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Resetting the Urban Network: 117-2012*

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Abstract

Do fixed geographic features such as coastlines and rivers determine town locations, or can historical events trap towns in unfavourable locations for centuries? We examine the effects on town locations of the collapse of the Western Roman Empire, which temporarily ended urbanization in Britain, but not in France. As urbanization recovered, medieval towns were more often found in Roman-era town locations in France than in Britain, and this difference persists today. The resetting of Britain's urban network gave it better access to natural navigable waterways when this was important, while many French towns remained without such access. We show that towns without coastal access grew more slowly in both Britain and France from 1200-1800, suggesting that towns that remained in locations without coastal access missed out on growth opportunities.

○KEYWORDS: Economic Geography, Economic History, Path Dependence, Transportation.

JEL CLASSIFICATION: R11, N93, O18

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1 Introduction

Our world is increasingly urbanized, with large cities located in many different environments. While some cities appear well situated, others are hampered by poor access to world markets or threatened by environmental hazards. But it is difficult to tell whether cities are in fact mislocated, because locational advantages that we cannot quantify could offset the costs that we do observe. To investigate whether cities are mislocated, one might examine whether cities that are devastated then relocate, and if so – where. But in recent years a growing literature, going back to Davis and Weinstein (2002), finds that cities are remarkably resilient and recover from shocks. This has generally been interpreted as evidence that locational fundamentals play an important role in pinning down the location of cities. At the same time, Bleakley and Lin (2012) show that once cities develop in particular locations, they persist even when the factors that led to their emergence are no longer important.

We contribute to this literature by examining the impact on urban locations of a shock that was sufficiently large to eliminate an urban network. Specifically, we study the collapse of the Western Roman Empire around the middle of the first millennium CE, which wiped out the towns in what is now Britain, but not in France.[1] We are, to the best of our knowledge, the first to examine whether in the aftermath of such a devastating shock, an urban network that gets a fresh start reconfigures in new locations. We also examine whether such a reconfiguration improves towns' locations in terms of their first nature locational fundamentals. In order to carry out our analysis, we develop a new dataset, which tracks the locations of towns in parts of northwestern Europe over two millennia.

We begin our empirical investigation by considering what may happen if an urban network is wiped out and restarts, while an initially similar urban network remains intact. In this event, the evolution of town locations may follow one of three scenarios. First, if first nature locational fundamentals, such as coastlines, mountains, and rivers, consistently favour a fixed set of locations, then these locations would be home to both surviving and reemerging towns, resulting in high persistence of locations in both urban networks. Second, if first nature locational fundamentals or their value change over time, and these fundamentals affect productivity more than the concentration of human activity (including the value of past investments), then both urban networks would similarly shift towards locations with improved fundamentals. Finally, if first nature locational fundamentals or their value change, but these fundamentals are less important for productivity than the concentration of human activity (including the value of past investments), then the locations of urban networks are path dependent. In this case, the urban network which was wiped out would reemerge in locations with better first nature locational fundamentals, while its counterpart would remain in its original locations due to path dependence. Even this third scenario has two variants: one in which the differences in the value of first nature locational fundamentals between locations are small and inconsequential (for example locations in a wide prairie or along a slow flowing river), and another in which they are consequential, leaving some towns in unfavourable locations.

[1] In this paper we typically refer to "towns" when considering older - and often smaller - precursors of cities.

To investigate the empirical relevance of these different scenarios, we trace the locations of towns in northwestern Europe back to the Roman era. Around the dawn of the first millennium, Rome conquered, and subsequently urbanized, areas including those that make up present day France and Britain (as far north as Hadrian's Wall). In the subsequent centuries, the Roman towns in France and Britain developed similarly in terms of their institutions, organization, and size. Around the middle of the fourth century, however, their fates diverged. Roman Britain suffered invasions, usurpations, and reprisals against its elite. Around 410CE, when Rome itself was first sacked, Roman Britain's last remaining legions, which had maintained order and security, departed permanently. Consequently Roman Britain's political, social, and economic order collapsed, and its towns no longer functioned from 450-600CE.[2] A recent quantitative analysis (Faulkner 2000) shows that the number of occupied rooms in private buildings in 16 major Roman-British towns fell by about 90 percent from the early fourth century to the early fifth century, and by the middle of the fifth century even the remaining homes were abandoned. The Roman towns in France also suffered when the Western Roman Empire fell, but many of them survived, and were taken over by Franks. So while the urban network in Britain effectively ended with the fall of the Western Roman Empire, there was much more urban continuity in France. The divergent paths of these two urban networks allow us to study the spatial consequences of the resetting of an urban network, as towns across northwestern Europe reemerged and grew during the Middle Ages. In comparing Britain and France during the High Middle Ages we note that both were again ruled by a common elite (Norman rather than Roman), and had access to similar production technologies, inasmuch as these may have affected the location of towns.

Our empirical analysis of town locations uses a grid of one kilometre squares, spanning the land area of the Roman Empire at its greatest extent, around the time of Emperor Trajan's death in 117CE. Focusing on northwestern Europe, we map onto this grid locational fundamentals and the locations of towns from the Roman and medieval eras to the present day. We define persistence relative to Roman-era towns as an odds ratio: the probability of finding a later town near the site of a Roman town, divided by the probability of finding a later town near the site without a Roman town. We find that from the Early Middle Ages (700-900) until the dawn of the Industrial Revolution (circa 1700), the persistence of towns compared to the Roman era in France was approximately three times higher than in Britain. The differences in persistence are still visible today; for example, only 3 of the 20 largest cities in Britain are located near the site of Roman towns, compared to 16 in France.

Our finding that the urban network in Britain relocated more than in France between the Roman and medieval eras is consistent with the third scenario outlined above, where town locations are path dependent. This finding is robust to many specification checks, including widening or narrowing the measure of geographic proximity; restricting the continental area to the north of France, which is more similar to Britain, or widening it to encompass all the area of northwestern Europe that lay within the boundaries of the Roman Empire; using alternative definitions of Roman towns, which

[2]The term "Western Roman Empire" refers to the western provinces of the Roman Empire, which were administered separately from its eastern provinces from the late third century. The Western Roman Empire underwent a series of crises and recoveries, and finally collapsed in the late fifth century.

rely on the size of their walled areas or their administrative status during the Roman era; controlling for the distance to Rome and to Scandinavia; or controlling directly for locational fundamentals, and allowing their effect to differ in Britain and France. We also show that our results are not driven by differential changes over time (due to different histories or secular environmental changes) that favoured particular regions within Britain and France**.** Nor is it the case that Britain's urban locations were perennially less stable than those in France: we find similar locational persistence in Britain and France from the Iron Age to the Roman era, and again from the Middle Ages until the Industrial Revolution. Furthermore, we show that our results are not the consequence of differential choice of town locations by the Romans in Britain and France: our findings are similar when we instrument Roman town locations using the locations of major Iron Age settlements. Our results are also not driven by the survival of Roman roads, fortifications, durable masonry, or tombs of late Roman era saints in Britain, since all these actually make the observed persistence of Britain's town locations higher and more similar to France's.

Our findings above indicate that the resetting of Britain's urban network allowed it to reconfigure, while France's urban network was largely shaped by its Roman origins. But was this because the Roman locations were still suitable for medieval French towns, or did they since become obsolete? Our analysis focuses on a particular dimension of each town's location: its accessibility to transportation networks. During the Roman era roads connected major towns, and other towns emerged alongside these roads, since the Roman army (which used the roads to move quickly in all weather conditions) played major economic and administrative roles. But during the Middle Ages, the deterioration of road quality and technical improvements to water transport increased the importance of coastal access. Using estimates from the history literature, we show that this change appears to have been quantitatively important: the cost advantage of water transport over land transport increased considerably from the Roman era to the Middle Ages. In our empirical analysis, we find that during the Middle Ages towns in Britain were roughly two and a half times more likely to have coastal access - either directly or via a navigable river - than during the Roman era. In other words, given a much cleaner slate, British town location responded to the changing value of locational fundamentals. In contrast, in France the weight of Roman history meant that there was little change in the urban network's coastal access over the same period.[3]

Our finding that Britain's urban network gained more coastal access than France's is not driven by fixed differences in geography. First, our cross-sectional measure of towns' coastal access accounts for differences in the proportion of land area with coastal access. This means that we account for fixed differences in the relative abundance of rivers and coasts between Britain and France. Second, we focus not on the cross-sectional differences between Britain and France, but on changes over time in coastal access. Third, the fact that Britain is an island mattered little for the towns that we examine, south of Hadrian's Wall. The medieval seaborne trade of these towns rarely involved circumnavigat-

[3]Troyes, Dijon, Chartres, and Autun are all French towns with long Roman and medieval histories, which have no (natural) coastal access.

ing Scotland's shoreline. Finally, we show medieval French towns were more likely than their British counterparts to have no coastal access (or poor access) while being within 25 kilometres of locations with coastal access (or with better access).[4] These towns therefore had alternative sites nearby with locational fundamentals which would have better served their local markets.

But did it actually matter that French towns did not move to locations with better coastal access? We argue that it did, since coastal access provided economic advantages to towns. First, in both Britain and France, towns with coastal access in 1200 grew almost 10 percent faster per century over the subsequent 600 years. This is a sizeable difference in growth rates, and it is important to emphasize that it hold within France as well as Britain. In other words, our evidence on the mislocation of French towns does not hinge only on comparisons between France and Britain, but also on comparisons within France. Second, many canals were dug over this period in both Britain and France to facilitate or improve water transportation.[5] The fact that these canals were dug and maintained at great expense shows that water transportation links were highly prized. Finally, among the towns that did not have coastal access in the Middle Ages, being (eventually) connected to a canal was associated with faster long-term population growth.

Our study of path dependence in the location of economic activity is related to the seminal theoretical work on path dependence by David (1985) and Arthur (1994), and to models of spatial agglomeration (e.g. Krugman 1991). One strand of empirical literature (Davis and Weinstein 2002; Brakman, Garretsen, and Schramm 2004; Miguel and Roland 2011; Paskoff 2008; Beeson and Troesken 2006) shows that local economic activity often recovers quite quickly from calamities of war or epidemics.[6] Like these papers, we study the effect of a shock (the collapse of the Western Roman Empire), but one which did not only seriously damage individual towns, but actually rendered an entire urban network non-functional for over a century. Moreover, the shock we investigate wiped out preexisting property rights, the role of preexisting towns as natural focal points, and the possibility of national reconstruction efforts. Our paper does not contradict the finding that urban networks generally recover from large scale shocks. But we do show an example of an even more extreme shock, which did lead to urban reconfiguration.

Our study is also related to Rauch (1993), Redding, Sturm, and Wolf (2011), and Bleakley and Lin (2012), who study evidence of path dependence in the location of economic activity, though over shorter time horizons than ours. In Redding, Sturm, and Wolf (2011), the location into which economic activity is locked in is no worse than the alternatives. The case examined in Bleakley and Lin (2012) is more nuanced: they find that the locations into which economic activity is locked in may have some drawbacks, although they do not quantify their costs. The path dependence that we document is consequential, leaving towns in worse locations than they might have otherwise been in. In this respect our paper is also related to Nunn and Puga (2012), who find that a history of

[4]The differences between Britain and France as a whole are statistically significant, but in this case the contrast between Britain and Northern France is less precisely estimated.

