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WHEN HISTORY LEAVES A MARK: A NEW MEASURE OF ROMAN ROADS

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When history leaves a mark: a new measure of Roman roads *

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Abstract

It has been twenty years since a new literature emerged. Nunn (2009) and three volumes edited by Michalopoulos and Papaioannou (2017) represent the most complete surveys on this 'new economic history' literature. In recent years empirical works on the persistence of history multiplied. If the 'new economic history' literature has no hesitation in confirming the long-term effect of history, some recent contributions reveal that this persistence does not always occur. By inserting into this framework, the paper has a twofold aim. First, it provides an alternative summary of this literature, collecting those contributions that do not retrieve in history an important factor explaining current economic results. On the other hand, starting from the huge amount of works that confirm the persistence of historical facts, it focuses on those contributions that find in the old transport infrastructure the link between past and present. In last five years, the historical Roman road network has assumed a leading role in this field. And by reviewing the original works that focus on the long-lasting effect of the Roman domination and infrastructure, this paper introduces a new measure of Roman roads that has been constructed at the Italian NUTS3 level. The measure computes the length in kilometers of Roman roads for each province in Italy, and contributes to the literature on historical infrastructures, providing a new precise measure to use for empirical purposes, easy to extend at the regional or at the country level and simple to replicate in all those territories where Roman roads have been constructed.

Keywords: Roman roads; History, Historical infrastructure; Persistence; Italy; Provinces.
Jel Classification: H11, H54, N00, O10, O50, R40.

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"*The construction of roads was the task into which he (Gaius Gracchus) threw himself most enthusiastically, and he took great pains to ensure that these should be graceful and beautiful as well as useful. His roads were planned so as to run across the country in a straight line, part of the surface consisting of dressed stone and part of compacted gravel. Depressions were filled up, any watercourses or ravines which crossed the line of the road were bridged, and both sides of the road were levelled or embanked to the same height, so that the whole of the work presented a beautiful and symmetrical appearance*" Plutarch C.G.7

1 Introduction

Historians and economists have argued how historical events influence economic development and how they have been crucial for better institutions and government attitudes. History has been questioned in terms of persistence, and its long-term effects have been recognized for having important implications on actual economic patterns.

Starting from the work of North (1981),[1] history has been found as having an important role in determining the current economic development, but it was during the first decade of two thousands that several contributions gave new insights on historical variables as fundamental determinants of growth and current economic outcomes.

As highlighted by Tabellini (2010), there is a widespread consensus for the legacy of history. However, some vagueness when referring to the issue emerges. Some economists argue that it is through institutions that history shapes the current economic performance. Limited government, in-corrupt bureaucracy, legal system, low taxation and regulation have been found beneficial to economic development. Economists came along with this conclusion centuries ago: Montesquieu and Smith, in the second half of the eighteenth century, stressed non-intervention of the Government, limited taxation and regulation as the best recipe for economic performance (La Porta et al., 1999).

Alternative to institutions (and history), geography has been recognized by economists as not only a fundamental determinant of economic development, but also as having long-run effects on it. Recently, there has been a large debate whether geography has a *direct* persistent impact

[1] An earliest proof of the long-lasting effect of history can be found in the work of Fogel (1964), who analyzes the impact of railways on American economic development in the nineteenth century. Subsequent the work of North (1981), a contribution by North (1990) and two papers of Greif (1993, 1994) can be considered the most influential contributions of the nineties that precede the birth of the 'new economic history' literature. They analyze the long-term relationship between international trade, growth and changing institutions.

on growth or not. Bleaney and Dimico (2008) refer to a separation between '*pro-geography*' and '*pro-institutions*' economists. Authors like Knack and Keefer (1995) and Hall and Jones (1999) stress the importance of institutions on affecting growth in a persistent way, meaning that geography affects growth *indirectly* only through institutions; others, like Diamond (1997), Olsson and Hibbs (2005), Sachs (2003), find in geography a key and direct explanation for having long-run effects on economy.[2] The well-known work of Acemoglu et al. (2001) emphasizes that only institutions matter for long-run economic growth, and that, once institutions are controlled for, geography has no significant direct effect on income. On the other hand, Sachs (2003) finds that geographical variables have a direct power in explaining the persistence in economic development.

Nunn (2009) refers to the debate in a more broad way, distinguishing between '*pro-geography*' and '*pro-history*' economists. The motivation behind the divergence lies in the fact that geography "*affects human actions in the past as well as today. In other words, in addition to affecting income directly, geography also influences history, which in turn affects current income*" (Nunn, 2009, p. 86).

While a clear consensus has not emerged, however, some distinct points from the discussion '*only history matters vs only geography matters*' can be inferred: i) history acts through institutions or, more generally, there are channels through which history plays its effects today, suggesting that history affects modern economy *indirectly*; ii) geography could have both a *direct* or *indirect* impact on current outcome; iii) scholars that claim the *indirect* effect of geography, suggest that it acts via institutions or through its impact on the past.

Other scholars, like Limão and Venables (2001) place their work between infrastructures and geography. They show the importance of infrastructures in determining transport costs and, consequently, bilateral trade, highlighting that remote, isolated and landlocked countries face higher disadvantages than coastal or island countries. A poor infrastructure system accounts 40 percent of predicted transports costs for coastal nations, 60 percent when considering landlocked countries.

While literature has extensively recognized the legacy of history, during last twenty years a wide list of mechanisms of persistence has been proposed, confirming that there is not only

[2] For these authors geography works through several channels, like climate, disease environment, soil quality, access to markets, availability and productivity of labor and other factors of production (Engerman and Sokoloff, 2002).

one channel through which history acts, since attitudes and procedures change according to time, lands and peoples. Moreover, one channel does not preclude other means, suggesting that the interaction of one or more mechanisms is possible. These mechanisms can be grouped into five main themes: i) early transplanted institutions (due to both environmental and man-made features); ii) culture (like language, religion, beliefs and norms, family ties); iii) geography, environment, genetic diversity; iv) infrastructures and transport systems (like roads, railways, ports); v) movement of people.

The spirit of this paper is twofold. On the one hand, it aims to provide an alternative summary of the literature. While the works that stress the importance of history in influencing current development levels of countries or regions have been highly reviewed by Nunn (2009) and by Michalopoulos and Papaioannou (2017), a review of those contributions that do not find a persistent character in history is, to the author's knowledge, still missing. For this reason, the first part of this paper is devoted to collecting all those studies that contrast with the long-lasting effect of history view. On the other, by entering the huge 'new economic history' literature, it focuses on the historical transport infrastructure channel. It first reviews all those works that find in old transport systems the link between the past and the present. This literature is relatively younger: early literature was basically concentrated on the importance of institutions. In a second step, it introduces the emerging literature that retrieves in the great Roman empire and in its heritage in terms of institutions and infrastructure an indelible mark on modern times. Third, it presents a novel measure of Roman roads specifically computed for the Italian provinces that has been used in the empirical application performed in De Benedictis et al. (2018), where the old Roman infrastructure is studied to assess its long-term effects on current trade costs of Italian provinces. The originality of this measure is that it can be easily implemented to all territorial levels and quickly extended to advanced investigations. The focus on the Roman empire and its legacy in terms of infrastructures is not of less importance. As pointed out by Wahl (2017), historians and economists have proposed different channels[3] through which the Roman domination might have left a mark on later developments, however the empirical analyses on this subject have increased especially during last years. This paper provides a review

[3] The performing institutions, the law and legal systems, the uncountable bishop residences, the urbanization patterns, the developed market economy, the big infrastructure projects (bridges, aqueducts, canals, ports) and the extended road system represented the strong points of the Roman hegemony and were the basis of the survival of the empire for more than seven centuries.

of these contributions as well.

This paper consists of six sections. Section 2 gives account of the stream of literature that does not give an evidence about long-lasting effects of historical events. Section 3 explores all those contributions that confirm the persistent character of history by the effect played by historical transport network systems. Section 4 is entirely devoted to those works that study the persistence of the Roman road system with a glance to that literature that evaluates the influences of the Roman domination other than the Roman roads. Section 5 is divided into three subsections. The constitution of a wide road network, considering the main features related to the development of the road network project and focusing on the state of mind behind the creation of an interconnected, efficient and cohesive empire, is examined in Subsection 5.1. Subsection 5.2 gives account of the important data source of the Roman road network represented by the McCormick et al. (2013) shapefile used to compute the new measure of Roman roads. Subsection 5.3 is the core section of this paper: it describes the novel data sets produced and the newly created Roman road measure in kilometers by Italian province. A descriptive analysis is also presented. Concluding remarks are provided in Section 6. The procedure and the technicalities behind the construction of the Roman road measure are presented in the Appendix.

2 Does history leave a mark?

Replying to this question is not trivial. For the majority of works belonging to the 'new economic history' literature the answer is clearly '*Yes*', and they are briefly summarized in Subsection 2.1. However, in recent years, some works that empirically tested the effect of history on our modern economy, did not find a similar evidence, suggesting that the answer to the question can be '*No*'. Subsection 2.2 collects these studies.

The evidence that emerges after this twofold summary is that history leaves a mark, but its effects not always persist. However, the evidence on persistence of history is large, suggesting that the long-lasting impact of history cannot be disregarded.

2.1 The persistent effect of history

1997 can be considered the birth year of a 'new' strand of economic literature, named '*new economic history*', which aims to highlight the important role of history in the current economic

development. The contributions flourished so rapidly that in 2009 Nunn produced a very complete and accurate survey on the persistence of history providing a precise distinction between the works that marked the origin of this literature, the more recent works and the channels through which history performs. In 2017, twenty years after the origin of this literature, Michalopoulos and Papaioannou edited three volumes, collecting new published economic history papers and separating all those contributions with a global perspective (volume 1) from those with a focus on Africa and Asia (volume 2) and those that look at Europe and the Americas (volume 3).[4]

A discussion of all the works that provide new insights into this growing literature is not feasible and is out of the purposes of this paper. Nevertheless, this section aims to provide a very brief introduction of those works that find long-lasting effects of history on modern economic results, highlighting how literature changed over the past twenty years depending on historical facts it considers and channels it retrieves.

