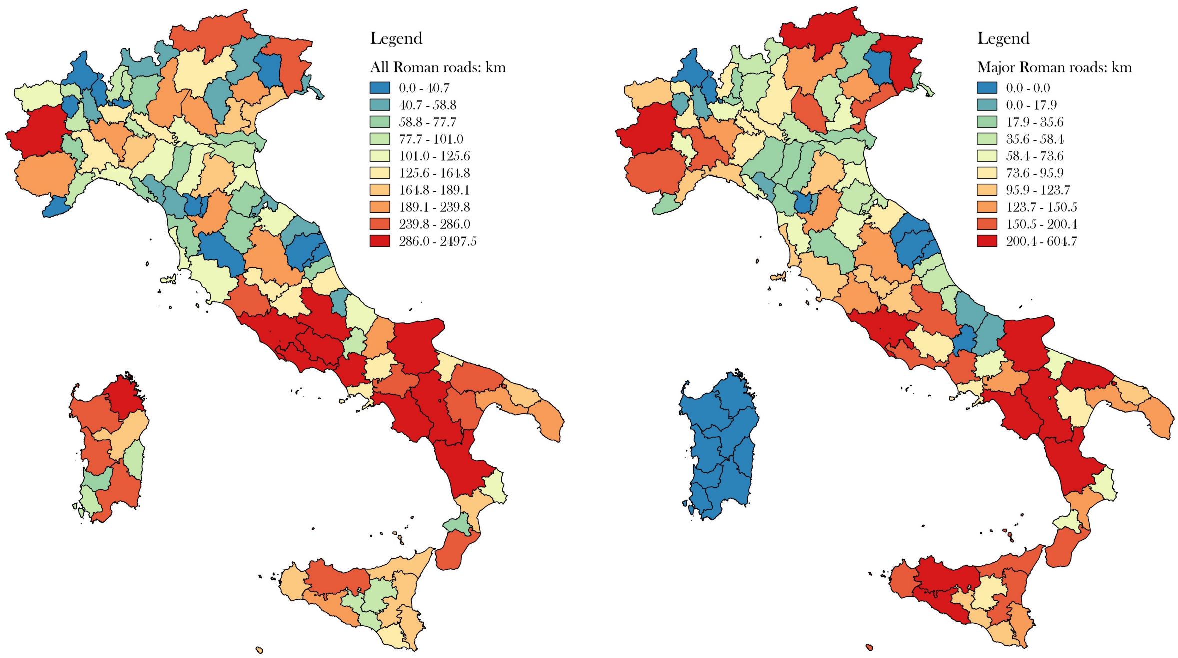
Source: Authors' elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5

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

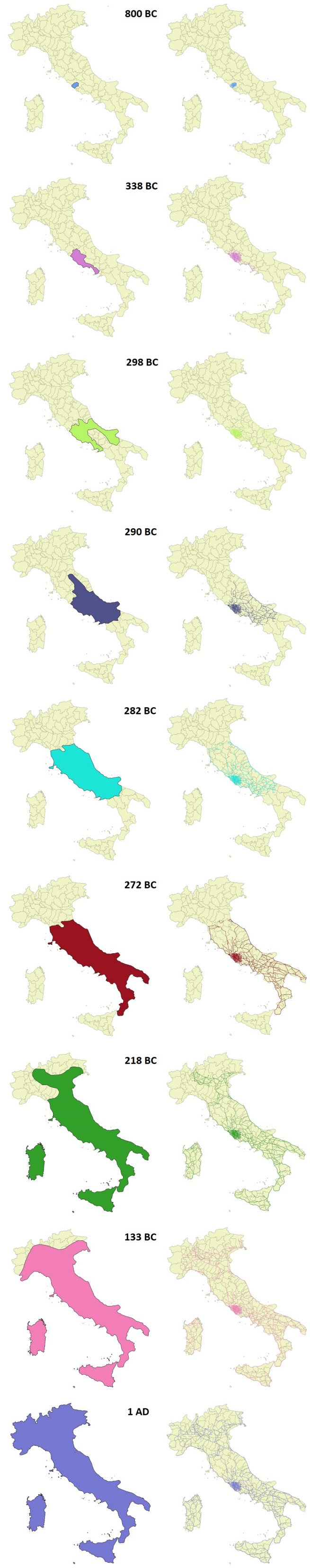
Figure A.3: Roman roads in length by Italian province