[5]French canals whose construction began from 1200-1800 currently span more than 1,880 kilometres.

[6]See also related discussion in Glaeser and Shapiro (2002).

slavery concentrated economic activity in rugged parts of Africa, and Glaeser (2005), who analyses New Orleans as an example of a poorly located city.[7]

Our study is also related to the research on the economics of the Roman Empire (Temin 2006 and 2012). While some studies (e.g. Bowman and Wilson 2011) examine the patterns of Roman urbanization, there is much less systematic econometric evidence on the relation of the Roman urban network to later periods. At the same time, existing studies of the role of access to water transportation in the development of European urbanization (e.g. Acemoglu, Johnson, Robinson 2005, Bosker and Buringh 2015, and Bosker et al. 2013) typically study the period starting in the Middle Ages. As far as we are aware, ours is the first study, which systematically tracks the location of towns over the course of two millennia.[8] The new dataset that we construct is one of our contributions, affording a much longer window into the origins of European urbanization, from the Iron Age, through the Roman and medieval eras, and until the present day.

A further contribution of our study is its methodology for tracking the persistence of urban locations over time, which allows us to account for the changing role of locational fundamentals. Our findings show that urban networks may reconfigure around locational fundamentals that become more valuable over time. This reconfiguration, however, is not inevitable, and towns may remain trapped in bad locations over many centuries, and even millennia.

This spatial misallocation of economic activity over many centuries has almost certainly induced considerable economic costs. Moreover, the conclusion that cities and towns may be misplaced still matters today, as the world's population becomes ever more concentrated in cities. Parts of Africa, for example, including some of its cities, are hampered by poor access to the world's markets due to their landlocked position and poor land transport infrastructure. And across the world many cities lie close to areas that are susceptible to flooding, earthquakes, volcanic eruptions, and other natural disasters. Our paper suggests that policy makers that influence the creation and expansion of towns should be aware that the choices they make may trap people in bad locations for centuries, and should take the long-term consequences of their decisions into account.

The remained of this paper is structured as follows. Section 2 discusses the historical setting. Section 3 describes the data. Section 4 contains the empirical analysis. Finally, Section 5 concludes.

2 Historical Setting

In this section we briefly review the early development of towns in the areas that make up present-day Britain and France during the Roman and early medieval eras. Before the Roman conquest, Celtic tribes using Iron Age technology occupied much of France and Britain.[9] Their society was predominantly agrarian, although some economic activity was concentrated in *oppida* or other set-

[7] Another recent and related study examines whether geography can cause cities to be misshapen (Harari 2015).

[8] An exception is Dittmar (2011), which studies the effect of the printing press and controls for Roman origins of some medieval towns, but does not examine Roman town sites that were later abandoned.

[9] Parts of southern France were an exception, with some colonies already integrated into the Greco-Roman world for several centuries.

tlements, which can be considered proto-urban (Wacher 1978, Jones and Mattingly 1990, and Woolf 1998).[10]

Rome conquered most of the area that constitutes present-day France from around 58-50BCE, under the leadership of Julius Caesar. Rome's conquest of Britain began about one century later, during the reign of the emperor Claudius (from around 43CE). In both areas, some towns were built for retired soldier-citizens, and others were designated as administrative centres for conquered or client tribes, either on or near the sites of Iron Age settlements or in newly selected locations. Still other towns emerged as civilian settlements around military forts or camps. And other towns emerged primarily to serve economic functions along the roads that were built to connect earlier towns.[11] During the first two centuries of the first millennium, many Roman towns in northwestern Europe thrived with long distance trade (Mattingly 2006, Fleming 2010, and Woolf 1998).

During this period, when the Roman Empire reached its zenith, larger Roman towns in both Britain and France provided a range of private and public services. These towns had markets, workshops, local governance centres, schools, places of worship, entertainment facilities, and baths. Smaller towns did not enjoy such a breadth of services, but were still places where local non-agricultural economic activity concentrated. While much information about these towns has been lost to time, existing evidence suggests that the Roman towns in Britain were in many ways similar to their counterparts in France, and especially to those in northern France.[12]

The third century saw a series of crises throughout the Roman Empire, including the formation of a breakaway Gallic Empire which temporarily ruled most of Britain and France before these territories were brought back into the Roman Empire. The warfare and usurpations were accompanied by a contraction of the towns in France, while the towns in Britain were less adversely affected until the early fourth century (Esmonde-Cleary 1989, Loseby 2000, and Faulkner 2000). Roman Britain's condition at the time is summarized by Ward-Perkins (2001): "... at least in the early fourth century, the province of Britain was flourishing, with a rich villa economy in the countryside, and a network of towns which included not only administrative capitals (*civitates*), but also secondary production and marketing centres whose prosperity depended primarily on economic activity."

The years that followed, however, dealt harsh blows to Roman Britain. It suffered incursions of Picts from the north and a series of usurpations and reprisals against its elite, and its economy and towns contracted severely (Mattingly 2006, Fleming 2010). Around 410CE Germanic tribes crossed

[10]According to www.oppida.org, which contains a list of oppida similar to Fichtl (2005): "*Oppidum* (plural *oppida*) was the name used by Caesar to describe the Celtic towns that he discovered during his conquest of Gaul. In archaeology, the term is now used to describe all fortified Celtic sites covering a minimum area of 15ha and dating back to the second half of the 2nd and 1st centuries BC (the late La Tène period). These towns were both economic and political centres."

[11]As we discuss in more detail below, while some towns were located near rivers, proximity to the coast or to navigable rivers was not essential for Roman towns in Britain and France.

[12]Some towns in southern France had longer histories and were closer to the Roman Empire's Mediterranean core. Nonetheless, recent estimates of the minimal population in Roman towns with 5,000 inhabitants or more (Bowman and Wilson 2011) suggest an urban population of 114,000 in Britain, compared to 222,000 in France, of which 69,000 were in northern France. While our sample of towns includes smaller towns in addition to those covered in Bowman and Wilson, their evidence supports the view that Roman urbanization in Britain had much in common with that of France, and especially northern France.

Rhine into Gaul, and Rome itself was sacked for the first time in centuries. Around that time, the remaining Roman legions left Britain with the last in a series of usurpers (Mattingly 2006).

This was, it appears, one blow too many for an already fragile economy. Palliser (2001, quoting Esmonde-Cleary 1989), writes that the economy of Roman Britain "...functioning with difficulty between c. 380 and 410, collapsed suddenly 'in the generation or so after 411. In that time the towns, the villas, the industries and the other material evidence diagnostic of Roman Britain disappeared'." Other researchers reach similar conclusions. Fleming (2010) writes that "within a generation or two of 400 all the towns of Roman Britain had ceased to function as towns". In other words, the towns in Britain collapsed before the arrival of the Anglo-Saxons, and as Mattingly (2006) writes, "It now seems clear that there was no real continuity of urban community between Roman Britain and Saxon England." In the ensuing centuries political control in Britain became highly fragmented; the use of coins and trade in bulky items such as pottery was discontinued (Fleming 2010); and the Church of Rome lost control until around 597 (Loseby 2000). As Ward-Perkins (2001) writes, "Post-Roman Britain, of the fifth and sixth century, retained almost nothing of the sophistications of Roman economic life and, although this is a fact that is initially hard to credit, even sank to an economic level well below that reached in the pre-Roman Iron Age." In the agricultural economy that remained in Britain there was no room for towns.

In a recent quantitative analysis, Faulkner (2000) estimated the number of rooms occupied in private buildings in 16 major Roman-British towns. He found that this number increased from the Roman invasion of Britain until around 200CE, and thereafter remained stable for about a century. The number of rooms then fell by around 90 percent from the first quarter of the fourth century to the first quarter of the fifth century, and by the middle of the fifth it fell to zero. It is important to emphasize that even important Roman towns in Britain, which reemerged much later as urban centres, including Londinium (London), Venta Belgarum (Winchester), Durovernum Cantiacorum (Canterbury), and Eboracum (York), were abandoned before being reoccupied during the Middle Ages.[13]

In France, meanwhile, the Western Roman Empire also struggled and eventually collapsed, and Germanic tribes (Franks) seized control. But in France these tribes were soon unified under the Merovingian Dynasty, which controlled most of France from the sixth century until the eighth century (Wickham 2009). So France, unlike Britain, experienced much less political fragmentation. Under its Christian Merovingian rulers, the Roman church continued to play important roles; Legal practices were not abandoned; coin use continued; and the economy, unlike Britain's, did not fail (Ward-Perkins 2006, Nicholas 1997, and Wickham 2005). Fleming (2010) describes fifth- to early seventh-century Gaul: "...many components of Roman culture and economy persevered here, in ways that they did not in Britain. Indeed, not only did written administration and the state survive, but so too did old Gallo-Roman elite families..., a money economy and towns. Even vestiges of Ro-

[13] Evidence for life within Roman towns after 450CE is extremely scant, as discussed for example in Fleming (2010) and Palliser (2001).

man modes of industrial-scale production were present... The Franks... produced copious amounts of jewellery, gold coins, wine, ceramics, and textiles...". In these circumstances, as Nicholas (1997) writes, "Although Roman urbanization... virtually ended in Britain... a stronger case for continuity can be made for some cities of interior Gaul, particularly those that housed bishoprics."

In summary, the urban networks in Britain and France, which had many similarities during centuries of Roman rule, experienced different fates when the Western Roman Empire fell. While the urban network of Britain was effectively reset by 450CE and only started to recover after 600CE, the urban network in France contracted but, for the most part, remained intact.

3 Data Description

In this section we briefly describe the data that we use in our empirical analysis, leaving a more detailed description to Appendix B. We construct our dataset around a grid of points, which allows us to consider all potential locations for towns within the areas we analyse. The small size of the squares of our grid, each covering one square kilometre, enables us to differentiate locations that are close by and yet differ in their fundamentals or in their urban histories.[14] As we explain below, we associate each town with a gridpoint, which approximates the location of the town centre. We take this approach mostly because of the impracticality of tracing the way in which towns areas have changed over time. In our empirical analysis, we typically allow for 5km bands around locations, to account for possible measurement error.

Using Geographic Information System (GIS), we begin with a grid that covers the entire land area of the Roman Empire at the time of its greatest extent, around the death of Emperor Trajan in 117CE.[15] At the time the Roman Empire had a land area of about 5 million square kilometres (Taagepera 1979), mostly around the Mediterranean and parts of Western Europe. We focus most of our analysis on Britain (as far north as Hadrian's Wall) and France, which had similar histories during the Roman and Norman eras. In some of our robustness checks we also use data on all the northwestern provinces of the Roman Empire, which presently lie within the United Kingdom, France, Belgium, Luxembourg, Netherlands, Germany, and Switzerland.[16]

To this grid we add, using GIS, data on a number of locational fundamentals. We compute a measure of elevation in meters using a 3x3km grid of elevation (ESRI 2010). Using these elevation data we also compute a measure of ruggedness, following Nunn and Puga (2012) and Riley et al. (1999). The summary statistics for these and our other variables are reported in Table 1.

We also calculate the closest distance from each grid point to the coast (using ESRI 2010) and to the nearest navigable river (using Historical GIS for European Integration Studies 2013). This allows

[14] We refer typically refer to "grid points", which are the centroids of the one kilometres squares that form our grid.