According to Nunn (2009),[5] six works and nine authors marked the birth of the literature on the persistence of history on present economic results: Engerman and Sokoloff (1997, 2002), La Porta, Lopez-de-Silanes, Shleifer and Vishny (1997, 1998), Acemoglu, Johnson and Robinson (2001, 2002). These six works share three main points which represent the key elements of their analyses as well. First, they explain differences in productivity and per capita Gross Domestico Product (GDP) as long-term consequences of better/worst historical institutions, via existing institutions. Second, they are the first to draw attention to a historical event as main explanatory factor of their analysis, looking at the same historical period: the European colonization from the sixteenth century. Third, all of them argue that historical events (like the colonial rule) have a big role in shaping institutions. What distinguishes them is the different source of colonization which shaped institutions. Engerman and Sokoloff suggest that the origin of the missed development of institutions that promote long-term economic growth should be retrieved in different endowments of land and geography. They call 'initial conditions' the reason of the diverse development paths of the American colonies. For La Porta et al., instead, the cause lies in the differences between legal systems based on British common law and those based on Roman civil law. La Porta and co-authors name these legal rules and regulations that typify a

[4] Spolaore and Wacziarg (2013) also provide an important survey of this literature, focusing on those works that consider environmental characteristics and human traits that have been transmitted intergenerationally.

[5] Michalopoulos and Papaioannou (2017) add two more contributions to Nunn's list: Acemoglu, Johnson and Robinson (2005) and La Porta, Lopez-de-Silanes, Shleifer and Vishny (2006).

country 'legal origins'. Whereas, for Acemoglu et al. what generated the settlement of European colonizers, which in turn encouraged growth-supporting institutions, was the subsistence of a less deadly disease environment.

If these first contributions are remarkable since they launched the literature on the persistence of history, the work of Acemoglu et al. (2001) is particularly significant in the economic literature for the quantitative method they use. They rely on an instrumental variables approach to deal with the possible endogeneity problem of institutions, using the mortality rates of the European settlers as instrument for current institutions in America.

Right after the six pioneering works, the interest of scholars remained on the themes that characterized the birth of the literature (colonialism of Americas and institutions) for a while. Djankov et al. (2002, 2003), Acemoglu and Johnson (2004), Glaeser et al. (2004), Lange (2004), Berkowitz and Clay (2005, 2006), Mulligan and Shleifer (2005a, 2005b) are the most influential contributions during this period. They followed the insights of the works of La Porta et al. (1997, 1998), suggesting new variables that interact with the legal origins and providing new evidence on the mechanism of persistence.

In 2005 the interest on colonial rule and institutions endured, but the geographical focus changed. Banerjee and Iyer (2005) look at India, Dell (2010) focus on South America (Peru and Bolivia), Acemoglu et al. (2008) consider Colombia, Nunn (2008), Berger (2009) and Huillery (2009) take into account Africa, Feyrer and Sacerdote (2009), using an innovative estimation strategy, look at islands.

After this setting-in period, where the interest was mainly focused on colonialism and persistence of institutions, new articles contributed to giving innovative insights on the channels through which history works. A flourishing literature started to grow, taking into account the impact of various and original historical shocks, with newly collected data and self-created measures and proxies, exploiting advanced econometric techniques and combining information and methods of different fields, generating an inter-disciplinary approach (Michalopoulos and Papaioannou, 2017).

A big share of this literature is composed by those works that find in the cultural traits (meant as features related to language, religion, beliefs, social rules, thoughts and family ties) the explanation of the heritage left by history on nowadays economic outcomes. The main contributions are those of Becker and Woessmann (2009), Fernández (2007), Fernández and Fogli

(2009), Voigtländer and Voth (2012). Becker and Woessmann (2009) argue that the Protestant religion is able to explain economic development of those regions where Protestantism has been established. Fernández (2007) and Fernández and Fogli (2009) find that labor force participation and fertility rate for second-generation female immigrants in the U.S. are positively correlated with the corresponding patterns in their country of origin. Voigtländer and Voth (2012) show that anti-Semitic culture and attitudes within Germany persisted over more than five centuries.

Other literature has focused on the transmitting role of geography and environment. As mentioned in the Introduction, Diamond (1997), Sachs (2003) and Olsson and Hibbs (2005) are the most influential contributions on this subject. Diamond (1997) argues that the success of European civilization and its ability to expand throughout three continents (America, Africa, Oceania) was not due to an intellectual superiority of Europeans, but rather it was because they had the fortune to live in a continent (Eurasia) whose environmental conditions favored the development and the diffusion of two elements that contributed significantly to the European supremacy on other peoples: weapons and diseases. The "health" factor is corroborated by Sachs (2003), according to whom geography affects health, environment and production, which, in turn, affect institutions. Accordingly, Fenske and Kala (2015) show how lower temperature during slavery in Africa, by reducing mortality and facilitating exports of slaves, predicts lower economic performance today. For Olsson and Hibbs (2005) the quality of current institutions should be retrieved in the role that geography played in determining the transition from hunting and gathering to farming, i.e. the start of Neolithic. Hornbeck and Naidu (2014) link the adoption of new technologies for improving productivity in the U.S. South to the Great Mississippi Flood. In 1927 the flood lead black people to migrate to other areas and, since the lack of labor, farmers were forced to implement new technological strategies to enhance their productivity. In Ashraf and Galor (2013) heterogeneity in current economic development can be predicted by genetic diversity.

The contributions of Hornbeck and Naidu (2014) and of Ashraf and Galor (2013) corroborate also that scholars that argue that the mechanism of persistence lies in the movement of people. Moser et al. (2014) find that during Nazism the migration of Jewish people from Germany to the U.S. increased the number of American patents in those fields where Jewish researchers were specialized and positively affected innovation by attracting new inventors. Grosjean and Khattar (2019) take into account the effects on current culture of the movement of male convicts

from England to Australia in eighteenth and nineteenth centuries.

A more recent literature has focused on the role played by historical infrastructures and transport systems, like roads, railways, ports. Section 3 explores these contributions.

2.2 The missing effect of history

The brief review until now presented argues that history is able to produce long-lasting effects, affecting past and modern economic outcomes. In almost twenty years, a wide range of historical episodes has been investigated and significant persistent effects have been retrieved in their shocks. However, the mark of persistence, allocated to history, does not always emerge. Inside the economic research on the legacy of historical facts, some contributions bring to light those cases and circumstances in which history has not produced inheritance on present economy. These are episodes that generated impacts in the past, but are not affected by the 'lasting feature' able to cause an effect today. This section is focused on these contributions.

One of the first contributions is the work of Davis and Weinstein (2002) that investigates the spatial pattern and heterogeneity of the economic activity across regions. In order to assess whether temporary shocks have persistent effects on urban areas, they look at the distribution of the regional Japanese population in a time span of 8,000 years, from the Stone Age to 1998, and exploit the bombing of Japanese cities by the Allied forces during World War II. The empirical evidence coming from their instrumental variables approach, where deaths and destruction are used as instruments for population growth rates, highlights how big temporary shocks do not affect in a permanent way the spatial structure of the economic activity and how Japanese cities recovered their former populations in a short time. In fact, although the magnitude of devastation and of bombing during World War II, there is no proof of long-run impact on the relative size of cities: the urban areas were restored in a period of fifteen years.

The work of Miguel and Roland (2011) shares with the paper of Davis and Weinstein (2002) the war subject. However, whereas for Davis and Weinstein the allied bombing of Japan during World War II is a tool to examine the spatial distribution of economic activity, in Miguel and Roland (2011) the historical issue is the core of their study. Starting from a twofold perspective of theory, according to which, on the one hand, the destruction of the capital stock during wartime may lead to a poverty trap with a subsequent long-run underdevelopment and, on the other, the economy is able to recover pre-war physical and human capital accumulation levels

without long-term impacts on the economy, they investigate what are the long-term effects of the U.S. bombing on the economic growth of Vietnam. Using the distance from a district to the North-South Vietnam boundary (where the U.S. army focused its bomb attacks) as an instrument for the bombing intensity, they find no empirical proof of long-lasting impacts on modern poverty levels, household consumption, literacy rates, infrastructural standards and population density. Vietnamese districts recovered fast from wartime bombing, suggesting that no poverty trap occurred and, consequently, the doubtfulness of the poverty trap theory for Vietnam. Vietnam, such as Japan and Germany, benefited from performing institutions able to arrange reconstruction and wealth redistribution, which allowed to successfully overcome the drawbacks of war.

In line with the work of Miguel and Roland (2011), the very recent contribution of Saing and Kazianga (2017) looks at the U.S. bombing in Cambodia between 1969-1973 to explore the long-run effects of armed conflicts on development. Exploiting bomb intensity as a measure of war destruction and adopting a difference-in-differences approach to calculate the effects of bombing on a wide set of economic outcomes, they find that war negatively affected years of education, and increased the number of birth and the age at first marriage for females. However, there is no evidence of long-term effects on earnings, employment rate and women's height, corroborating Miguel and Roland's findings.

To empirically explore the industrial location, Redding, Sturm and Wolf (2011) look at the division of Germany after World War II and the reunification of East and West Germany in 1990. In particular, they consider a particular economic activity, the air hub, and a particular historical fact, the relocation of the main German airport from Berlin to Frankfurt after World War II. Two different classes of theoretical models predict the distribution of industrial activities. The first class argues that initial conditions, historical shocks and agents' expectations determine multiple steady state distributions. According to the second class, instead, institutions and endowments are the main factors affecting a unique steady state industrial location. If Davis and Weinstein (2002) and Miguel and Roland (2011) are two empirical proofs of the existence of a unique stable steady state, suggesting a central role of economic fundamentals in determining industrial locations, they do not provide, however, a proof against the existence of multiple equilibria. Redding et al. (2011), instead, find how the treatment effect of the division is statistically significant and how, on the other hand, the treatment effect of reunification in 1990

is not statistically significant, suggesting a persistent character in the location of the economic activity after the movement. Redding, Sturm and Wolf explain this result as a consequence of high sunk costs of building air infrastructures and argue that multiple steady states for airport locations are possible.

A further evidence of the absence of long-lasting impacts of history can be found in the work of Valencia Caicedo (2014), who argues that the foundation of Jesuite Missions during the seventeenth and eighteenth centuries is able to explain the current income and education level in South America, but this is not the case when considering the Franciscan Missions. Although Franciscan Missions have been established before the Jesuite ones and had the opportunity to locate in better sites, there is no evidence of long-lasting effects on modern incomes or literacy. Valencia Caicedo describes how these differences can be explained by considering the duty of the missions. Franciscans were more focused on reducing poverty and inequality. The Jesuits, instead, were more oriented towards the technical and human capital formation. Moreover, the Franciscans were more subject to the Spanish colonial rule. The Jesuits, instead, were more able to obtain lower taxes and labor tributes from the Spanish government.

Another recent work is the one of Cantoni (2015) who puts his work in that branch of the literature according to which Protestant, rather than Catholic, religions positively affect economic development in the long-run. On these bases, since the heterogeneity in religious beliefs in Germany during the Middle Age, Cantoni looks at the Holy Roman Empire between 1300 and 1900 as a natural experiment to empirically assess the relationship between Protestantism and economic growth. Using a difference-in-differences setup in order to measure disparities in urban growth between Protestant and Catholic cities and exploiting an additional instrumental variables approach, where the distance to Wittenberg, the Martin Luther's city, is used as an instrument for Reformation across Germany, Cantoni finds no long-run differences in economic performance between Protestant and Catholic cities. The explanation behind this original result might be connected to the works of Doepke and Zilibotti (2005, 2008), according to which, the economic circumstances, rather than the religious beliefs, are the main drivers of individuals' personal improvement in terms of prudence, literacy and parsimony.