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

Source: Authors' elaborations

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



Appendix B - The *Via Appia* and *Via Annia*

B.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.[1] 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[2] 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. But, they were not the only ones. The Samnites were an Italic population living in southern-central Italy, in territories corresponding today to north-eastern Campania, northern Apulia, Molise and southern Abruzzo, who were in conflict with the Romans, due to the aggressive expansionistic policy of both. At first, the Romans and the Samnites concluded a non-aggression pact, agreeing to expand their possessions in different directions, but this treaty was irremediably broken when these directions clashed. On the one hand, the Samnites intended to extend their area in the western part of Campania. On the other, 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

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

[2] 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).

merchants (Musti, 1990), but, later, the ultimate challenge was the conquest of the Magna Graecia and to extend 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 situation of Roman supremacy was as shown in the upper part of Figure B.2. The Romans controlled the entire central and southern parts of the Italian peninsula, 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. As shown in the upper part of Figure B.3, the Romans aimed to expand northwards (in those territories under the control of the Celts), into Gaul, Spain, North Africa and into Greece. The construction of the *Via Appia*, and its stepwise extension 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.

An interesting and nontrivial point has to do, however, with the direction followed by the *Via Appia*. Between 400 and 300 B.C. (i.e. before the construction of the first segment of the *Via Appia*) the major economic centers were located in the southwestern part of Italy, in those territories corresponding today to the NUTS2 regions Campania, Calabria and Sicily. Rhegium, Messana, Panormus, Syracusae, Catana, Agrigentum and Pompeii were thriving cities in the fourth century B.C and were all located in the regions of Campania (Pompeii), Calabria (Rhegium) and Sicily (Messana, Panormus, Syracusae, Catana, Agrigentum). Rhegium (modern Reggio Calabria) was one of the oldest Greek colonies in southern Italy, founded in 3000 B.C. by the Ausones, an Italic people inhabiting the southern and central regions of Italy. During 500 B.C. Rhegium gained, under Greek rule, incredible political and economic significance. Messana (modern Messina) too was a Greek colony, founded in the eighth century B.C. During the seventh and sixth centuries B.C., Messina was a flourishing port and played a central role in Mediterranean trade. Panormus (modern Palermo) was founded by the Phoenicians between the seventh and sixth century B.C. Thanks to its geographical position, Palermo was an important commercial hub. Like Messina and Palermo, Syracusae (modern Siracusa), Catana (modern Catania) and Agrigentum (modern Agrigento) were all Greek *polis* established between the eighth and sixth century B.C. and played a key role in the economy and trade of ancient times. Pompeii (modern Pompei) was founded by the Osci, an ancient Italic population, in the ninth century B.C., important for its port and market. These seven urban centers are the most important testimony to pre-Roman colonisation and confirm that, although economic development was basically concentrated in the southwestern part of the peninsula and in Sicily, the Romans' first major road took another direction, confirming that the first main reason for their construction was military.

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 started from 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. These facts suggest 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.