[15] Data on the boundaries of the Roman Empire and its partition into provinces are from the Digital Atlas of Roman and Medieval Civilization (McCormick et al. 2013). The shapefiles with the location of the land and coastlines, and of present-day countries, are from the Economic and Social Research Institute (2010).

[16] We use modern country border shapefiles from Eurostat (2013). We do not analyse Italy, which lay at the heart of the Roman Empire and was therefore more heavily urbanized, and Spain and North Africa, whose subsequent histories differed due to the Muslim conquest.

us to construct indicators for whether each gridpoint is within 5 kilometres of: (a) the coast or a (narrowly defined) navigable river, which flows into the ocean or a sea ("Coastal access I"); or (b) the same, except using a broader definition of navigable rivers ("Coastal access II").[17]

Having discussed the measurement of the terrain, we now describe how we measure towns.[18] Our main source of data on modern towns (including cities) is the World Gazetteer (2012), which compiles population data from official national statistical agencies.[19] Based on these official data the website provides an estimate of each town's 2012 population. We focus our analysis of modern towns on those with estimated populations of 10,000 or more in 2012. We use the World Gazetteer, complemented by other sources, to identify each town's coordinates, and we assign each town to its nearest grid point. We then use the grid with the modern towns as the basis for matching in earlier towns and sites, most of which are identified by name and approximate location, from a variety of sources, as we discuss in more detail in Appendix B.

In reconstructing the historical populations of towns we use, like many researchers before us, the estimates of Bairoch et al. (1988). Unfortunately, this source covers French towns from 800CE and Britain towns only from 1000CE, so in order to look further back in time we require other data.[20] In tracing the origins of western European urbanization back into the first millennium, we tried to balance a number of criteria. First, we wanted measures that capture the spatial concentrations of economic activity, which typically characterize towns. Second, we sought where possible to obtain estimates made in recent years, reflecting knowledge that has been built up by historians and archaeologists. Third, we looked for town definitions that were as comparable as possible for the areas that make up present-day Britain and France. Fourth, when considering post-Roman urbanization in particular, we searched for measures of urbanization dating back as early as possible, even if in some cases the locations were at the time only proto-towns and not fully-fledged ones. Finally, wherever possible, we aimed for definitions that covered more than a handful of sites in both Britain and France, to facilitate a meaningful statistical analysis, starting with the pre-Roman era.

Some scholars (e.g. Wacher 1978 and Woolf 1998) conclude that pre-Roman northwestern Europe was largely a pre-urban world. Nevertheless, this world, which was largely populated by Celtic tribes, had some settlements with features that we might recognize as urban (or proto-urban), such as coin use. To capture the location of the main pre-Roman settlements, we use data from Fichtl (2005) on Iron Age *oppida*. This source lists 107 *oppida* in France, but only 11 *oppida* in Britain, so we

[17] We acknowledge that the shapes of some rivers have changed since the Middle Ages (or the Roman era for that matter), but accounting for changes in navigability is difficult in practice. For example, see debates discussed in Blair (2007) regarding the extent of navigability of British rivers in the early and late Middle Ages. We therefore use present-day navigability to proxy for historical navigability.

[18] One of the definitions of "town" in the Merriam-Webster (2013) dictionary is of "a compactly settled area as distinguished from surrounding rural territory". In this paper we use "towns" to denote urban areas (including cities), where economic activity - and population - concentrate. Since this paper analyses around two millennia of urbanization, our empirical definition of towns varies by period, as we discuss below.

[19] For example, the site contains 1,000 such units in the United Kingdom and 1,000 in France. The smallest of the towns in each of the countries we use (listed above) are estimated to have had fewer than 10,000 people in 2012.

[20] Chandler (1987) provides earlier population estimates for some towns around the world, but mentions very few ancient towns in Britain and France.

also use Jones and Mattingly (1990) to locate other important Iron Age settlements in Britain, which may be seen as harbingers of British urbanization.

In measuring Roman-era towns, we face the challenge that different authors define Roman towns differently, and arrive at different lists of towns. To mitigate this problem, we do not rely on just one particular definition a "Roman town", but instead use three different definitions. Our first (baseline) measure is an indicator for Roman towns using classical references: Wacher (1995) for the main towns of Britain, Burnham and Wacher (1990) for the "small towns" of Britain, and Bedon (2001), for Roman towns of various sizes in France.[21] These sources, which describe the archaeology of each town in some detail, reveal many similarities between the Roman towns in Britain and France, as one might expect from neighbouring areas within the empire. In particular, larger Roman towns in both Britain and France had civil, commercial, and residential buildings that served a broad range of economic functions, whereas smaller towns typically had a more limited range of buildings, mostly residential and commercial. As Appendix Table A1 shows, our baseline sample includes 74 Roman towns in Britain and 167 Roman towns in France. Panel C of the table also reports separately the number of Roman towns in northern France, defined using the two Trajan provinces of the Roman Empire (Belgica and Lugdunensis). The table also shows that the Roman towns in Britain were quite similar to their counterparts in France in their origins (pre-Roman or Roman) and their coastal access, although towns in France were generally located in higher elevations and in more rugged terrain.[22] Our empirical methodology (below) allows us to control for pre-existing differences in locational fundamentals.

Our second measure of towns uses the size of walled (defended) areas of towns. Since precise population estimates for towns are unavailable, researchers often use these walled areas to construct population estimates.[23] We apply a common quantitative criterion - at least 5 hectares of walled area - for selecting Roman towns across northwestern Europe. When using this approach, like the one above, we still focus on Roman towns, as opposed to garrison forts that did not develop into towns (such as Chester). This approach has advantages, but also its limitations: some Romans lived outside town walls (see Goodman 2007); within the walls population densities may have differed; and some important Roman towns, especially in France (e.g. Marseille) did not have town walls. Nonetheless, this approach provides a useful complement to our baseline definition of Roman towns.[24] Each of these towns probably housed at least 500-1000 people and at most tens of thousands of people (see for example Bowman and Wilson, eds., 2011). As Table A1 shows, Roman towns with walled areas of five hectares or more number 38 in Britain (with an average log walled area in hectares of 2.93) and 58 in France (with an average log walled area in hectares of 2.96), of which 30 are in northern France (with an average log walled area in hectares of 2.78). The similarity of these figures suggests that in

[21] We are grateful to Greg Woolf and Penelope Goodman for their advice on these data sources.

[22] For more details on the origins of the Roman towns, see below.

[23] For a recent discussion of this methodology and its applications, see Bowman and Wilson (2011).

[24] The data we use on walled areas come from recent estimates for Britain (Mattingly 2006), France (Bedon 2001), and the rest of northwestern Europe (Esmonde-Cleary 2003). We focus our analysis on towns with defended areas of 5 hectares or more, since Mattingly does not list smaller towns.

terms of their population, the towns of Roman Britain were not too dissimilar from those of France. Moreover, a comparison of the walled areas of Roman towns in Britain and northern France suggests that it is highly improbable that urbanization survived in northern France and not in Britain because Britain's towns were vastly inferior.

While defence was important for many Roman towns, we wanted to focus our study on sites that had an urban character, and not on military camps. For this reason, we did not rely on the Barrington Atlas of the Greek and Roman World (Talbert 2000), whose classification of sites by importance does not correspond closely with urbanization. For example, two of the major sites that it reports for Britain (one in present day Chester and the other in Scotland) appear to correspond to Roman military camps without much civilian urbanization. We also note that among the Roman military sites reported in Åhlfeldt (2015), the smaller camps are generally located away from key areas of Roman urbanization, such as the South of France and the south of Britain. And the legionary camps reported in Åhlfeldt (2015) also generally do not overlap with the Roman towns we study, with only two exceptions in Britain and one in France.

Our third and final definition of Roman towns relies on the administrative classifications of the Romans themselves. Each Roman administrative town was classified as either *colonia*, *municipium* or "*civitas* capital" (see Mattingly 2006 for Britain and Bedon 2001 for France). These administrative designations became less important over time, and they imperfectly captured towns' evolving size and economic importance. As we discuss in Appendix B, these measures are also more problematic for Roman Britain. We therefore use them only in a limited number of robustness checks. In total our dataset includes 24 administrative Roman towns in Britain and 110 in France, of which 46 are in northern France (as defined above).

We complement the data on the location of Roman towns using these three definitions with additional information. We use data from Bedon (2001) to identify Roman towns that had bishops in the fourth century.[25] To identify whether the Roman towns had pre-Roman origins, we use Millet (1990) for Britain and again Bedon (2001) for France.[26]

During its post-Roman period, from 450-600CE, Britain had no functional towns (as discussed in Ward-Perkins 2001, Palliser 2001, Fleming 2010, Mattingly 2006, and Nicholas 1997), while in France many towns survived. From the seventh century onwards, trading settlements known as emporia (or "wics") began to emerge in Britain (Fleming 2010). These emporia had some urban features (and are sometimes described as "proto-urban"), although they were typically undefended. Only few such sites have been identified in Britain, however, and they have almost no counterpart in France (Quentovic being a rare exception), making a quantitative analysis impractical.[27]

[25]We include towns where Bedon specifies that the existence of a fourth-century bishop is uncertain. There is, however, much greater uncertainty on the location of Roman-era bishops in Britain, so we use the Roman bishop identifier for France only.

[26]Note that this measure of pre-Roman origins may include relatively minor settlements, and is therefore different from the measures of main Iron Age settlements described above (which also include Iron Age settlements that did not develop into Roman towns).

[27]In contrast, burghs were local defended centres in England during the reign of King Alfred and his successors in the

Our first measure of post-Roman urbanization identifies the seats of bishops (including archbishops), known as bishoprics, from 700-900 (Reynolds 1995). From these locations bishops exercised power at a time when the church was central for many aspects of life. The bishops and their followers also produced and consumed various products and services, sustaining a spatial concentration of economic activity (Fleming 2010 and Nicholas 1997). The bishoprics thus provide a window into early post-Roman (proto) urbanization.

Our next measure of (proto) urbanization is more directly related to the location of economic activity in early medieval Europe, namely the minting of coins. While the size and importance of early mints varied considerably, their presence suggests a concentration of local economic activity for a period where good measures of economic activity in both Britain and France are difficult to come by. We use data from Spufford (1988), who describes the location of mints in Carolingian and post-Carolingian France and in pre-Norman Britain (from 768-1066).

The main advantage of the bishoprics and the mints is that they allow us to trace the early stages of urban recovery in post-Roman Britain and France. For later years, however, we have more direct and conventional measures of urban activity in the form of population estimates. As discussed above, Bairoch et al. (1988), which is a standard reference, reports town population estimates for Britain only from 1000 onwards, and in the first few centuries of the second millennium the number of British towns it covers is low compared to the numbers discussed in Holt (2000). Given our focus on the location of towns, albeit small, we construct an indicator for towns with 1,000 people or more in Britain or France, using any town with estimated population in this range from Bairoch et al. (1988) for 1000-1200 or Dyer (2000), which provides estimates based on the Domesday Book. While this approach has its drawbacks (it may for example miss small towns in France if they are excluded from Bairoch et al. 1988) it permits a quantitative analysis of the location of early towns in both Britain and France.

Despite its limitations, Bairoch et al. (1988) is our main source for the population of towns for each century from 1200-1800. Because of the selection problems related to smaller towns, we focus on towns with at least 5,000 inhabitants. Since town populations grew rapidly during the industrial revolution, we use an additional population threshold of 10,000 inhabitants or more for towns in 1800.