The very recent contribution of Waldinger (2016) concludes this brief review. In his contribution the historical event is used to examine what is the effect of human and physical capital on scientific productivity. He looks at Germany under the Nazi rule and during World War

II. Since the endogeneity problem linked to both inputs (most productive departments attract better scientists and invest in physical capital, and good researchers and advanced physical resources enhance productivity), two historical shocks are used to exogenously identify human and physical capital levels: the dismissal of Jewish scientists and the allied bombing. Waldinger, exploiting data on publications and citations for different years until 1980, finds that the layoff of many Jewish researchers (human capital shock) negatively affected both in the short- and in the long-run the knowledge productivity in departments and universities. The allied bombing (physical capital shock), instead, had a negative effect only in the short-run; persistent impacts are not retrieved in recent productivity. The main conclusion is that both inputs are determinant in the production of scientific knowledge; however, whereas physical capital is able to restore in short time its pre-existing levels, negative shocks on human capital persist much longer.

3 The persistent effect of historical infrastructure

Recent literature has revealed interest in the effect of historical great transportation infrastructure projects on reducing trade costs, on playing a positive impact on productivity and on increasing the level of the real income in trading regions.

Public investments in transportation infrastructure and their effects on income, exports and education have been largely debated since the earliest projects in ancient times. Some politicians, historians or simply observers were skeptical about the positive impact that new roads and railways might perform on development and wealth, while others argued that these investments could have promoted beneficial effects on several spheres of economy. Today, the positive consequences deriving from public investments in new transportation infrastructure are highly recognized, although policy makers claim for more proofs on the extent of their effects. The experience of historical big transportation constructions represents a helpful and practical evidence of what have been the favorable results of new transportation infrastructures.

During last ten years, a growing number of contributions about the old historical infrastructure emerged. Starting from the work of Aschauer (1990), which pioneered the empirical evaluation of the effects of transportation projects, a younger literature on a variety of transportation infrastructures in different areas of the world has been developed: from the Inca roads in Peru to the railways in Sweden, from the steamships in Argentina to the railways in America, from the Chinese railways to the railway network in America and India.

Fourteen years ago, Banerjee, Duflo and Qian started to investigate the long-term effects on economic growth of better access to transportation infrastructure. The interest was to empirically assess the causal impact on a twenty years period (1986-2006) of rapid growth in China. In order to avoid the potential endogenous location of roads, they rested on the idea of drawing a straight line connecting the historical Chinese cities as an instrument for the modern infrastructure (railways and coastal routes) in China. They suggested that the straight lines linking the historical Chinese cities capture the old historical Chinese railways, constructed by the Chinese government in the late nineteenth-early twentieth century, which, in turn, capture the modern transportation infrastructure developed in China during the 1980s. Carrying out an innovative identification strategy and performing a detailed empirical analysis, the results emerging from their investigation confirm how being close to transport networks leads, although moderately, to higher GDP per capita levels, increases the number of firms and has a positive effect on firms' profits. This work generated further investigations in following years[6] and assumed its up-to-date version in 2012. The work of Atack et al. (2010) exploits the straight-line concept to evaluate the effect of access to railways in the U.S. on urbanization and population growth during the mid-nineteenth century by drawing a straight line between two counties representing the starting point and the endpoint of a potential railway. Similarly, Faber (2014) exploits a straight-line instrument, based on Banerjee and co-authors' historical lines of transportation, in conjunction with other additional lines to capture the modern China's highway system and evaluate whether reduced trade costs induce industrial concentration or diffusion of economic activity to periphery. Faber finds that non-connected peripheral counties experience a reduction in industrial output growth which, in turn, reduces the local GDP growth. The straight-line instrument adopted by Banerjee and co-authors is particularly important also in the discussion about the construction of Roman roads from an engineering point of view. Following Section 5 will recall these thoughts.

Along the investigation on railways, Donaldson in two subsequent works (the second one with Richard Hornbeck) analyzes two great historical railway projects: the railway network designed and built by the British government in India between 1853 and 1930 and the railway network expansion in the U.S. during the late nineteenth century. Donaldson (2018), with its investigation on the impact of the Indian railway network during the colonial India, presents three

[6] Atack et al. (2010) and Faber (2014).

important contributions in the understanding of the effects of large transportation infrastructure projects and their expansion. By using a Ricardian model based on Eaton and Kortum (2002), Donaldson finds that railways are the best instrument to reduce distance and trade costs: trade costs increase with effective distance and the railway freight rates are lower than those of roads, rivers or coastal transport. When considering trade flows, railways significantly enlarged trade in India, producing also welfare gains due the increased gains from trade. Moreover, in terms of welfare gains, the access to the railway network raised the real agriculture income by over 16 percent. The agriculture sector in America is considered also in Donaldson and Hornbeck (2016): alterations in the railway network influenced counties' market access and that changes in market access were capitalized into agricultural land values. The authors find that railways had a positive effect on the agriculture sector and that removing all railways in 1890 would produce a loss in the Gross National Product (GNP) equal to 6.3 percent.

Two further works that look at historical railways are the contribution of Jedwab et al. (2017) and Berger and Enflo (2015). Jedwab and co-authors put their work in that vast literature aimed at understanding what determines the distribution of economic activity across space and how historical shocks shape the pattern development. In Subsection 2.2 some of these contributions (Davis and Weinstein, 2002; Miguel and Roland, 2011; Redding et al., 2011) have been examined; however, the empirical evidence is various. The work of Jedwab et al. (2017) uses the case of colonial railways in Kenya as a natural experiment. The colonial period in Kenya started in 1895 and ended in 1963, when it became independent from the British government. During that period, in 1896, European colonizers began the construction of the railway in Kenya, that reached its maximum extension in 1930. Focusing on this year, the authors construct a measure of railways, exploiting both rail and placebo (railways that were planned but not constructed) lines, and perform a double empirical analysis. On the one hand, they assess the effects of railways in the short-term, using as dependent variable outcome variables related to the colonial period: population growth, European inhabitants, agriculture, and other historical factors. On the other hand, they look at the long-term effects, exploiting long-run and modern economic measures (population growth, nightlight luminosity, poverty, and other contemporary factors). The authors find that railways had a main role in determining the outline of European settlements which, in turn, due the economic development they generated, influenced the location of Kenyan cities at independence. These cities are the most developed still today, confirming the

persistent effect of railways. Regarding the matter of industrial distribution across space, Jedwab et al. (2017) confirm the existence of path dependence and multiple steady states for economic activity locations, as suggested by Redding et al (2011). The contribution of Berger and Enflo (2015) is in line with conclusions emerging from Jedwab et al. (2017). Looking at the railway infrastructure in Sweden, built during the middle of the nineteenth century, Berger and Enflo aim to explore the effects of transportation infrastructures on urban growth and location of economic activity across towns. They distinguish towns that had access to railways during the first wave (1850-1870) of railway construction (treatment group) from non-connected towns (control group). Moreover, they connect endpoints by straight lines and measure a buffer zone, creating an instrument to identify connected towns. Exploiting both a difference-in-differences and an instrumental variables approach, they find short- and long-term effects: railways increased urban population in towns that gained access to the transportation infrastructure. This growth is mainly due to a redistribution of industrial activities from non-connected cities to connected ones. The increasing in population lasted in the long-run: cities which grew during the first wave of construction expanded in later centuries too. Finally, Berger and Enflo contribute to the literature on the location of economic activity and existence of a unique equilibrium or multiple steady states, arguing that path dependence in the distribution of industrial activities occurs.

Fajgelbaum and Redding (2014) take into account the introduction of big steamships in Argentina in late-nineteenth century. The integration into world markets of Argentina is used as natural experiment to examine how geographic heterogeneity within the country affects external integration by reducing global transport costs which, in turn, determines economic growth and welfare. The improvement in sailing reduced the external shipping cost, making it profitable to export from Argentina to Europe a large amount of agricultural products and meat, and stimulating the expansion of the railway infrastructure. Developing a general equilibrium model, Fajgelbaum and Redding highlight how being close to world markets increases population density, employment, relative prices of non-trade goods and of land.

The original contribution of Volpe Martincus, Caraballo and Cusolito (2014) concludes this review. They analyze the case of Peru, in order to assess which has been the effect of the new road infrastructure on firms' exports and employment and investigate whether public policies

supporting transportation infrastructure projects positively affect firms' global trade.[7] In order to not incur in endogeneity concerns, Volpe Martincus and co-authors use the Inca road network (built by the Inca empire before 1530) as an instrument for the current road infrastructure in Peru. The Inca road network represents an exogenous source of variation in transport infrastructure, since the reasons behind its construction are completely unrelated with current firms' foreign trade and employment. Moreover, the authors confirm that the only channel through which the Inca roads affect today's exports is represented by the correlation with the spatial allocation of new roads. They find that domestic road infrastructure increased firms exports, and this expansion in global trade induced firms to hire more employees. Moreover, improvements in road networks lead advantage to firms' exporting activity and job growth, thanks to the ease of more and larger shipments that the new roads allowed.

4 The persistent effect of Roman roads

The economic history has widely devoted interest to the magnificent Roman past of most of European countries, emphasizing how the Roman empire has represented for more than seven centuries an interesting and impressive domination from an historical point of view as well as from an economic perspective. During recent years, rather than investigating the past, the economic literature started wondering whether the Roman legacy persisted until today. This interest has become significant and the greatness of the empire, and all those elements characterizing the Roman domination, have started to be included in appealing contributions focused on the understanding of the long-term effects of the Roman world. In some of these works the importance of the Roman road infrastructure is mentioned, but it has been only during last years that the literature has begun to investigate on the persistent effect of Roman roads on modern economy and, at the time of writing this paper, there are only three works completely devoted to analyzing whether there has been and what has been the impact of the Roman road network on present economic outcomes.