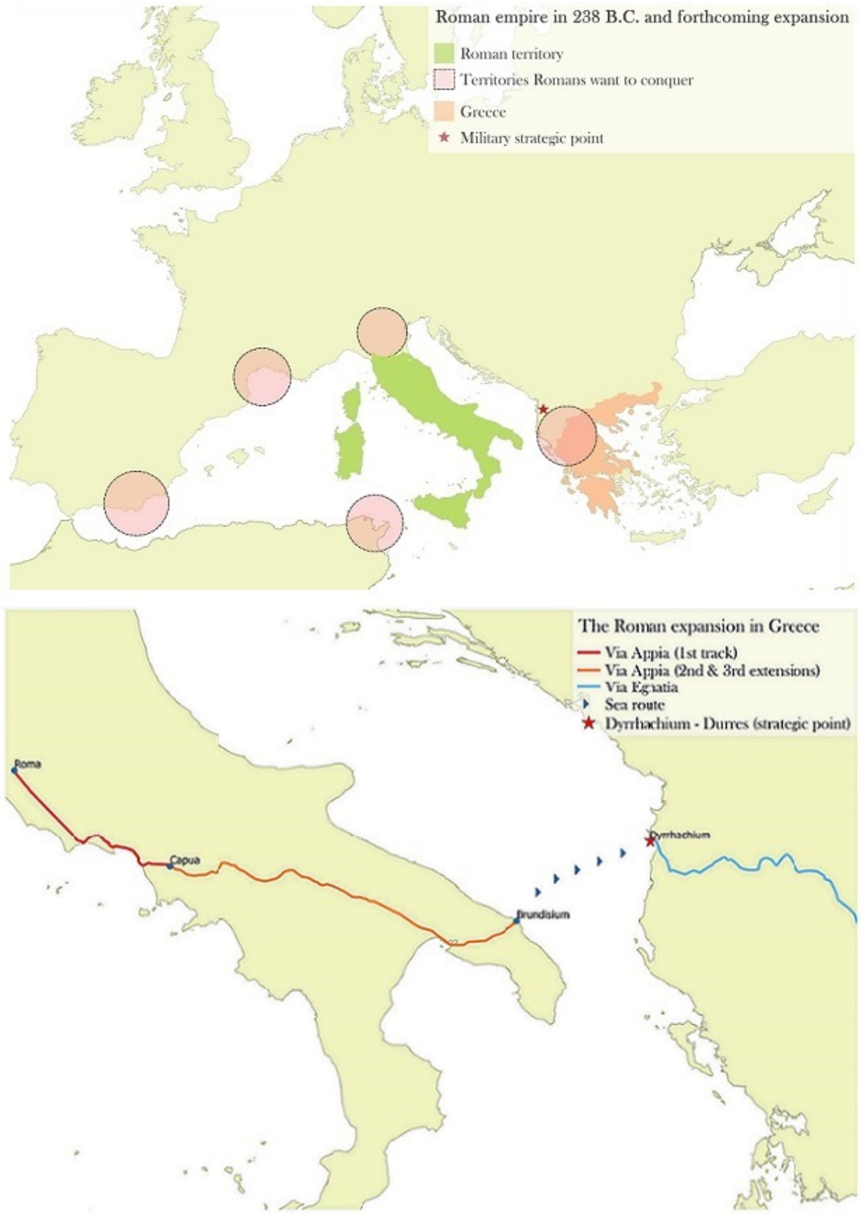
Figure B.1: Roman Empire and Via Appia in 312 B.C.

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

B.2 - The case of the *Via Annia* and the Magna Graecia

Further and clear evidence that roads served as a means to exercise military control over the territory, and that they were designed in successive sections, is the Via Annia.

The *Via Annia*, also known as Via Popilia or Via Popilia Lenate or Via Capua-Regium,[3] was

[3] The name is still being debated since it is not certain which Roman consul was responsible for the construction

the most important road in southern Italy. Built in 132 B.C. (200 years after the *Via Appia*) at the request of the Roman judiciary and, with its 475 kilometers in length, it had the precise function of connecting Capua to Regium (modern Reggio Calabria) so as to guarantee military power in the *Civitas foederata Regium*. In the second century B.C., Romans had already secured the entire South of Italy and they needed a road that easily connected Rome with the foot of the peninsula.

[Figure B.4]

The *Via Annia* covered a tortuous path. As shown in Figure B.4, to reach Regium, the road ran along the western coastline of Campania and Calabria. Starting from Capua, it arrived at Salernum (modern Salerno) first and then at Regium. Along its route, the *Via Annia* touched several Roman *Stationes*: Nuceria (modern Nocera), Moranum (modern Morano), Cosentia (modern Cosenza), Valentia (modern Vibo Valentia). These stations were all located to the West. However, at that time, economic development and urbanisation was concentrated along the eastern Calabrian coastline, where the former Greek colonies were located. Sibari, Crotone and Locri were large and important centers for trade, but were all concentrated eastwards. Figure B.4 clearly shows that the route followed by the *Via Annia* was not intended to connect all those municipalities and though, as in the case of Sibari, the colony lay very close to the road, the Roman constructors designed and built paths that had the primary function of being safe and convenient in terms of repositioning and defence.

Two main indications emerge from the construction of the *Via Annia*: 1) the Roman concept behind road construction is closely related with creating a system of roads that connects strategic military points rather than a network among the major urban centers, and this is true of both major and minor roads; 2) roads were conceived as the assembly of linear segments, the easiest and fastest way to join two strategic points.

of the road.

Figure B.4: The Via Annia

Source: Authors' drawing