Because the medieval era is important for our analysis, we also use Russell (1972) as alternative estimate of town populations circa 1300, before the onset of the Black Death. From Russel's estimates we again construct an indicator for towns with 5,000 people or more, as we do using the estimates of Bairoch et al. (1988) for that period.

For the period following the Black Death we construct an indicator for the 50 most populous towns in Britain and France. This measure takes the largest 50 towns as reported by Bairoch for 1400, and adds the 50 largest town in Britain as measured by the number of taxpayers based on the poll

ninth and tenth centuries, but it is difficult to identify close counterparts in France.

taxes of 1377-1381, as reported in Dyer (2000).[28] While the size of towns included in this measure most likely differs between Britain and France, this measure helps us understand the location of towns up to a fixed threshold in the town size hierarchy.

Finally, to examine individual towns that are locally important, irrespective of their absolute or relative size within a country, we compute arbitrary grid cells of 100 kilometres by 100 kilometres using an equal area projection in GIS. We then compute indicators for the largest towns within each of these cells for each century from 1200-1800 (using Bairoch et al. 1988) and for 2012 (using the World Gazetteer 2012). We also use these same cells to cluster the standard errors in our analysis below.

4 Empirical Analysis

4.1 Measuring the Persistence of Town Locations

To motivate our empirical analysis, we present in Appendix A a simple model of town location. This model allows for possible changes in first-nature locational fundamentals (or their value) and also for shocks that could destroy the towns, such as the one experienced by the ending of Roman Britain. This model allows for different possible scenarios. In Scenario 1, locational fundamentals consistently favour a particular location. Here, even if a shock destroys the town, it will form again in the same location. In the Scenario 2, first-nature locational fundamentals (or their value) change over time, and the town follows. In the Scenario 3, even if first nature fundamentals or their value change, the town persists in its location for historical reasons - in the model it is held in place by agglomeration, but in reality this may be reinforced by the value of past sunk investments. In this case a shock that ends the town will leads to it re-formation in a different location - the one with improved fundamentals. There are two variants to this third scenario: differences in first nature fundamentals may be relatively small and inconsequential; or they may be large, but not large enough to shift the town unless it is exogenously destroyed.

Before proceeding with the econometric analysis of these possible scenarios, we begin our examination of the persistence of town locations from the Roman era by examining the data visually. Panel A of Figure 1 shows the location of the baseline Roman towns in present-day Britain and France. The other three panels of the figure compare the locations of these towns to our three earliest measures of urbanization (or proto-urbanization) in the post-Roman early medieval era, starting with the medieval bishoprics. Historians have commented on the spatial reallocation of power centres, both secular and ecclesiastical, in post-Roman Britain.[29] Loseby (2000) discusses the efforts of Pope Gregory I to bring Britain back into the fold of the Roman Church in the late sixth century. The old

[28] Bairoch et al. (1988) list only 21 towns in Britain for that year, including 10 of 5,000 people or more. It lists 60 towns in France, including 38 with 5,000 people or more.

[29] For example Heather (2001, p. 459), writes: "Neither the boundaries of the host of small Anglo-Saxon kingdoms which had emerged by c. 600 nor, perhaps more surprisingly, those of their British counterparts bore much relation to the civitas geography of the Roman period. Bishops did survive among the British, though not among the pagan Anglo-Saxons, but their sees were also not based on the old civitates."

Roman towns seemed like natural targets for the early missionaries, but in many cases the location of power centres had already shifted by 600CE, and the location of the newly established bishoprics had to adjust to the new reality. And as Panel B of Figure 1 shows, the location of Bishoprics (including Archbishoprics) from 700-900 in Britain appears to differ from the location of Roman towns much more than it does in France.

The location of economic activity in early medieval Britain, as reflected (admittedly imperfectly) by the location of pre-Norman mints, tells a similar story. The locations of coin mints in Britain bear relatively little resemblance to the location of Roman towns, unlike their counterparts in France. Finally, in the early Norman period, the location of towns with 1,000 people or more from 1086-1200 in Britain is again quite different from the location of Roman towns, while in France there is much more locational persistence. Appendix Figure A1 shows comparisons of the locations of Roman towns with defended areas of 5 hectares or more to early medieval towns, and once again we see more persistence in France than in Britain.

The maps also show that the difference in persistence of town locations is not driven by differences in the number of towns (in absolute terms or relative to land area) between Britain and France. For example, early bishoprics are rarer in Britain, while coin mints are far more common. This is noteworthy for our empirical analysis below, since the number of larger towns (with 5,000 people or more) was lower in Britain compared to France for a long time after the collapse of Roman Britain.

While these measures of towns during the Middle Ages are admittedly imperfect, we prefer them, and especially the population estimates of towns from 1086-1200, to the more precise population figures from later years. This is because as we move beyond the Middle Ages, England become the preeminent maritime power, and this could have affected the differences in its outcomes compared to France.

Nevertheless, we note that the differences in persistence between France and Britain lasted for many more centuries. As Table A2 shows, the difference in persistence of town locations compared to the Roman era continued through to 1700, around the eve of the Industrial Revolution, when only 5 of the largest 20 towns in Britain were within 5km of Roman town sites, compared to 16 in France (and 13 in the northern parts of France, covering the Roman provinces of Lugdenensis and Belgica). The picture today is still strikingly similar: only 3 of the top 20 British towns are located near Roman town sites, compared to 16 in France as a whole (and still 13 in northern France, as defined above).[30]

Having examined the data, we now conduct more formal empirical tests of the persistence of town locations in Britain and France. We use a cross section of grid points (indexed by i) to estimate the following specification for various time periods (indexed by t):

$$Y_{it} = \beta_1 + \beta_2 Town_i + \beta_3 Britain_i + \beta_4 Town_i \times Britain_i + \epsilon_{it}, \tag{1}$$

where Y_{it} is an indicator for being close (within 5km) to later (medieval or modern) town; $Town_i$ is

[30] In fact, even three of the top-20 present-day towns in northern France, which are not within 5km of a Roman town site, Boulogne-Billancourt, Argenteuil, and Saint-Denis, are effectively suburbs of Paris, which is itself cantered around a Roman town (Lutetia).

an indicator for the site of a settlement, in this case a Roman-era town; $Britain_i$ is and indicator for Britain; and ϵ_{it} is an error term.[31] This specification allows us to calculate the probability that a site with (and without) a Roman town is used by a later town in both Britain and France. Specifically, we calculate the following odds ratio:

$$\frac{\Pr\left(\text{site of an early town is used by later town}\right)}{\Pr\left(\text{site without an early town is used by later town}\right)}, \tag{2}$$

where "used by" denotes proximity (within 5km in the baseline specification), and here "early town" denotes a Roman town, and "later town" denotes a number of measures of towns in the post-Roman era. We calculate this odds ratio because the spatial density of later towns differs by country over time, and when the network is denser there is a higher probability that later towns might be located near Roman town sites purely by chance. The odds ratio accounts for this by normalizing by the probability that a non-Roman town site is correspondingly more likely to be near a later town.[32] We calculate the odds ratio as $(\beta_1 + \beta_2)/\beta_1$ for France and $(\beta_1 + \beta_2 + \beta_3 + \beta_4)/(\beta_1 + \beta_3)$ for Britain, and test the null hypothesis that these ratios are equal, as predicted by Scenarios 1 and 2, against the alternative that the ratios are different, as predicted by Scenario 3.[33]

As Table 2 shows, for many different measures of towns (and proto-towns) from 700-1700, the persistence measured by the odds ratio is around 7-13 in Britain, or about three times smaller than in France (where the odds ratio is around 20-40). The tests reject the equality of the odds ratios, consistent with the predictions of Scenario 3, where the persistence of town locations is high in France and lower in Britain. This holds both in cases where there are fewer later towns per square kilometre in Britain than in France (as in the case of the medieval bishoprics), and in cases where the opposite is true (as in the case of medieval mints).[34] The table also shows that using correlations instead of odds ratios yields similar results, although we prefer the odds ratios approach, which allows us to add regression controls, as we explain below.

We conduct a number of checks to show the robustness of the findings described in Table 2. Panel A of Appendix Tables A3 and A4 shows that the results hold when we expand the measure of proximity from 5km to 10km. We note that these 10km bands cover an area of over 300 square kilometres closest to each grid point. Panel B shows results from specifications with a narrower definition of proximity, looking only at whether the same point was used by towns in different periods, and again the differences between Britain and France are large and significant.[35] In Panel C we restrict the

[31] To account for spatial correlation, we cluster the standard errors on arbitrary 100 kilometre by 100 kilometre squares. This approach follows Bleakley and Lin (2012) and Michaels, Rauch, and Redding (2012) and is based on Bester, Conley, and Hansen (2011). Using the alternative Conley (1999) approach is computationally unfeasible given the large size of our dataset.

[32] The odds ratios that we calculate below use regressions, which allow for 5km radii around towns; hence they are considerably larger than the figures presented in Table 1.

[33] Scenario 3 specifically predicts that France's ratio is higher than Britain's.

[34] During the Industrial Revolution there was further movement of British towns, even compared to French towns, resulting in an even higher ratio of ratios in 1800 and 2012, as discussed in Bairoch (1988). Our findings, however, show significant differences in locational persistence relative to the Roman urban network long predate the formation of separate national economies.

[35] This approach yields much higher estimates of persistence in Britain and France, but this is due to the way we match

area in France to its northern regions, which are more similar to Britain, and again our estimates are very similar to the baseline. In Panel D we use the same specification as in our baseline, but this time using only Roman towns with defended areas of 5 hectares or more, and again the differences between Britain and France are similar, and perhaps even slightly starker. Panel E uses the same definition of towns as Panel D, but expands the geographical coverage to all the parts of the Roman Empire in northwestern Europe, and the results are again similar to the baseline. Panel F is the same as the baseline, but this time using only Roman administrative towns. Here the differences between Britain and France are still mostly significant, although not in all cases, perhaps because only 24 Roman towns in Britain are known to have had an administrative status. Panel G restricts the baseline Roman towns to those with pre-Roman origins, with results that are similar to the baseline. This shows that our results are not driven by the Romans' decision to locate some towns in previously unsettled sites, which may have potentially differed in present-day Britain and France. Finally, Panel H uses the same specification as in the baseline, except that now we control directly for measures of locational fundamentals, and allow their effects to differ in Britain. Our findings are again similar, and perhaps even stronger, showing that the higher persistence of town locations compared to the Roman era in France is not driven by differences in observed locational fundamentals.[36]

One particular concern is that Roman town sites in Britain may have remained locally important even if they declined in absolute size along with their local economy. This may affect our results on persistence if changes in climate or technology during the medieval era favoured areas in Britain that had few Roman towns, while perhaps inducing less regional change in France. A casual inspection of Figure 1, however, suggests no marked shift in the regional concentration of towns in Britain, with towns remaining more concentrated in southern England and the Midlands than in northern England and Wales. Nonetheless, to address the concern that regional reallocation may affect our results, we estimate specifications similar to those above, using as outcomes indicators for the largest town in each 100×100 kilometre square cluster in different points in time. The results in Table A5 show that even using this measure the persistence of town locations is lower in Britain than in France. As before, restricting the areas in France to its northern regions leaves the picture essentially unchanged.[37]

One potential concern for our identification strategy is that Roman choice of town locations may have, perhaps for military reasons, differed in Britain and in the continent. We already saw that our findings were robust to using only towns with pre-Roman origins, but again one might be concerned

towns over time (e.g. matching Londinium to London and Lutetia to Paris). Towns often span more than one square kilometre, and the coding of the precise grid point is prone to measurement error. We therefore consider the point-by-point analysis as a robustness check, rather than as a preferred specification.