In the work of Buringh et al. (2012), the Roman road issue appears marginally: the road

[7] As highlighted by Volpe Martincus et al. (2014), Peru has experienced in the first decade of two thousands an important expansion of its road network and some figures claim that firms, in those municipalities whose roads connections to the main port improved, increased both exports and employment between 2003 and 2010. Although this statistical evidence, it is not totally informative due the problem of reverse causality that typically affects the relationship between infrastructure and exports or infrastructure and employments.

stations are used to identify a type of settlement in Roman times. Buringh and co-authors aim to study the development and the spatial distribution of a market economy during the Roman civilization using the size and place of Roman settlements as a proxy for the urbanization and the distributions of low denomination coins as a proxy for the market economy. They find that the Roman military presence in a given area and the big demand of goods and services is the explanation behind the constitution of a market economy and the differences in the economic development in north-western Europe around the year 150 A.D. These differences are confirmed also by the recovery of coins. The presence of a market economy can be retrieved in the small denomination coins circulating during the Roman period; the absence of these coins during pre-Roman times and the higher fraction of precious metals in the coins found after the collapse of the Roman empire confirm that the market economy has developed with the military payments, which not only played an important role in creating a cash based market economy, but contributed to urbanizing those territories where the military demand of goods and services was high. The perspective of the paper is mainly devoted to understanding the past, rather than investigating the effects on the present, and the use of the Roman road subject is only instrumental. On the other hand, the work informs about how originally military settlements had later on developed into a mixed civil-military settlement with the arrival of civilians, highlighting a legacy of the Roman domination in influencing subsequent developments and urbanization.

Bosker et al. (2013) use Roman roads as a potential for cities to trade. The contribution is aimed at appreciating the different development of Europe and of the Islamic world in a long-run period, from 800 to 1800. The authors find that the reasons behind Europe's growth and Islamic world's stagnation must be retrieved in specific characteristics of the two worlds, since the interaction between them was limited by their divergent religious orientation. In the work, Roman roads are used to identify those settlements that could benefit from a close land-based transportation. According to the authors, the Roman roads have the advantage of being uniform in both Europe and Islamic world, since they were constructed with similar standards and methods in the entire Roman empire, and they are not affected by endogeneity. The Roman road reasoning is used as a tool to identify those settlements that could benefit from the proximity to the road, but differently from the previous work, there is no interest for the Roman world. On the other hand, the authors remark how the fall of the Roman empire caused a period of stagnation in Europe and suggest that the role of the Roman road network

in determining development and urbanization in the Islamic world was limited and weak.[8]

While Roman roads played a marginal role in influencing settlement in North Africa and in the Middle East, this is less the case when considering Europe. In this regard, the work of Bosker and Buringh (2017) is aimed at understanding what determined urbanization in Europe over the period 800-1800. The authors find that geographical features (like being close to water- or land-based transportation, the existence of agricultural possibilities, accessibility) have been fundamental in determining the city location during the starting phases of the constitution of the European urban center. It was only in a second stage, from the seventeenth century onwards, and with the decrease of trade costs, that the geographical characteristics of the surrounding urban system (like being close to already existing cities) influenced the city location. In this contribution, rather than appreciating the comparison between two different worlds (the European and the Islamic), the attention is completely devoted to the old continent, and the Roman road issue comes out in a more substantial manner. Bosker and co-author, as in the previous work (with J.L. van Zanden), use Roman roads to identify those locations that take advantage from being located close to a road or, even, where two or more Roman roads crossed. The findings coming from the work are interesting. Their results suggest that both location on a river and by the sea significantly and positively affect the possibility of a location becoming a city. Locations on a Roman road or on a hub of two Roman roads, instead, have less chances of developing into a urban center. These results are not robust when distinguishing the one thousand years period between pre-1600 and post-1600. In the pre-1600 period, being located at a hub of Roman roads is beneficial for a settlement; in the post-1600, this advantage becomes insignificant or even negative (disadvantage).

The work of Micheals and Rauch (2018) represents one of the first attempts in studying the impact of the Roman empire after two millennia. They analyze whether history is able to affect and to entrap the location of a town for centuries or whether geographical features are the only ones responsible for it. In order to test this research question, they trace the locations of towns in France and Britain back to the Roman Empire. France and Britain represent a perfect case study: they were both touched by the Roman domination and, in later centuries,

[8] As highlighted by Wahl (2017), the modest or absent effect of Roman roads in fostering development in North Africa and the Middle East may be explained by the fact that the *"[...] most of the Roman parts of North Africa are located in the Sahara, making large settlements anywhere other than the coastal area almost impossible"* (Wahl, 2017, p. 315).

French and English towns were characterized by similar institutions, organization and size. But, after the collapse of the Western Roman Empire, France and Britain went through different destinies. While in Britain the urban network stopped, in France this was not the case. The fall of the Western Roman Empire represents the shock to investigate the spatial consequences of the relocation of towns. The authors argue that, from the Early Middle Ages until the beginning of the Industrial Revolution, French towns, compared to the British ones, were settled three times closer to old sites of Roman towns. This medium-term persistence is confirmed in nowadays France and Britain's urban locations, suggesting how town settlements in Britain relocated more than in France and how urban networks are affected by path dependence not only in the medium-run, but also in the long-term. Moreover, Micheals and Rauch use the Roman road issue to explain whether the difference between the urbanization in France and Britain can be ascribed to the road network. Roads were constructed to allow the move of the Roman army in a quick and easy way, and during the hegemony of Roman empire some towns grew alongside the roads. But during the Middle Ages, with the deterioration of road quality and with the increasing improvement of water transportation, coastal access became more important and towns were more prone to having a port.

In all these studies, the heritage of the Roman empire comes out in the development and urbanization in future periods: most of old Roman towns became important cities in subsequent centuries[9] and the Roman legacy appears more acting in the medium-run (during the Middle Ages) rather than in the long term. Moreover, from these contributions, it emerges the important role of roads in facilitating settlements and in creating urbanized centers[10] in early stages of urbanization. Although the key function of roads comes into view, none of these works is entirely focused on understanding which has been the legacy of the old Roman road network. The works of Wahl (2017), Dalgaard et al. (2018) and De Benedictis et al. (2018) are the first ones that study whether the Roman road system is able to affect the modern economy by its persistent effects.

Wahl (2017) argues that the distinction between a West developed Germany, crossed by an integrated Roman road system, and a less advanced (compared to the West) East Germany originates from the division in ancient times between a Roman and a non-Roman part. The

[9] See Pirenne (1969) and McCormick (2001) for a more detailed analysis.

[10] Lopez (1956) discusses the importance of the Roman road system in Europe during the Middle Ages.

Roman Western and Eastern parts of Germany do not belong to the division between West and East Germany after the World War II, but the separation corresponds with the track of the German Limes wall, which crosses the entire southern part of Germany and the most Central-Western Germany. In fact, differently from other countries (like France, Italy and Spain), Germany has not been completely touched by the Roman domination and the Limes wall represents the geographical discontinuity between the Roman German part and the non-Roman one. Wahl takes advantage from this fact and bases the empirical identification of an effect of the Roman road network on a spatial regression discontinuity approach using the German Limes border as a cut-off to separate treated (crossed by Roman roads) and non-treated (not crossed by the Roman infrastructure) areas. Using the nightlight luminosity, Wahl shows that the Roman Limes border wall represents the boundary in the economic development of actual Germany. Moreover, Wahl shows how the Roman road infrastructure positively influenced the constitution, the growth and the agglomeration of cities resulting in current higher urbanization and economic progress.

Likewise, employing the current nightlights intensity and the population density in Europe, Dalgaard, Kaarsen, Olsson and Selaya (2018) find a long-run causal effect of Roman roads on economic development: the intensity of the Roman road network is able to predict the historical urban population levels and current levels of economic activity. According to Dalgaard and co-authors, the channel of persistence is represented by a link between the historical Roman infrastructure and the modern road infrastructure. However, this mechanism is weakened by its use in time. In those territories, like North Africa and Middle-East, where after the collapse of the Roman empire roads were abandoned and wagons were substituted by camels, the effect of persistence disappears. In Europe, instead, where during Middle Ages the Roman infrastructure was maintained and wheeled vehicles continued to traverse the roads, the heritage in terms of a more developed modern infrastructure and economic activity emerges.

Accordingly, the link between the Roman and the modern infrastructure is corroborated by De Benedictis, Licio and Pinna (2018), who apply a meso-approach considering the case of Roman roads in Italy. The Italian peninsula represents an ideal case study since the whole territory was under the Roman empire and 108 out of 110 NUTS3 provinces have been crossed by the Roman road network. They exploit a measure in kilometers of Roman roads and focus on the major (consular) roads as an instrument for the current infrastructure. Econometrically, the use

of historical transport systems rather than geographical instruments allow to overcome all those situations where geography does not fulfill the exclusion restriction condition. According to the authors, the old Roman roads are a good predictor of both current motorways and railways and are able to explain differential patterns in trade: provinces with a denser Roman infrastructure have lower trade costs today and tend to trade more internationally than domestically.

5 The Roman road network

5.1 The Roman road network: a brief overview

The Roman empire has represented, in Italian and non-Italian history, one of the (say the) greatest empires of all time in terms of territory possessed and duration of political power. As highlighted by Laurence (1999), historians have recognized that the Roman state was involved in the development of an extensive transport network of roads starting from the fourth century B.C., but understanding the impact of the road building has not been one of the main objectives in their studies.

The tactical purpose, the logistics for the war campaigns and the supply of the army across roads represent the spirit of the road system and of the whole Roman empire. Although the military aim is at the core of the road network, when talking about Roman roads there are other four main aspects that should be considered and that are strictly related to the constitution of an intricate road system: i) the development of a great empire, ii) the advanced engineering abilities of the Romans, iii) the openness and mobility culture, iv) the other ways of transport and trade. In this section, all five themes (military, empire, engineering, openness, transport) will be briefly covered, focusing on how the army purposes led the engineering knowledge of Romans to construct roads that lasted until today, that served the foundation of a complex and huge empire continually expanding and that enabled openness and connectedness.

Starting from the military theme, Roth (1999) underlines that the Romans built their roads primarily for military reasons; the commercial travel was only an indirect advantage of the road network. The majority of the weight of the Roman army supplies was represented by three elements: food, fodder and firewood. Hence, all military decisions were determined by the need to assure the provision of supplies to the army. Accordingly, Thompson (1997) explains that the construction of a road network originated from the need to ensure that a large number of

horses, cattle, carts and infantry could circulate: primordial non-Roman routes were problematic during wet and rainy days, since the deep mud impeded or delayed the movement of goods and services. Therefore, the construction of a network of paved roads empowered not only the transport of goods and services, enabling the movement of larger quantities and people and making transfers easier, but armies were able to travel twenty-five miles a day, even in bad weather conditions. During the Republican and Imperial periods, the Roman empire conquered territories in the Mediterranean Sea (like Sicily, Sardinia, Corsica, the northern coasts of Africa), in the Atlantic Ocean and in the Black Sea. Roth (1999) describes that the Romans were aware that moving supplies to the army by ship was cheaper and faster than by land, but transport by sea was dangerous and expensive. Seafaring in the Mediterranean was limited between March and November, although it was really safe only during the summer months (from June to September). On the contrary, land transport had no limitations and was practicable all year round. The Romans understood that the need of a logistical infrastructure was fundamental for the movement of armies and supplies and consequently for the enlargement of the empire. Hence, in order to facilitate the move of the army from place to place, they constructed roads intended mainly for wagon travel used for supplies; soldiers and pack-animals could travel as well. Since the military purpose was the priority for the Romans, expansion, maintenance and repairing of the road network were continuously performed for and associated with military campaigns and strategic and tactical purposes.