[36]We have also tested whether our baseline results are robust to controlling for distance to centres of economic and political importance located outside the area that we analyse. Specifically, we have added controls for the distance to Rome, even as this city fell into rapid decline during the Middle Ages, and for distance to Ribe, a town founded in Denmark in the early middle ages, which reflects the rising fortunes of Scandinavia during this period. The general pattern reported in Table 3 persists when we include these controls (the results are available from the authors).

[37]We also note that in western and northern Britain - despite their distance from Rome - the remnants of Roman life survived better than in eastern Britain (see for example Mattingly 2006 and Fleming 2010). This again suggests that there is no geographic determinism in regional pattern of town persistence.

that the Romans only selected to build towns on certain pre-existing settlements. To address this concern we use major pre-Roman Iron Age settlements as an instrument for Roman town location. This approach relaxes the assumption that the Romans chose town sites in a similar way in Britain and France. It does, however, assume that Iron Age sites were more likely to serve medieval or later towns only because they also served Roman towns. If some Iron Age sites became medieval towns because they provided refuge for people in the volatile post-Roman era, this might result in 2SLS estimates that are larger than the OLS estimates, especially in Britain, where the collapse was more severe.

To construct our instruments, we first identify the location of important Iron Age settlements known as *oppida* (Fichtl 2005). As we discuss above, these were focal points for economic activity, typically with some defences, which existed prior to the Roman conquest. As column (1) of Table A6 shows, the location of oppida is a good predictor of the location of Roman towns in France. But as column (2) shows, the statistical power of *oppida* in predicting town locations in Britain is weaker, probably because there were only 11 oppida in Britain. We therefore also use data on the location of a broader set of major Iron Age settlements in Britain (Jones and Mattingly 1990). As columns (3) and (4) of Table A6 show, these have stronger predictive power for the location of Roman-era towns in Britain.

We use the location of Iron Age settlements from Fichtl (2005) and Jones and Mattingly (1990) as excluded instruments for $Roman_i$ and $Roman_i \times Britain_i$.[38] The 2SLS estimates in Table A7 show higher persistence than the OLS estimates, perhaps for the reasons discussed above. The persistence of town location is still higher in France than in Britain, although the estimates are noisier and the ratios are significantly different from each other only in 7 out of 12 of the cases. Across all town measures from 700-1700, the ratio of ratios (Britain's divided by France's) averages around 0.37, compared to an average 0.31 in the OLS estimates above. Overall, then, these results suggest that the difference in persistence of town locations from the Roman era is not driven by differences in locational choices made in the Roman era.

Another question we examine is whether Britain's urban network showed locational persistence that is similar to France's in periods when neither underwent a shock as severe as Britain did when the Western Roman Empire fell. To examine this, we estimate specifications as in equation (1) using an indicator for towns with 5,000 people or more in 1200 instead of Roman towns. The results, reported in Table A8, show similar persistence in town location in Britain from 1200 until 1700, around the dawn of the Industrial Revolution.[39] Similar tests comparing the locations of Iron Age settlements and Roman baseline towns (available from the authors on request) likewise show similar persistence

[38] The first stage joint F-statistic is around 9.7, suggesting that the instruments are not very strong. We therefore use Limited Information Maximum Likelihood (LIML) estimation, although the results are very similar when we use Two-Stage Least Squares (2SLS). We also note that since these instrumental variables estimates are derived from a non-saturated model the point estimates are not all in the [0,1] range as in the OLS model above, although in practice even the two negative estimates are very close to zero.

[39] During the Industrial Revolution, towns in the Midlands and northern England, especially near coalfields, grew rapidly. France, which is less coal-abundant, experienced fewer changes in the relative size of its towns.

in both countries. Therefore, were it not for the collapse of Britain's towns during the fall of the Western Roman Empire, we might have expected the persistence of its town locations to have been similar to France's.

Our econometric analysis of town locations builds on the work of many historians and archaeologists, who have rigorously pieced together a picture of the Roman urban network. Nevertheless, one potential concern is that we might be unable to account for some Roman towns that are now lost. This concern is probably more applicable to Britain, because there is more written evidence for France (see Appendix B for further discussion). Since archaeological evidence on Roman towns often comes up incidentally during excavations, which are more common in present-day towns than in rural areas, any Roman towns that we may be missing are most likely Roman towns in Britain on whose sites no later towns developed. This type of measurement error, if present, would therefore cause us to understate the differences in persistence of urban locations between France and Britain.

While we find that the persistence of Roman-era town locations is low in Britain (compared to France) this persistence is still significantly larger than 1 in most of our estimates. But is this necessarily because locational fundamentals attracted population long after the Roman town ceased to function? In evaluating the persistence of Roman town sites in Britain, we should consider other reasons, besides than natural advantage, which attracted population back to some sites. First, in some cases non-urban populations continued to dwell in the former Roman towns (see for example Wacher 1995). Second, some of the roads built by the Romans, and which connected their towns, survived to serve the Anglo-Saxons (Fleming 2010).[40] Third, some Roman walls survived and were put into use many centuries later, as in the case of medieval London.[41] Fourth, even when buildings and walls were no longer serviceable after centuries of dereliction, they sometimes still provided usable masonry. Finally, some Roman towns, which were home to early Christian saints, later became medieval pilgrimage sites, which sometimes developed into towns.[42]

All these considerations suggest that if the towns of Roman Britain had been wiped out without leaving any trace, the locational persistence of towns in Britain from the Roman era onwards may have been even lower than our estimates suggest. By the same token, the persistence of town locations in France may have been much more than three times higher than in Britain if persistence in Britain had been driven only by natural features, such as rivers and coasts.

This consideration is also important when comparing our findings to other recent studies of persistence in modern cities that suffered devastating shocks (e.g. Davis and Weinstein 2002). Modern

[40] For our measure of medieval towns with at least 1,000 people from 1086-1200, the probability of finding a Roman road within 5 kilometres was just over 80 percent in both Britain and France.

[41] London was not the site of any important pre-Roman Iron Age settlement. It was the Romans who built Londinium, which eventually developed into the main town of Roman Britain, and lay at the centre of its road network, with a population which may have reached 30,000 (Fleming 2010; Mattingly 2006). The Roman town ceased to function by around 450CE, and around 150 years later an undefended trading *emporium* developed a few kilometres outside its walls. Following Viking raids in the ninth century, the population moved into the safety provided by the surviving Roman walls, which proved useful even four centuries after the town they were built to serve had ceased to function.

[42] The town of Saint Albans bears the name of an early Christian martyr, who lived in the Roman town of Verulamium. Saint Albans developed in the Middle Ages next to the abandoned Verulamium, and its medieval cathedral uses some of Verulamium's masonry.

cities subjected to these shocks may have subsequently attract population because of their cultural legacies, or because they were part of transportation networks. Moreover, when modern towns are devastated, property rights for land may attract population even when buildings are destroyed; but in post-Roman Britain property rights from the Roman era were no longer upheld (Wickham 2005). Thus there is reason to believe that the success of cities in recovering from war or outbreaks of disease may not be driven only by their favourable geographic location.

4.2 Why Britain's Urban Network Reconfigured

But why did Britain's urban network, which was reset by the fall of the Roman Empire, reconfigure around a different set of locations than its Roman predecessor? We argue that medieval British towns formed in locations that had become more productive in that era, compared to the Roman era. Our empirical analysis below focuses on a particular locational advantage, which is related to the changes in trade costs over time.

During the Roman era, the Roman army played an important role in administrating and securing the northwestern parts of the Roman Empire. The Roman army was instrumental in procuring taxes - both in kind and in currency - and in buying locally produced goods and services. The Roman army needed good roads in order to move swiftly and reliably in all weather conditions, so the Romans built an extensive road network to connect the urban networks in present-day France and Britain. The Romans did, of course, use water transportation, but mostly in and around the Mediterranean. In contrast, the North Sea and the English Channel were viewed as more hazardous, and their use was more sporadic (Morris 2010).

While a few Roman towns in Britain and France did serve as ports, most towns served local markets. For these towns, which serviced nearby locations, being away from the coast may have actually been advantageous, allowing them to serve larger land areas within a given Euclidean distance. Rivers were important for many Roman towns, providing them with water for consumption and manufacturing, fishing opportunities, and in some cases serving as a defensive barrier (Nicholas 1997).[43] But most of these benefits could be derived from non-navigable rivers or other water sources (sometimes using aqueducts), and many Roman towns developed without coastal access.[44]

In the Middle Ages, the importance of water transportation increased compared to land transportation in present-day Britain and France, for two different reasons. First, the quality of roads in the medieval era was typically worse than in the Roman era.[45] Second, the shallow draft of Norse-designed ships allowed these ocean-going vessels to travel on inland waterways (Brøgger and Shetelig 1971), which may have reduced transshipment costs. For a while, this new technology also made locations with coastal access more vulnerable to Viking raids. By the late eleventh century, however, the Normans controlled most of Britain and France, and raids were no longer a major

[43] Most notably, the Rhine and the Danube defined the northern boundary of the Roman Empire for many years.

[44] Examples include Venta Icenorum and Calleva Atrebatum in Britain, which did not become medieval towns, and Troyes, Dijon, Chartres, and Autun in France, which did.

[45] Hitchner (2012) discusses the deterioration in quality of roads in France from the Roman era to the medieval era.

problem.

Comparing the cost advantage of water transport over land transport over time is an imprecise exercise. Still, Scheidel and Meeks (2013) estimate that during the Roman era, land transport may have been, on average, around 6 times more expensive than river transport. In contrast, Jones (2000) discusses river navigation in England around 1300 and concludes that "carriage by land could be more than ten times the price of transport by water".[46] We have no similar quantitative evidence for medieval France, but it seems likely that its relative costs would have been similar. All this suggests that coastal access would have been more important for towns during the High Middle Ages than during the Roman era.[47]

We now examine whether the growing importance of water transportation shifted the urban networks towards locations with coastal access. As Figure 2 shows, approximately half of the baseline Roman towns in both Britain and France had some coastal access. By 1086-1200, however, over three quarters of British towns had coastal access, while in France still only about half did.[48] Appendix Figure A2 shows a similar comparison, with similar results, using only the Roman towns with defended areas of 5 hectares and the medieval towns.[49]

We now proceed to test more formally whether Britain's towns had more coastal access in the Middle Ages than in the Roman era, and whether or not this was the case for France. We begin by pooling a pair of cross-sections of our grid, one using Roman era town locations, and the other using a later era's town locations. We then use these data to estimate regressions of the form:

$$Y_{it} = \sum_{i=0}^{1} [\gamma_{i1} I_{t=i} + \gamma_{i2} I_{t=i} \times Britain_i + \gamma_{i3} I_{t=i} \times Access_i + \gamma_{i4} I_{t=i} \times Britain_i \times Access_i] + \epsilon_{it}, \quad (3)$$

where Y_{it} is an indicator for the location of a town (in the Roman or later period); $I_{t=0}$ and $I_{t=1}$ are indicators for the earlier (typically Roman) and later (typically post-Roman) periods, and $Access_i$ is an indicator for coastal access at each point on our grid using either of our two measures, which are described above.