Historians have argued how the design of an intricate road system and the development of a great empire were strongly correlated. On this point, Thompson (1997) argues that the vast and comprehensive Roman road system changed the entire empire. Accordingly, Gleason (2013) stresses that the enlargement of the empire was possible thanks to a developed road system. In fact, the Roman army was too small to conquer the enemies of Rome, but the constitution of a vast empire was possible investing in the construction of a complex road network rather than enlarging the infantry forces. Knapton (1996) underlines that the new conquered regions, on the one hand, enlarged the Roman empire contributing to its power, authority and wealth; on the other hand, the payments of conquered territories were mainly used for the public infrastructures, like roads and aqueducts. This led to the development of the engineering capability of the Romans. The peak of the Roman empire corresponds with full extent of the road network (117 A.D.-death of Trajan) as further proof of the fact that roads construction and the constitution

of a vast empire were highly related.

The engineering behind the construction of roads subtend incredible and high-level skills. Romans were mainly focused on getting the road straight, since it was easier for the network structure and shape. To achieve this straight configuration, they defined points that could be quickly connected by a straight line (Davies, 1998). Accordingly, Gleason (2013) explains that to mark the roads path with either stakes or furrows, creating roads as straight as possible, was the first purpose of Romans. Legionaries and slaves belonging to the army were involved in the roads construction process. This process included first of all the digging of a 1.5 meters deep trench for the width of the road. In order to guarantee the stability and durability of the substrate, the trench was filled and packed with several textures and types of material from the land around it. Then they applied a layer of gravel or pavestones, ensuring that the road had a camber, or rise in the center, to prevent erosion and make the surface all-weather capable.

Behind the development of an intricate and technological road system there is a culture of openness and mobility. Geographical distance between places creates distance between people. Knapton (1996) describes how the Roman road network represented a system which connected different peoples and cultures from Newcastle to North Africa, from Portugal to Arabia. The Italian territory was itself a mixture of peoples: Greek colonies and the Samnites in the South, the Latins and the Sabines in the Centre, the Etruscans in the North of Rome, the Celts in northern Italy and other peoples in the rest of the peninsula. During what has been called 'the golden age of Roman road building' (second century B.C.), the Roman empire became interlinked with a network of roads which led to greater mobility and the Romans used to live overseas and to become wealthy. On this point, Laurence (1999) highlights that the understanding of the nature of Roman space-time is fundamental to appreciate the cultural change associated with road building and the improvement in terms of road technology. Roman roads changed the speed of communication and created connections throughout the year: the space-time concept integrated the elements of physical distance and time taken to complete a journey over that distance. The road system created an interconnection between places that allowed for a mobile elite and citizen body and also the mobility of surplus products and profits. The developments in the road system technology and the increased efficiency of transports, together with a state of mind of space-time that emphasised the transport of people and goods over a distance, were features of a culture that had an emphasis on mobility. The issue of mobility was embedded

particularly in a system of elite land holding, that depended on mobility of the landowner for its economic survival, and an elite culture, that laid claim to active involvement in the management of their estates (Laurence, 1999).

Road transport can be seen as a complementary system to river and maritime transport. It has been argued that land transport was an inferior, expensive alternative to maritime transport. Goods were constantly transported throughout the Roman Empire and it has been largely discussed that, despite the risks, dangers and problems, the most efficient way to transport goods was by sea. According to its size, it could carry cargo weighing between 70 and 350 tons (Snedden 1998). Ships were preferred to roads since they could transport large amounts of goods and people in a shorter time. Six hundred passengers or six thousand amphorae of wine, oil and other products were highly traded using sea transports. The Romans put much effort in improving the effectiveness of shipping, developing harbors and lighthouses. The journey from Egypt to Rome took only two to three weeks by ship. When transporting commercial goods, river transport was also used and preferred to roads, and the same principle applied for the movement of military supplies. The access to the inland regions of the empire was allowed by the large navigable rivers: the Rhone into Gaul, the Rhine into Germany, the Danube into Pannonia, Dacia and Noricum, the Tigris and the Euphrates into Mesopotamia and the Nile into Ethiopia (Roth, 1999). Despite the apparently overwhelming economic advantage of trade by water, Pawson (1977) pointed to the key advantages of land transport, arguing that the land transport system could be classified in two parts: a complementary system, which was interdependent with water transport and performed a feeder and distribution role for it, and a competitive, independent system which did not rely on water transport linkages.

5.2 The Roman road network: the starting data set

Geo-coded data on the Roman road network refers to the McCormick et al. (2013) shapefile.[11] The linear layer is obtained digitizing the information in Talbert (2000)[12] and this allows to perform, by using Geographic Information Systems (GIS) approaches, spatial and mapping analyses for the Roman world. The information provided is accurate and detailed due the georeferenced data and the strict connection with the Barrington Atlas of the Greek and Roman

[11] Data is made freely available on the internet by the Digital Atlas of Roman and Medieval Civilizations (DARMC).

[12] Barrington Atlas of the Greek and Roman World (2000).

World (2000).

The shapefile consists in 7,154 segments of ancient Roman roads existing at the peak of the empire, corresponding with the death of Trajan (117 A.D.). The network covers 36 countries[13] over three continents (Europe, Africa and Asia) and the peculiarity of the shapefile is represented by the way according to which roads are recorded: it does not classify single and complete roads, but it provides a list of segments which compose roads.[14] For each segment four different types of information are provided: its position in space, its length in meters, its size and its certainty.[15]

Size and certainty of the road are the two main features evaluated in the shapefile. Figure 1 and Figure 2 provide a representation of these two characteristics classifying roads between major and minor and between certain and uncertain, respectively.

[Figure 1]

[Figure 2]

Figure 2 shows that there is a reasonable balance between certain (green lines) and uncertain roads (orange lines).[16] This is less the case when considering the size of the road: Figure 1 shows a higher presence of blue lines (minor roads) than red ones (major roads). Moreover, when drawing only major roads, it is immediately possible to distinguish present nations' borders and to recognize the outline of the Mediterranean Sea, since a high number of roads have been constructed along the coasts.

The total Roman road network is almost two hundred thousand kilometers long.[17] The information on the length of each segment of the Roman road network originates from the typology of the data set (geo-coded data). On the one hand, it allows to appreciate the extent and the coverage of the whole Roman infrastructure. On the other hand, it does not allow to appreciate the length of the infrastructure by geographical territories. As remarked by the DARMC, the data set of the Roman road network is thought to be used in combination with

[13] Albania, Algeria, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Egypt, France, Germany, Greece, Hungary, Israel, Italy, Jordan, Lebanon, Libya, Liechtenstein, Luxembourg, Macedonia, Montenegro, Morocco, Netherlands, Palestine, Portugal, Romania, Saudi Arabia, Serbia, Slovenia, Spain, Switzerland, Syria, the U.K., Tunisia, Turkey.

[14] A single road, such as the *Via Appia*, is composed by 67 segments, and each segment has a unique id number.

[15] Certainty refers to the path followed by the road. The road is certain in the existence and in the Roman origin, it is uncertain in the route.

[16] For the majority of Roman roads in Greece and Turkey there is no information available about the certainty.

[17] Exactly 192,861 kilometers.

own historical data. In fact, the potential of the DARMC's shapefile lies more on what can be done with it rather than on the mere representation of the Roman road system. In other words, the use of geographic information system approaches and the implementation of technical and geometric tools to the starting shapefile allows researchers to extract new information and to generate new data ad hoc devised for specific investigations. This will be at the core of the following Subsection 5.3, which describes what has been performed and what has been produced starting from the Roman road layer provided by the DARMC.

5.3 The Roman road network: the new-created data sets

Beyond being interesting *per se*, the information included in the shapefile by McCormick et al. (2013) is appealing for the potential elaborations and the promising investigations it allows.

The empirical analysis performed by De Benedictis et al. (2018) inspired the creation of two new data sets: a shapefile of the Roman road infrastructure for the sole Italian territory and a measure of Roman roads in kilometers by Italian province. On the one hand, the new constructed data sets should be considered as a contribution to that strand of research aimed at studying and collecting all those elements and features of the Roman world in order to create new and available data sources. On the other hand, the method exploited to construct them provides a scheme and a technique that can be easily converted for other investigations and simply followed and reproduced for extended or reduced territorial analyses.

[Figure 3]

[Table 1]

Figure 3 shows the newly created layer of the Roman road system for the sole Italian territory obtained from the starting shapefile provided by the DARMC.[18] Italy includes 10 percent of the entire network (1,817 out of 7,154 segments) and the provincial partition displayed allows to appreciate the ramification at the NUTS3 level. The Italian shapefile of Roman roads is a subset of the DARMC's layer: Table 1 allows to compare the two shapefiles in terms of number and types of segments. The complete starting data set is composed by 7,154 parts of Roman roads; 1817 when considering just Italy. 44 percent of the complete data set are major roads, in Italy they represent 35 percent of the total Italian segments. Almost half of the segments

[18] The Appendix provides all technical notes about the geoprocessing tools performed.

are evaluated as certain in the Italian layer, 44 percent in the complete one. When considering both features (size and certainty), the majority of segments are minor and uncertain in both shapefiles.

[Table 2]

If Table 1 describes the segments composing the whole and the reduced (Italian) data set, Table 2 takes the point of view of Italian provinces. 108 out of 110 provinces have Roman roads,[19] 94 have major roads, 85 have certain roads, 80 have both certain and major Roman roads.

The creation of the new Italian layer has represented the first stage for the construction of the new measure of Roman roads in kilometers by province. The computation has consisted in steps[20] and has been performed using GIS and two digital maps: the linear shapefile of Roman roads for the Italian territory and a polygonal shapefile of 110 Italian provinces provided by Istat.[21] According to the information about size and certainty provided, five different measures have been computed: i) kilometers of all Roman roads; ii) kilometers of just major Roman roads; iii) kilometers of just certain Roman roads; iv) kilometers of both major and certain Roman roads; v) binary variable (1 if the province has Roman roads). To have a road density measure, the first four measures have been weighted by the area of the province in square kilometers (Source: Istat) in order to have a general picture about the density of the road system.