We use these regressions to examine whether towns in Britain moved towards locations with coastal access from the Roman to later periods. Specifically, we test whether the ratio of the probability of finding a town in a location with coastal access to the probability of finding a town in a location without coastal access increased in Britain from the Roman to later periods. This ratio is useful, since

[46]The importance of high transportation costs persisted for many centuries. Glaeser and Kohlhase (2003) discuss how high these costs were during the nineteenth century in the US.

[47]For more evidence on the importance of water transportation for town development in Europe see Acemoglu et al. (2005) and Bosker and Buringh (2015).

[48]The growth in the fraction of towns with coastal access in Britain from the Roman to the medieval era was due to both higher persistence in Roman town locations with coastal access and a greater propensity for new towns to emerge in locations with coastal access. The precise contributions vary, but as an example we focus on Roman baseline towns, medieval towns with at least 1000 people from 1086-1200, and our broader definition of coastal access. In this context, the odds of survival of a Roman baseline town in Britain were approximately 27% with coastal access and 8% without it. In France, the corresponding figures were 43% with coastal access and 27% without it. Looking from another perspective, in Britain 27% of the medieval towns with coastal access had a Roman predecessor, and the same figure applies to towns without coastal access. In France the corresponding figures were 79% with coastal access and 58% without it.

[49]More precisely, the fractions of towns with coastal access were 52 (54) percent in Roman Britain (France) and 77 (51) percent in medieval Britain (France).

it tells us by how much a particular locational fundamental (in this case coastal access) increased the odds of a town in a given location, in a given area and period. Formally, the test we conduct is:

$$H_0 : S_1 \equiv \frac{\gamma_{11} + \gamma_{12} + \gamma_{13} + \gamma_{14}}{\gamma_{11} + \gamma_{12}} - \frac{\gamma_{01} + \gamma_{02} + \gamma_{03} + \gamma_{04}}{\gamma_{01} + \gamma_{02}} = 0, H_1 : S_1 > 0. \tag{4}$$

We also conduct an equivalent test for France:

$$H_0 : S_2 \equiv \frac{\gamma_{11} + \gamma_{13}}{\gamma_{11}} - \frac{\gamma_{01} + \gamma_{03}}{\gamma_{01}} = 0, H_1 : S_2 > 0. \tag{5}$$

Finally, we test whether the shift over time towards coastal access was more pronounced in Britain than in France:

$$H_0 : S_3 \equiv \frac{(\gamma_{11} + \gamma_{12} + \gamma_{13} + \gamma_{14}) / (\gamma_{11} + \gamma_{12})}{(\gamma_{01} + \gamma_{02} + \gamma_{03} + \gamma_{04}) / (\gamma_{01} + \gamma_{02})} - \frac{(\gamma_{11} + \gamma_{13}) / \gamma_{11}}{(\gamma_{01} + \gamma_{03}) / \gamma_{01}} = 0, H_1 : S_3 > 0. \tag{6}$$

Table 3 shows that in Britain the effect of coastal access on towns (as reflected in the odds ratio discussed above) roughly tripled from the Roman era to the Middle Ages, and remained at its higher level at least until 1700. For the three cases where we observe a sizeable number of towns in Britain (towns measured in 1086-1200, 1377-1400, and in 1700) the increase is statistically significant, while for the remaining outcome (towns in 1200), where the number of towns we observe in Britain is smaller, the change is even larger in magnitude but only marginally significant. The table also shows that French towns barely shifted towards locations with better coastal access. The magnitude of the ratios is also informative: in Britain in 1700 the ratio for the coastal access measures was around 6, implying that coastal access was as good a predictor of towns in 1700 as Roman towns (for which the ratio was around 7.5). In contrast, in France in 1700 the ratio for the coastal access measures was around 4, compared to the ratio for Roman towns which was almost 20. Finally, we note that the differential change between the two countries is typically either significant or marginally significant, again with more precision in cases where the number of towns in Britain is larger.[50]

Appendix Table A9 shows a similar comparison of Britain to northern France, instead of France as a whole. In northern France the shift towards the coast is somewhat larger in magnitude than in France as a whole, but unlike in Britain it still not significant. Appendix Table A10 compares Britain to the whole of France, but this time using only towns with defended areas of 5 hectares or more. While the sample is smaller and not all the estimates are precise, the picture that emerges is consistent with the results described above, with the urban network reconfiguring towards locations with coastal access in Britain but not in France.

We earlier noted that changes in transport technology meant that coastal access was probably more important for medieval towns than for Roman towns in Britain and France. But is there more

[50]Both proximity to the coast and proximity to navigable rivers separately appear to increase the odds of having medieval towns (with 1,000 people or more from 1086-1200) compared to (baseline) Roman towns in Britain - the effects for coasts is precisely estimated and the effects for rivers is marginally significant. The effects for France are much smaller and imprecise. When comparing across Britain and France, the effect in Britain is significantly larger than in France for coasts, and large but imprecisely estimated in the case of rivers. For later towns (those with 5,000 people or more in 1700) the effects are similar. Both proximity to navigable rivers and to coasts separately and significantly increase the odds of these towns in Britain, and again not in France. The difference between the two countries is again in Britain's favour – it is significant in the case of navigable rivers and marginally significant in the case of the coast.

direct evidence that coastal access actually mattered? While we have no causal evidence on the effect of coastal access on towns (since towns are a selected sample of points on our grid), we provide below evidence, which strongly suggests that it did. First, we use data on towns with 5,000 people or more in 1200 to estimate specifications of the type:

$$\Delta \ln \left(pop_{i,t}\right) = \lambda_1 + \lambda_2 Access_i + \lambda_3 \ln \left(pop_{i,1200}\right) + \lambda_4 Britain_i + \epsilon_{it}, \tag{7}$$

where $pop_{i,t}$ is the population in town i in year t, and the change in population is measured from 1200 until 1800 (a year for which we have population data for all towns with 5,000 people or more in 1200), or in alternative specifications until 1700 and 2012.[51] As Table 4 shows, the population of towns with coastal access grew almost 10 percentage points faster per century from 1200-1800 than that of towns without coastal access. The estimates for growth from 1200-2012 are still sizeable but although smaller and less precise. This may be because since the Industrial Revolution the cost of building canals and maintaining them have fallen, and the importance of coastal access decreased with the advent of trains and highways. If so, we are now again seeing an environment where road transport is a good substitute for land transport, and this particular advantage of coastal access has diminished. Other aspects of locational fundamentals, such as good weather, may now be more important, though (Rappaport 2007). But even if we are now back in an environment where maritime transport is not so important for most cities, our results suggest that having no coastal access was costly for towns' growth prospects over more than half a millennium.

A second piece of evidence on the importance of coastal access for towns comes from the construction of canals. Thousands of kilometres of canals currently exist in both Britain and France, connecting many of their towns. These are the product of many centuries of costly construction and maintenance of canals, which itself strongly suggests the economic importance of access to waterways for towns. At least 40 of France's canals were begun from 1200-1800, and the total length today is over 1,880 kilometres (Dictionnaire des rivières et canaux de France 2013). We have no comparable list for Britain, but Blair (2007) discusses the importance of canals in medieval England.

To examine the relation between access to canals and town growth for towns with poor (or no) coastal access (where Coastal Access I measure equals zero), we estimate regressions as in specification (7) using an indicator for canals instead of an indicator for coastal access. The results in Appendix Table A11 suggest that faster growing towns with poor (or no) coastal access eventually received access to canals. While these results do not necessarily reflect the causal effect of canals, they are consistent with our argument that water transport was valuable for towns for many centuries.

Given this evidence on the value of access to water transportation routes, it is therefore striking that so many medieval French towns had no coastal access. Our finding that the French urban network did not realign towards locations with natural coastal access suggests that the path dependence in their location was in fact consequential.

[51] The specifications use different sets of controls, and in one of them we add as a control the interaction term $Access_i \times Britain_i$, allowing for the effect of coastal access to differ in Britain.

Still, even if coastal access was important, is it possible that there were no plausible locations with coastal access near medieval French towns? To examine this possibility, we define a location as "locally suboptimal" if it is further than 5km, but no further than 25km, from a coast or a navigable river. The idea is that for towns in these suboptimal locations there is a plausible site nearby on which the town may have been built with better coastal access. We use a specification similar to (3), replacing the indicator for coastal access with an indicator for "local suboptimality". We then test whether towns in Britain moved significantly away from locally suboptimal locations; whether the same can be said of France; and whether the movement away from suboptimal locations was similar in Britain and France. The results in Appendix Table A12 show that towns in Britain moved away from locally suboptimal locations between the Roman era and the medieval era. At the same time, there was almost no movement away from locally suboptimal locations in France. Finally, the table shows that the difference in changes between the two countries is large and statistically significant.

It is difficult to ascertain how much faster the French urban network would have grown from 1200-1800 if its towns all had coastal access. Our estimates from Table 4 suggest that coastal access was associated with roughly 50% more population growth over the period. Aggregating this up to the network level requires strong assumptions about the complementarity or substitutability of different towns' growth. But it is nevertheless plausible that the lack of coastal access of many French towns had a significant aggregate impact.

But if Roman-era locations imposed high costs for French towns, we might wonder why their population did not relocate during the early Middle Ages, when towns were relatively small and weak. In Appendix C we discuss one possible explanation, which emphasizes the role of bishops. As Nicholas (1997) and Wickham (2009) discuss, bishops and their followers played important roles in town life in France after the fall of the Western Roman Empire. In the Appendix we show that Roman towns in France, which were bishoprics (home to bishops) in the fourth century, before the Roman Empire's collapse, were more likely than others to survive through the Middle Ages and up to the present day. Interestingly, Roman-era towns without bishops in France were about as (un)likely to survive as Roman towns in Britain.[52]

We conclude by noting that even if religious considerations made bishopric locations viable in France, any locational advantage that they conferred was the result of people's investments.[53] In other words, French towns stayed in locations with poor first-nature fundamentals because they were home to concentrations of people, and because of the value of physical and cultural investments made in those locations. Today, many cities around the world concentrate many more people than in the past, and much more physical and cultural capital. Our findings suggest that this could allow them to remain stranded in locations that are even more unsuitable in terms of their physical geography.

[52] While Christianity persisted in parts of Britain during these turbulent centuries, the Roman Church establishment did not, and its reintroduction to Britain began in the last few years of the sixth century.

[53] While some locations housed important religious relics, medieval history shows that these relics were often moved from one location to another.

5 Conclusions

The collapse of the Roman Empire temporarily ended urbanization in Britain, but not in France. We find that as urbanization recovered in the Middle Ages, the location of towns in France was closely related to their Roman predecessors. This was not, however, the case in Britain, whose urban network largely realigned. We find that Britain's medieval towns benefitted from better coastal access than their French counterparts. We also find that from the Middle Ages until the Industrial Revolution, towns with coastal access grew more quickly than others, in both Britain and France. We calculate that with better coastal access, France's urban population would have been roughly 20-30 percent larger in 1800.

Taken together, our findings suggest that France's towns remained trapped in locations without coastal access. We interpret this as evidence for consequential path dependence in the location of economic activity. In other words, once economic activity concentrates in a given location, it can persist there for many centuries even if the location is no longer optimal. Today's major cities are much larger than their historical counterparts, and may therefore be even more persistent if their locations become ill-suited.

Our evidence is important in an increasingly urbanized world. While in the developed world coastal access may no longer be as important as it once was, it may still relevant for parts of the developing world, where trade costs are high. And even in the developed world, many large urban centres are located in areas susceptible to natural disasters, such as earthquakes and flooding. Our paper's findings underscore the importance of decisions on the location of urban infrastructure. Policies that affect the location of cities may have important consequences for generations to come.

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Table 1. Summary Statistics

Variable	Full sample (906,075 observations) Mean	Full sample (906,075 observations) Std. Dev.	Britain and France only (697,198 observations) Mean	Britain and France only (697,198 observations) Std. Dev.
Britain indicator	0.16	0.37	0.21	0.41
France indicator	0.61	0.49	0.79	0.41
Elevation (meters)	350	433	296	377
Ruggedness	446	540	462	535
Coast within 5km	0.05	0.22	0.06	0.24
Coastal access I	0.11	0.32	0.14	0.34
Coastal access II	0.20	0.40	0.25	0.43
Suboptimal location I	0.26	0.44	0.32	0.46
Suboptimal location II	0.38	0.49	0.47	0.50
Pre-Roman origins	0.00010	0.00997	0.00013	0.01136
Iron Age settlement	0.00017	0.01295	0.00019	0.01376
Belgica indicator	0.10	0.30	0.09	0.28
Lugdunensis indicator	0.18	0.38	0.23	0.42
Roman road within 1km	0.17	0.37	0.17	0.37
Roman town (baseline)	0.00027	0.01631	0.00035	0.01859
Roman town with 5+ hectare defenses	0.00012	0.01082	0.00014	0.01173
Roman administrative town	0.00017	0.01320	0.00019	0.01386
Roman bishopric in the 4th century	0.00010	0.00985	0.00013	0.01123
Bishopric (or archbishopric) between 700-900	0.00016	0.01252	0.00018	0.01323
Mint between 768-1066	0.00020	0.01421	0.00023	0.01524
Town with 1k+ population between 1086-1200	0.00022	0.01467	0.00019	0.01381
Town with 5k+ population in 1200	0.00013	0.01146	0.00011	0.01051
Town with 5k+ population in 1300 (Russell)	0.00009	0.00951	0.00008	0.00872
Town with 5k+ population in 1300	0.00011	0.01051	0.00007	0.00830
Largest 50 towns 1377-1400	0.00011	0.01051	0.00014	0.01198
Town with 10k+ population in 1400	0.00015	0.01216	0.00009	0.00958
Town with 5k+ population in 1500	0.00018	0.01329	0.00012	0.01084
Town with 5k+ population in 1600	0.00028	0.01667	0.00024	0.01552
Town with 5k+ population in 1700	0.00035	0.01858	0.00031	0.01748
Town with 10k+ population in 1700	0.00015	0.01207	0.00012	0.01104
Town with 5k+ population in 1800	0.00068	0.02598	0.00061	0.02462
Town with 10k+ population in 1800	0.00024	0.01551	0.00022	0.01491
Town with 10k+ population in 2012	0.00323	0.05674	0.00250	0.04998
Town with 20k+ population in 2012	0.00176	0.04191	0.00138	0.03708
Town with 50k+ population in 2012	0.00051	0.02255	0.00043	0.02070
Town with 100k+ population in 2012	0.00018	0.01357	0.00014	0.01204

Notes: The full sample includes the parts of the Roman Empire, which lie within present day Belgium, France, Germany, Luxembourg, the Netherlands, Switzerland and the United Kingdom. We do not include a separate indicator for the Roman province Britannia, since it is identical to the Britain indicator. See the text and Appendix B for a description of the dataset and variable construction.

Table 2. Probability of towns (700-2012) within 5km of Roman towns

	Bishopric or Arch-bishopric in 700-900	Coin Mint in 768-1066	Town with 1k+ people in 1086-1200	Town with 5k+ people in 1200	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	One of largest 50 towns in 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500
Roman town	0.566	0.343	0.365	0.279	0.234	0.162	0.203	0.203	0.225
	(0.041)	(0.041)	(0.041)	(0.036)	(0.032)	(0.027)	(0.033)	(0.033)	(0.032)
Britain	-0.006	0.031	0.012	-0.001	-0.000	-0.000	0.018	-0.001	0.001
	(0.002)	(0.008)	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
Roman town	-0.466	-0.114	-0.159	-0.205	-0.185	-0.127	-0.012	-0.141	-0.14
x Britain	(0.054)	(0.062)	(0.058)	(0.046)	(0.043)	(0.034)	(0.052)	(0.044)	(0.051)
Intercept	0.015	0.011	0.012	0.009	0.006	0.005	0.007	0.007	0.009
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Ratio Britain	13.12	6.52	9.79	10.93	9.78	8.08	8.62	10.93	9.91
Ratio France	39.58	33.32	31.81	33.25	41.03	31.75	30.90	29.68	27.38
Ratio Britain/France	0.33	0.20	0.31	0.33	0.24	0.25	0.28	0.37	0.36
p-value[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001
Correlation Britain	0.025	0.026	0.030	0.019	0.015	0.011	0.027	0.017	0.019
Correlation France	0.082	0.058	0.059	0.052	0.053	0.039	0.043	0.042	0.043

	Town with 5k+ people in 1600	Town with 5k+ people in 1700	Town with 10k+ people in 1700	Town with 5k+ people in 1800	Town with 10k+ people in 1800	Town with 10k+ people in 2012	Town with 20k+ people in 2012	Town with 50k+ people in 2012	Town with 100k+ people in 2012
Roman town	0.365	0.432	0.249	0.564	0.352	0.542	0.504	0.298	0.169
	(0.037)	(0.040)	(0.031)	(0.033)	(0.038)	(0.037)	(0.039)	(0.038)	(0.029)
Britain	-0.000	-0.001	0.001	0.016	0.013	0.2	0.135	0.065	0.024
	(0.003)	(0.004)	(0.002)	(0.007)	(0.005)	(0.026)	(0.023)	(0.012)	(0.004)
Roman town	-0.248	-0.292	-0.191	-0.364	-0.23	-0.249	-0.234	-0.107	-0.076
x Britain	(0.062)	(0.055)	(0.041)	(0.052)	(0.051)	(0.070)	(0.075)	(0.060)	(0.047)
Intercept	0.018	0.023	0.009	0.04	0.013	0.074	0.041	0.013	0.005
	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)	(0.009)	(0.006)	(0.002)	(0.001)
Ratio Britain	7.53	7.42	7.01	4.55	5.62	2.07	2.54	3.44	4.15
Ratio France	21.17	19.69	29.47	15.00	28.06	8.28	13.42	23.83	33.83
Ratio Britain/France	0.36	0.38	0.24	0.30	0.20	0.25	0.19	0.14	0.12
p-value[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Correlation Britain	0.020	0.021	0.013	0.019	0.017	0.015	0.016	0.016	0.012
Correlation France	0.048	0.050	0.046	0.050	0.054	0.036	0.044	0.046	0.041

Notes: The number of observations is 697,198. Robust standard errors are clustered to account for spatial correlation. "Ratio Britain" and "Ratio France" measure urban persistence using the displayed regression coefficients, as explained in the text.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Table 3. Location of Roman and later towns

	Later town:							
Dependent variable: Roman town (baseline) or later town	Town with 1k+ people in 1086-1200		Town with 5k+ people in 1200		One of largest 50 towns in 1377-1400		Town with 5k+ people in 1700	
Coastal access measure:	I	II	I	II	I	II	I	II
Roman period	0.00023	0.00019	0.00023	0.00019	0.00023	0.00019	0.00023	0.00019
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Roman period x Britain	0.00017	0.00019	0.00017	0.00019	0.00017	0.00019	0.00017	0.00019
	(0.00008)	(0.00008)	(0.00008)	(0.00008)	(0.00008)	(0.00008)	(0.00008)	(0.00008)
Roman period x Coastal access	0.00071	0.00051	0.00071	0.00051	0.00071	0.00051	0.00071	0.00051
	(0.00014)	(0.00008)	(0.00014)	(0.00008)	(0.00014)	(0.00008)	(0.00014)	(0.00008)
Roman period x Britain x Coastal access	-0.00028	-0.00018	-0.00028	-0.00018	-0.00028	-0.00018	-0.00028	-0.00018
	(0.00018)	(0.00012)	(0.00018)	(0.00012)	(0.00018)	(0.00012)	(0.00018)	(0.00012)
Later period	0.00011	0.00009	0.00008	0.00006	0.00006	0.00005	0.00022	0.00019
	(0.00002)	(0.00002)	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00002)	(0.00002)
Later period x Britain	0.00003	0.00002	-0.00005	-0.00003	0.0001	0.00007	-0.00009	-0.00008
	(0.00004)	(0.00005)	(0.00002)	(0.00002)	(0.00003)	(0.00003)	(0.00005)	(0.00004)
Later period x Coastal access	0.0004	0.0003	0.00031	0.00023	0.0003	0.0002	0.00082	0.00054
	(0.00009)	(0.00005)	(0.00007)	(0.00004)	(0.00007)	(0.00004)	(0.00013)	(0.00008)
Later period x Britain x Coastal access	0.00033	0.00031	-0.00001	-0.00003	0.00041	0.00044	-0.00016	0.00001
	(0.00016)	(0.00011)	(0.00011)	(0.00007)	(0.00014)	(0.00011)	(0.00018)	(0.00012)
Coastal access effects in Britain:								
on Roman towns (=C1)	2.08	1.87	2.08	1.87	2.08	1.87	2.08	1.87
on later towns (=C2)	6.09	6.3	12.18	7.49	5.41	6.64	5.89	6.36
Change in effect: C2/C1-1	1.93	2.37	4.86	3.01	1.6	2.55	1.83	2.4
Test H0:C2/C1≤1 vs. H1:C2/C1>1, p-value:	0.011	0.026	0.059	0.076	0.002	0.003	0.027	0.042
Coastal access effects in France:								
on Roman towns (=C3)	4.10	3.71	4.10	3.71	4.10	3.71	4.10	3.71
on later towns (=C4)	4.55	4.32	4.92	4.84	6.04	5.24	4.71	3.89
Change in effect: C4/C3-1	0.11	0.16	0.20	0.30	0.47	0.41	0.15	0.05
Test H0:C4/C3≤1 vs. H1:C4/C3>1, p-value:	0.333	0.263	0.236	0.102	0.0983	0.122	0.234	0.39
Differential change, Britain minus France: (C2/C1)-(C4/C3)	1.82	2.21	4.66	2.71	1.13	2.14	1.68	2.35
Test H0:(C2/C1)-(C4/C3)≤0 vs. H1:(C2/C1)-(C4/C3)>0, p-value:	0.029	0.029	0.059	0.088	0.072	0.009	0.07	0.057

Notes: The number of observations is 1,394,396, since the dataset is composed of two cross-sections with 697,198 observations each. Robust standard errors are clustered to account for spatial correlation. Coastal access measure I: within 5km of the coast or of a major navigable river which leads to the coast. Coastal access measure II: within 5km of the coast or of any navigable river which leads to the coast.