[Table 3]

[Figure 4]

Table 3 ranks Italian provinces according to the length in kilometers, considering all, major and certain Roman roads. Unsurprisingly, the first place is occupied by the province of Rome, which owns, in absolute terms, the largest extent of roads; even if we consider only major or only certain roads, Rome keeps its leading position. Provinces of Latina (close to Rome) and Foggia (in Apulia, South-East) are in second and third position, respectively, in terms of total Roman

[19] The two Italian provinces where the Roman road network is absent are the province of Pordenone (in North-East) and the province of Verbano-Cusio-Ossola (in North-West).

[20] The Appendix provides a detailed explanation of how the measure has been computed.

[21] Istat (Istituto Nazionale di Statistica) is the Italian National Institute of Statistics that provides the official statistics for Italy.

roads; they switch places when looking at certain roads. Number two and three in terms of major roads are, respectively, Potenza and Cosenza in southern Italy. The picture that emerges from Table 3 is that the Romans built roads mainly in the central and south-eastern part of the peninsula: the first fifteen places in the three classifications comprise mostly southern provinces; only five are in the North: Torino, Udine, Bolzano, Cuneo and Alessandria. The "numerical" information provided by Table 3 is confirmed by Figure 4 that shows the distribution of Roman roads in the Italian peninsula. When considering all the roads (certain and uncertain, major and minor), it seems that the Romans devoted more efforts to building roads in the South rather than in the North. A possible explanation of this fact can be found in the way the Roman empire enlarged: firstly towards the southern regions, then to the North. When looking just at the certain or at the major roads, this weak spatial distribution disappears.

[Table 4]

Table 4 classifies Italian provinces by density of the network. Again, Rome stands out against the other provinces. Latina (in the Center) and Trieste (in the North-East) follow in second and third place. The table depicts a picture a bit different from the one described by Table 4. When looking at the network in relative terms, northern Italy has some importance in the Roman empire; nevertheless, the Center and the South hold their character of being at the core of the main street junctions.

6 Concluding remarks

In the late nineties-early two thousands the economic literature has grown interest in documenting the links between historical events and current economic and political outcomes. The evidence provided came along with the same result: history matters and has long-term effects on actual economic development. What has changed across the years is the channel through which history performs. First studies focused mainly on past colonization, persistent formal institutions and factor endowments. More recent works started to concentrate on other channels through which history transmits its effects on the present economy, such as informal institutions, culture, technology, transport infrastructure. Alternatively to history, geography has been proposed as being affected by persistence and determining actual economic outcomes. The literature has been divided into one side suggesting that geography has a direct effect on current economic

results and one side that refers to an indirect effect of geography through its influence on past events.

In this paper the aim was twofold. The first purpose was to give account of that literature that retrieves in history an important factor explaining present economic results, providing a different review. Starting from the main traditional and more recent contributions, the summary moved in two different directions. It first reviewed all those works that find in history a short impact: historical facts considered did not persistently affect the economic system, and modern organizations recovered from the shock briefly. Then, the second part was devoted to considering the new branch of the 'new economic history' literature that argues the important role played by the historical transport infrastructure in connecting the past to the present. Within these contributions, a new literature devoted to understanding the effects of the Roman road network in the long-run has emerged in last two years. Starting from this new evidence, the latter part of the paper aimed to present a new measure of Roman roads.

The Roman road network represents, in the view of historians and common people, one of the main traits of the Roman domination and the major sign of the glorious past of the Roman empire. To begin with, all those contributions that put interest in the lasting effects of the Roman domination in modern world have been summarized. The evidence coming from these works suggests that the impact of the Roman domination lasted not only in those centuries after the fall of the empire, but that it has been beneficial for the current development. Most of the research on the Roman world emphasizes how development and urbanization took advantage from the Roman domination, whereas less attention has been dedicated to the effect of the Roman road network. In last two years three works have tried to fill this gap. Wahl (2017) considers the case of Germany, De Benedictis et al. (2018) look at Italy, and Dalgaard et al. (2018) adopt a more broad perspective. To conclude, the final part of the paper introduced the measure of Roman roads in kilometers that has been used in the empirical work of De Benedictis et al. (2018).

Thanks to the availability of geo-coded data on the distribution of the Roman roads, it has been possible to create an original measure of Roman roads and to track the extension of the network in Italy. The new measure constructed produces three important contributions in economics. First, it adds a novel index of Roman roads for the Italian provinces to the existing group of old historical infrastructure measures. Second, it contributes to the literature on the

persistent effect of history, allowing new empirical studies and applications. Third, it provides a method to generate additional measures of the Roman infrastructure for other countries and other territorial disaggregations.

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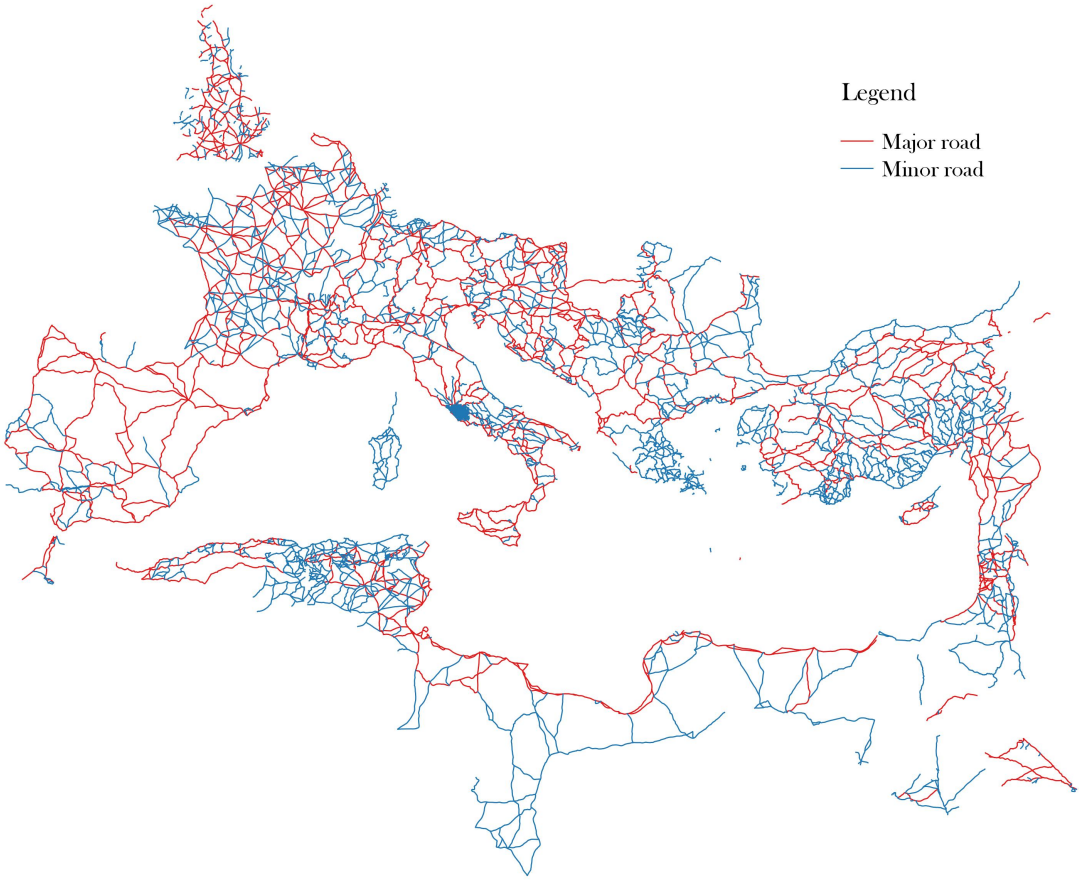
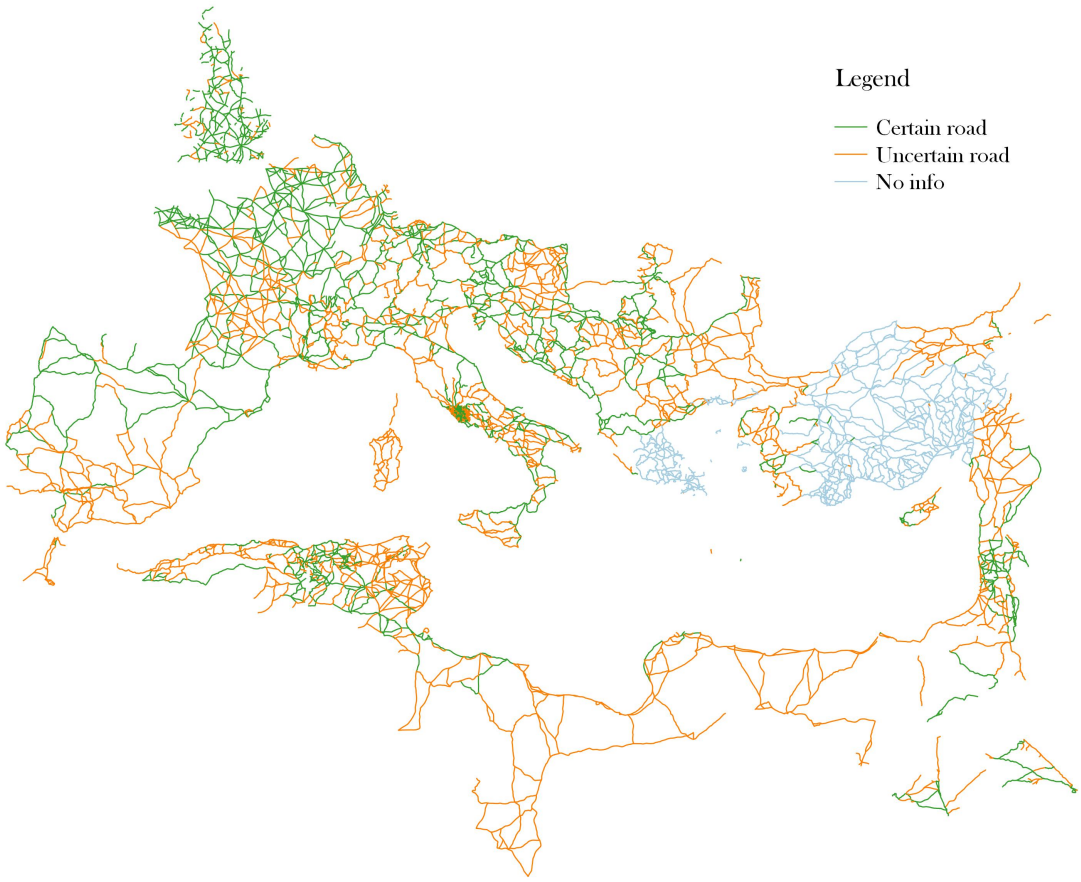
Figures and tables

Figure 1: Roman roads by size: major and minor roads



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

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

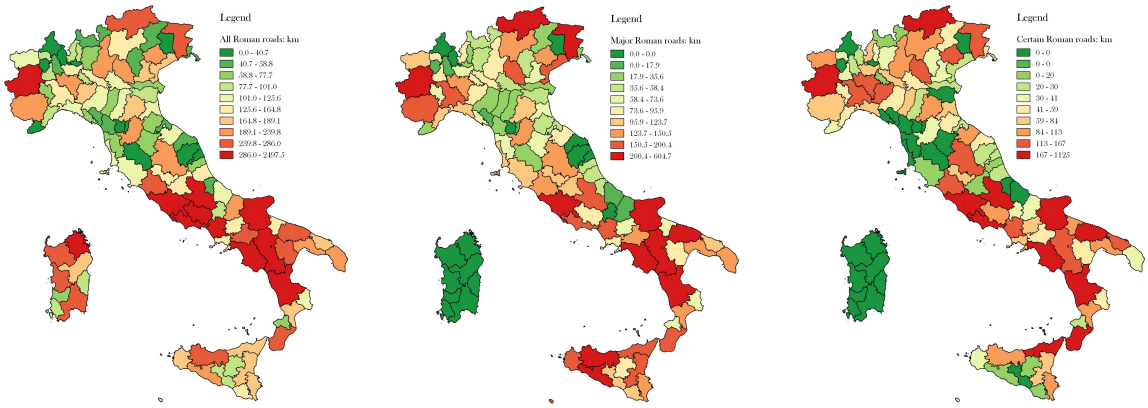


Source: Author's elaboration from McCormick, M. *et al.* 2013. "Roman Road Network (version 2008)," DARMC Scholarly Data Series 2013-5

Figure 3: Italian Roman road layer

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

Figure 4: Roman roads in length by Italian province



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

Table 1: The "Roman Road Network (version 2008)" shapefile description: original and new layer

	Number of segments	
	Original complete layer	*New Italian layer*
Size		
Major roads	3144	640
Minor roads	4010	1177
Total	7154	1817
Certainty		
Certain roads	3117	879
Uncertain roads	3131	938
Not defined	906	0
Total	7154	1817
Size and certainty		
Major and certain roads	1911	466
Major and uncertain roads	1006	174
Major and undefined-certainty roads	227	0
Minor and certain roads	1206	413
Minor and uncertain roads	2125	764
Minor and undefined-certainty roads	679	0
Total	7154	1817

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

Table 2: Roman roads by Italian NUT3 province

	Number of provinces
Size	
Only major roads	20
Only minor roads	14
Both major and minor roads	74
Total	108
Certainty	
Only certain roads	9
Only uncertain roads	23
Both certain and uncertain roads	76
Total	108
Size and certainty	
Only major and certain roads	3
Only major and uncertain roads	6
Only major and both certain and uncertain roads	11
Only minor and certain roads	4
Only minor and uncertain roads	9
Only minor and both certain and uncertain roads	1
Both major and minor but only certain roads	2
Both major and minor but only uncertain roads	8
Both major and minors and both certain and uncertain roads	64
Total	108

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

Table 3: Kilometers of Roman roads by Italian province

Italian province	*All RR*	*All RR: rank*	*Major RR*	*Major RR: rank*	*Certain RR*	*Certain RR: rank*	*Italian province*	*All RR*	*All RR: rank*	*Major RR*	*Major RR: rank*	*Certain RR*	*Certain RR: rank*
Roma	2497.53	1	604.66	1	1124.76	1	Ravenna	123.86	56	64.98	61	65.94	41
Latina	670.87	2	159.12	20	263.98	3	Crotone	117.21	57	64.97	62	48.99	52
Foggia	569.74	3	264.91	6	396.77	2	Mantova	116.38	58	50.51	70	50.51	50
Potenza	560.16	4	329.63	2	118.58	19	Aosta	112.53	59	112.53	36	112.53	23
Cosenza	530.98	5	314.39	3	249.02	4	Livorno	111.51	60	111.51	37	0.00	86
Salerno	426.73	6	288.44	4	168.87	9	Grosseto	109.89	61	96.56	43	3.90	84
Frosinone	386.49	7	86.71	48	91.21	31	Chieti	109.27	62	16.78	90	0.00	86
Olbia-Tempio	379.13	8	0.00	95	0.00	86	Modena	107.10	63	28.06	83	28.06	70
Torino	366.30	9	254.17	8	210.53	5	Genova	104.92	64	104.92	39	78.22	35
Caserta	356.00	10	194.35	13	166.47	12	Pesaro-Urbino	102.56	65	86.56	49	102.56	26
L'Aquila	341.93	11	161.66	18	186.63	6	Parma	101.33	66	35.24	78	49.02	51
Bari	279.73	12	226.00	10	178.95	8	Savona	100.43	67	100.43	41	52.89	47
Viterbo	271.52	13	133.23	30	113.86	22	Lodi	99.74	68	78.03	52	8.07	81
Udine	271.47	14	203.58	11	126.15	15	Como	99.49	69	85.75	50	68.75	40
Bolzano	266.32	15	266.32	5	167.89	10	Calatanissetta	97.95	70	97.95	42	0.00	86
Palermo	264.59	16	264.59	7	96.26	28	Enna	92.83	71	89.54	47	9.39	80
Matera	260.69	17	77.29	53	53.32	46	Vercelli	91.41	72	73.64	55	41.28	56
Sassari	260.56	18	0.00	95	0.00	86	Isernia	90.17	73	0.00	95	30.63	66
Cagliari	255.43	19	0.00	95	0.00	86	Lecco	88.56	74	34.75	79	32.20	64
Reggio Calabria	250.91	20	184.92	14	184.92	7	Carbonia-Iglesias	85.85	75	0.00	95	0.00	86
Oristano	249.63	21	0.00	95	0.00	86	Ogliastra	85.55	76	0.00	95	0.00	86
Avellino	245.07	22	130.71	31	44.00	54	Ferrara	77.85	77	45.78	72	0.00	86
Perugia	238.43	23	148.08	24	154.93	13	Ascoli Piceno	77.40	78	57.71	67	19.69	78
Agrigento	234.89	24	234.89	9	5.88	82	Rovigo	76.34	79	32.08	82	21.77	76
Firenze	229.38	25	125.58	33	39.13	59	Bergamo	76.25	80	38.05	76	39.76	58
Brescia	228.50	26	95.74	45	95.74	29	Arezzo	70.92	81	70.92	58	0.00	86
Lecce	210.39	27	130.68	32	31.92	65	Vibo Valentia	69.64	82	69.64	59	23.51	75
Verona	205.94	28	157.31	21	120.38	18	Forlí-Cesena	69.42	83	50.45	71	51.62	48
Taranto	202.47	29	137.17	28	96.98	27	Medio Campidano	68.86	84	0.00	95	0.00	86
Cuneo	200.06	30	200.06	12	72.07	39	Pisa	65.47	85	62.93	64	0.00	86
Campobasso	199.58	31	16.93	89	36.04	61	La Spezia	65.43	86	64.16	63	0.00	86
Treviso	198.41	32	134.76	29	116.72	21	Reggio Emilia	62.49	87	33.42	81	62.32	42
Pavia	192.20	33	137.30	27	117.88	20	Asti	58.84	88	58.84	66	51.59	49
Trapani	187.80	34	181.93	15	40.87	57	Ancona	58.68	89	0.00	95	58.68	45
Bologna	183.89	35	96.03	44	109.84	24	Belluno	57.10	90	27.70	84	48.27	53
Nuoro	182.10	36	0.00	95	0.00	86	Sondrio	56.33	91	53.15	68	10.60	79
Brindisi	176.38	37	122.85	34	122.85	17	Pescara	54.05	92	40.30	74	0.00	86
Siracusa	175.97	38	149.91	23	84.97	33	Massa Carrara	54.05	93	15.99	91	0.00	86
Venezia	175.92	39	161.23	19	28.58	69	Novara	51.57	94	13.12	92	25.05	74
Catanzaro	174.88	40	137.82	26	92.26	30	Vicenza	51.53	95	35.78	77	35.78	62
Catania	174.51	41	152.72	22	82.92	34	Rimini	48.64	96	39.19	75	28.69	68
Padova	172.57	42	66.93	60	36.58	60	Lucca	47.57	97	25.28	86	0.00	86
Messina	167.50	43	167.50	16	167.50	11	Trieste	44.48	98	44.48	73	27.05	72
Piacenza	165.89	44	92.55	46	124.90	16	Gorizia	41.41	99	26.30	85	41.41	55
Alessandria	164.14	45	164.14	17	126.30	14	Imperia	34.47	100	34.47	80	34.47	63
Ragusa	161.87	46	119.20	35	4.36	83	Pistoia	32.35	101	0.00	95	0.00	86
Cremona	161.49	47	75.38	54	74.14	37	Varese	27.27	102	0.00	95	27.27	71
Terni	152.86	48	110.85	38	77.71	36	Fermo	26.74	103	0.00	95	26.74	73
Benevento	150.84	49	61.43	65	61.43	43	Monza	23.08	104	23.08	87	0.00	86
Milano	147.83	50	71.74	57	73.51	38	Macerata	20.03	105	0.00	95	20.03	77
Trento	138.16	51	138.16	25	88.68	32	Siena	18.17	106	18.17	88	0.00	86
Barletta-Andria-Trani	136.68	52	73.50	56	107.83	25	Prato	9.86	107	0.95	94	0.00	86
Teramo	134.29	53	50.92	69	29.01	67	Biella	7.11	108	7.11	93	0.00	86
Napoli	128.70	54	81.32	51	60.31	44	Pordenone	0.00	109	0.00	95	0.00	86
Rieti	127.39	55	102.83	40	1.78	85	Verbanio-Cusio-Ossola	0.00	109	0.00	95	0.00	86

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

Table 4: Density of Roman roads (kilometers of road per 100 square kilometers of land area) by Italian province

Italian province	*All RR*	*All RR: rank*	*Major RR*	*Major RR: rank*	*Certain RR*	*Certain RR: rank*	*Italian province*	*All RR*	*All RR: rank*	*Major RR*	*Major RR: rank*	*Certain RR*	*Certain RR: rank*
Roma	46.57	1	11.27	2	20.97	1	Monza	5.69	56	5.69	23	0.00	86
Latina	29.74	2	7.05	11	11.70	3	Rimini	5.62	57	4.53	41	3.32	35
Trieste	20.93	3	20.93	1	12.73	2	Cagliari	5.59	58	0.00	95	0.00	86
Caserta	13.43	4	7.33	8	6.28	7	Udine	5.53	59	4.15	45	2.57	46
Lodi	12.74	5	9.97	3	1.03	78	Torino	5.37	60	3.72	50	3.08	38
Frosinone	11.90	6	2.67	66	2.81	44	Palermo	5.28	61	5.28	27	1.92	57
Olbia-Tempio	11.13	7	0.00	95	0.00	86	Messina	5.13	62	5.13	29	5.13	11
Napoli	10.92	8	6.90	12	5.12	12	Mantova	4.97	63	2.16	74	2.16	52
Lecco	10.87	9	4.27	43	3.95	22	Bologna	4.97	64	2.59	68	2.97	41
Ragusa	9.97	10	7.34	7	0.27	82	Catania	4.88	65	4.27	42	2.32	48
Brindisi	9.48	11	6.60	14	6.60	6	Brescia	4.77	66	2.00	77	2.00	54
Milano	9.38	12	4.55	40	4.67	15	Massa Carrara	4.68	67	1.38	84	0.00	86
Livorno	9.19	13	9.19	4	0.00	86	Nuoro	4.63	68	0.00	95	0.00	86
Cremona	9.12	14	4.26	44	4.19	18	Rieti	4.63	69	3.74	49	0.06	85
Gorizia	8.87	15	5.63	24	8.87	4	Ogliastra	4.61	70	0.00	95	0.00	86
Barletta-Andria-Trani	8.86	16	4.76	32	6.99	5	Alessandria	4.61	71	4.61	38	3.55	29
Avellino	8.73	17	4.66	36	1.57	63	Calatanissetta	4.58	72	4.58	39	0.00	86
Salerno	8.61	18	5.82	19	3.41	34	Medio Campidano	4.54	73	0.00	95	0.00	86
Potenza	8.49	19	5.00	31	1.80	59	Pescara	4.39	74	3.28	60	0.00	86
Siracusa	8.28	20	7.06	10	4.00	19	Vercelli	4.39	75	3.54	55	1.98	56
Oristano	8.23	21	0.00	95	0.00	86	Chieti	4.20	76	0.65	91	0.00	86
Taranto	8.21	22	5.56	25	3.93	23	Rovigo	4.20	77	1.76	78	1.20	72
Foggia	8.13	23	3.78	47	5.66	9	Pesaro-Urbino	3.99	78	3.37	59	3.99	20
Padova	8.05	24	3.12	62	1.71	60	Modena	3.98	79	1.04	86	1.04	77
Treviso	8.00	25	5.43	26	4.71	14	Asti	3.90	80	3.90	46	3.42	33
Cosenza	7.91	26	4.69	34	3.71	26	Novara	3.85	81	0.98	88	1.87	58
Reggio Calabria	7.82	27	5.76	20	5.76	8	Perugia	3.76	82	2.34	70	2.44	47
Como	7.78	28	6.70	13	5.38	10	Enna	3.61	83	3.48	57	0.36	80
Agrigento	7.69	29	7.69	5	0.19	83	Bolzano	3.60	84	3.60	52	2.27	50
Trapani	7.60	30	7.37	6	1.66	61	Aosta	3.45	85	3.45	58	3.45	31
Lecce	7.52	31	4.67	35	1.14	74	Pistoia	3.36	86	0.00	95	0.00	86
Viterbo	7.51	32	3.69	51	3.15	36	Fermo	3.10	87	0.00	95	3.10	37
Matera	7.49	33	2.22	72	1.53	64	Ancona	2.99	88	0.00	95	2.99	39
La Spezia	7.42	34	7.28	9	0.00	86	Imperia	2.99	89	2.99	63	2.99	40
Benevento	7.25	35	2.95	64	2.95	42	Ferrara	2.95	90	1.74	79	0.00	86
Bari	7.24	36	5.85	18	4.63	16	Parma	2.94	91	1.02	87	1.42	68
Catanzaro	7.24	37	5.71	22	3.82	25	Forlí-Cesena	2.92	92	2.12	76	2.17	51
Terni	7.19	38	5.21	28	3.65	28	Cuneo	2.90	93	2.90	65	1.05	76
Venezia	7.11	39	6.52	15	1.16	73	Bergamo	2.78	94	1.39	83	1.45	66
Teramo	6.87	40	2.61	67	1.48	65	Reggio Emilia	2.73	95	1.46	81	2.72	45
Campobasso	6.82	41	0.58	92	1.23	71	Prato	2.70	96	0.26	94	0.00	86
L'Aquila	6.77	42	3.20	61	3.70	27	Lucca	2.68	97	1.43	82	0.00	86
Crotone	6.75	43	3.74	48	2.82	43	Pisa	2.68	98	2.57	69	0.00	86
Ravenna	6.66	44	3.49	56	3.55	30	Grosseto	2.44	99	2.14	75	0.09	84
Verona	6.65	45	5.08	30	3.89	24	Varese	2.28	100	0.00	95	2.28	49
Firenze	6.53	46	3.57	54	1.11	75	Trento	2.23	101	2.23	71	1.43	67
Savona	6.49	47	6.49	16	3.42	32	Arezzo	2.19	102	2.19	73	0.00	86
Pavia	6.47	48	4.63	37	3.97	21	Vicenza	1.89	103	1.31	85	1.31	70
Piacenza	6.42	49	3.58	53	4.83	13	Sondrio	1.76	104	1.66	80	0.33	81
Ascoli Piceno	6.30	50	4.70	33	1.60	62	Belluno	1.55	105	0.75	90	1.31	69
Sassari	6.08	51	0.00	95	0.00	86	Biella	0.78	106	0.78	89	0.00	86
Vibo Valentia	6.05	52	6.05	17	2.04	53	Macerata	0.72	107	0.00	95	0.72	79
Isernia	5.87	53	0.00	95	2.00	55	Siena	0.48	108	0.48	93	0.00	86
Carbonia-Iglesias	5.72	54	0.00	95	0.00	86	Pordenone	0.00	109	0.00	95	0.00	86
Genova	5.72	55	5.72	21	4.27	17	Verbano-Cusio-Ossola	0.00	109	0.00	95	0.00	86

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

Appendix - Technical notes

The potential of the Roman road measure described lies in two main points. On the one hand, the availability of a new index contributes to the existing data sets on the features and traits of the Roman world, enabling inferential analyses. On the other, it gives a method that can be simply followed to produce the Roman road measure in kilometers at different territorial levels and for one or more countries. This Appendix aims at analyzing more in detail those technical aspects linked to the use of GIS approaches.[1]

All elaborations have been computed using QGIS, a free open-source GIS software,[2] and Stata. Two starting layers have been used to compute the Roman road measure: the linear shapefile of the Roman road network by McCormick et al. (2013) and the polygonal shapefile of 110 Italian provinces provided by Istat. Both shapefiles need to be projected using the same spatial reference. The selection of the appropriate coordinate reference system (CRS) should consider the spatial reference system in use in the country or in the specific area the analysis looks at. Istat makes available the shapefiles of the Italian administrative borders (regions, provinces, municipalities) for the main reference system in Italy: UTM WGS 84 Zone 32N. This reference system is employed to homogenize the small and middle scale cartography at the European level. An important step of this starting phase lies in the choice of the reference system and in the attribution of the same selected CRS to both shapefiles. The two shapefiles with the same CRS serve the construction of a linear layer of the Roman road network for the sole Italian territory and the calculation of the Roman road network by Italian province.

The Italian linear layer of the Roman road network is derived superimposing the complete linear layer by McCormick et al. (2013) on the polygonal one with the provincial decomposition and using the latter as a mold to derive the ramification of Roman road for the sole Italian territory. In this way, segments that are in common between Italy and adjacent countries are split and only the parts of the road included within the Italian territory are ascribed to Italy. Moreover, the provincial decomposition acts as a cutter for the segments of roads that are in common between adjacent provinces, and only the parts of roads within the boundaries of the selected province are assigned to the province. In this way, as shown in Figure A.1, it is possible

[1] The instructions and technical notes of this Appendix are the ones employed by the author. The procedure described is not the only one available. Expert users of GIS methods might come out with the same result using different tools or following a diverse method.

[2] Elaborations can be performed using ArcGIS as well.

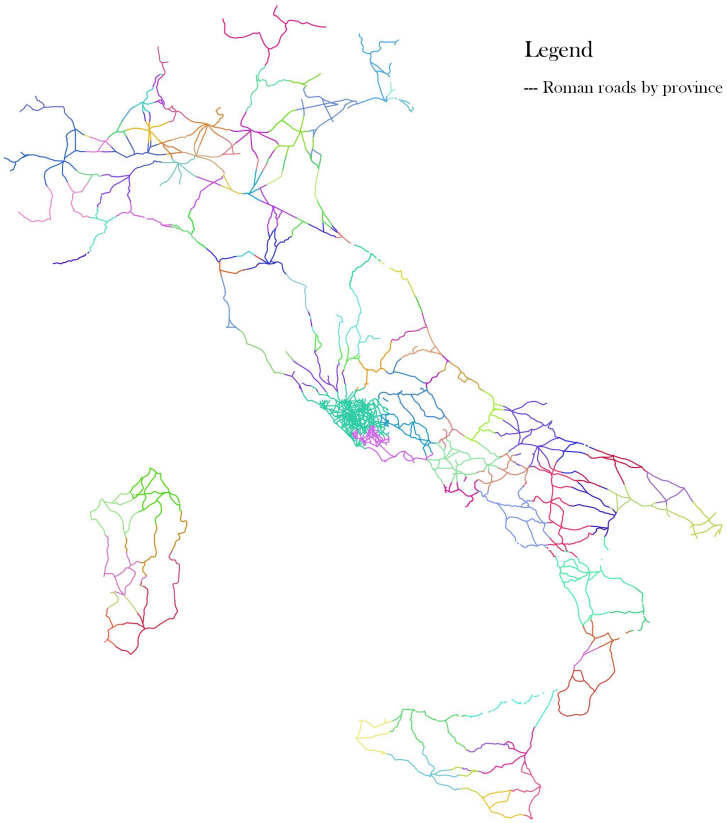
to obtain a shapefile for the sole Italian territory with a distinction of segments by Italian province.

[Figure A.1]

The computation of the Roman road measure in kilometers by province requires the newly created linear layer of Roman roads in Italy. Although the starting linear layer by McCormick et al. (2013) provides the length of each segment, after having isolated and ascribed the segments to each provincial territory, the length in meters is not more valid since it refers to the complete section. Therefore, it is necessary to compute the extent of each segment within each provincial linear layer, by adding a geometry column with the length of each segment. This procedure applied first to all Roman roads (disregarding any type of classification) should be repeated selecting only major roads or only certain roads or both major and certain roads.

Last step consists in exporting the data to Stata and in collapsing and adding up by province all lengths in order to obtain a single measure for each province. All measures are divided by 1000 to express the length in kilometers.

Figure A.1: Italian Roman road layer



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

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