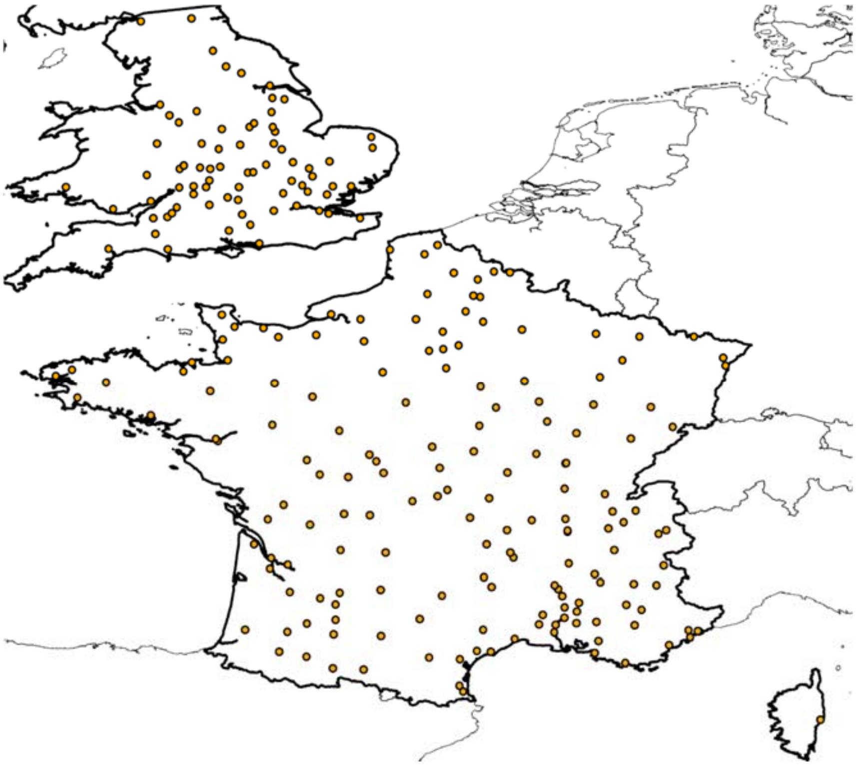
Table 4. Coastal access and the growth of towns with 5,000 people or more in 1200

Sample:	Britain and France	Britain and France	Britain and France	Britain and France	Britain and France	Britain and France, only areas ≤25km of coast or navigable river	Britain and France, only Britannia, Belgica, and Lugdunensis	Northwestern Europe, all Roman provinces	Britain and France
Dependent variable is population growth from:	1200-1800	1200-1800	1200-1800	1200-1700	1200-2012	1200-1800	1200-1800	1200-1800	1200-1800
A. Coastal access measure I									
Coastal access	0.600	0.631	0.614	0.424	0.312	0.595	0.542	0.616	0.505
	(0.177)	(0.171)	(0.170)	(0.173)	(0.224)	(0.248)	(0.282)	(0.156)	(0.185)
ln(population in 1200)		-0.202	-0.195	-0.108	-0.222	-0.179	-0.176	-0.251	-0.173
		(0.140)	(0.150)	(0.157)	(0.188)	(0.196)	(0.289)	(0.120)	(0.151)
Britain			0.0618	0.145	0.629	0.105	0.176	0.0491	-0.467
			(0.297)	(0.289)	(0.338)	(0.373)	(0.436)	(0.287)	(0.308)
Coastal access x Britain									0.726
									(0.484)
Observations	77	77	77	72	74	50	41	119	77
B. Coastal access measure II									
Coastal access	0.551	0.611	0.577	0.424	0.349	0.642	0.67	0.538	0.464
	(0.165)	(0.153)	(0.155)	(0.159)	(0.201)	(0.189)	(0.251)	(0.138)	(0.165)
ln(population in 1200)		-0.229	-0.209	-0.116	-0.232	-0.199	-0.124	-0.264	-0.183
		(0.151)	(0.158)	(0.161)	(0.191)	(0.173)	(0.273)	(0.124)	(0.158)
Britain			0.195	0.236	0.687	0.247	0.313	0.156	-0.385
			(0.293)	(0.281)	(0.320)	(0.318)	(0.389)	(0.286)	(0.311)
Coastal access x Britain									0.765
									(0.480)
Observations	77	77	77	72	74	65	41	119	77

Notes: Robust standard errors are clustered to account for spatial correlation. Coastal access measure I: within 5km of the coast or of a major navigable river which leads to the coast. Coastal access measure II: within 5km of the coast or of any navigable river which leads to the coast.

Figure 1

Panel A: Roman Baseline Towns (●)



Panel B: Roman Baseline Towns (●) and Medieval Bishoprics and Archbishoprics, (8th and 9th century, ●)

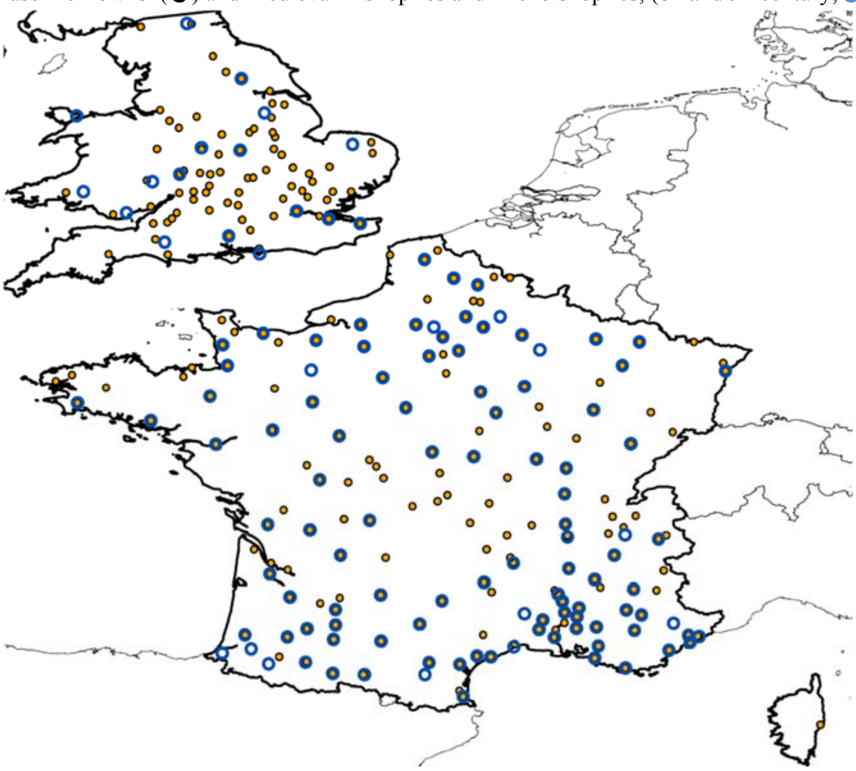
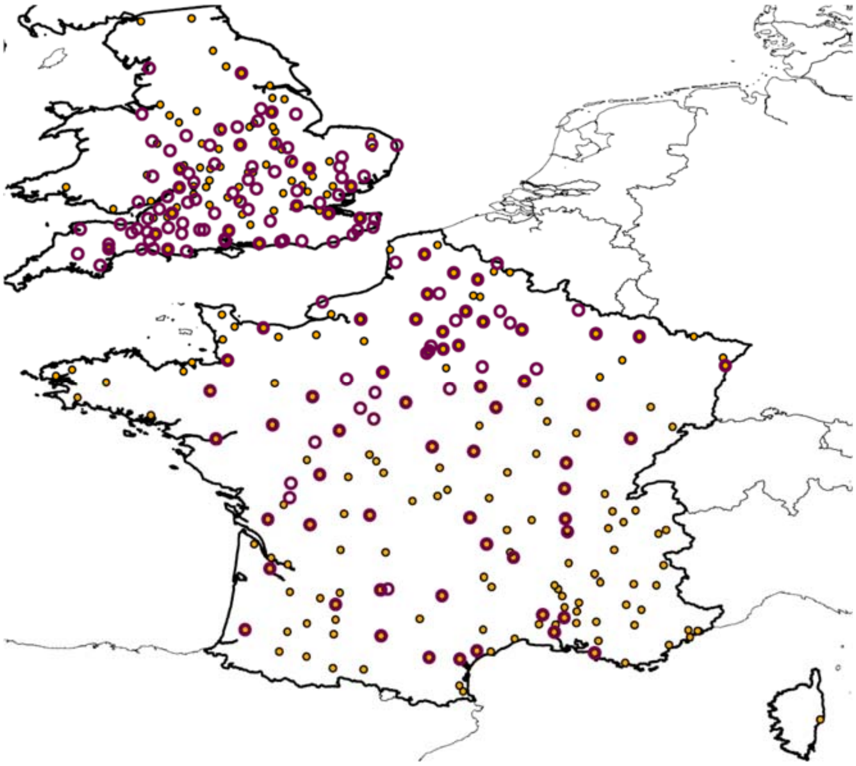


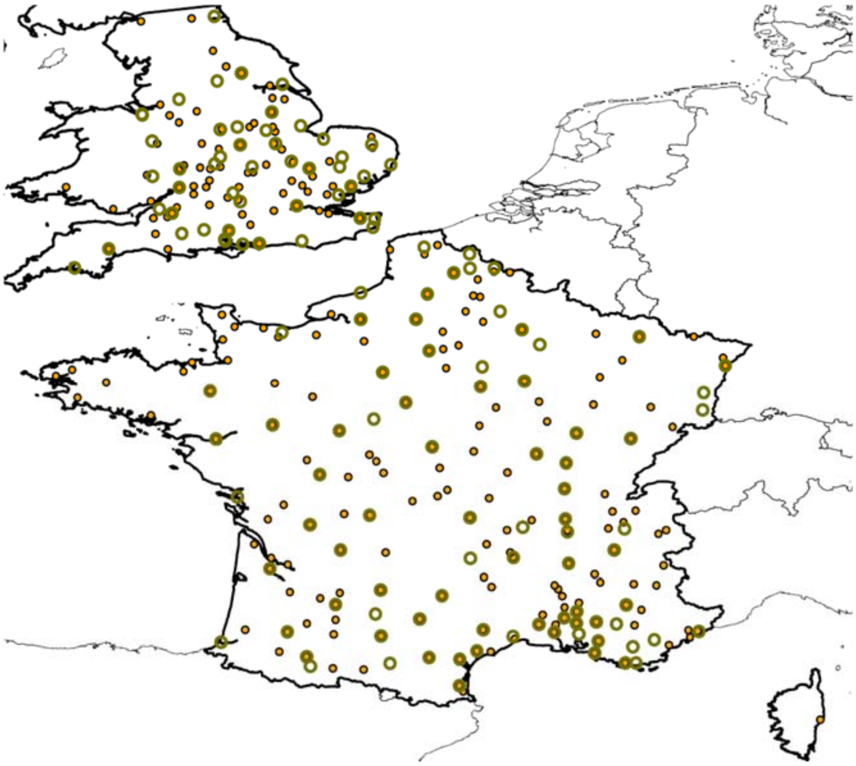
Figure continues overleaf

Figure 1 continued

Panel C: Roman Baseline Towns (●) and Medieval Mints (768-1066, ○)



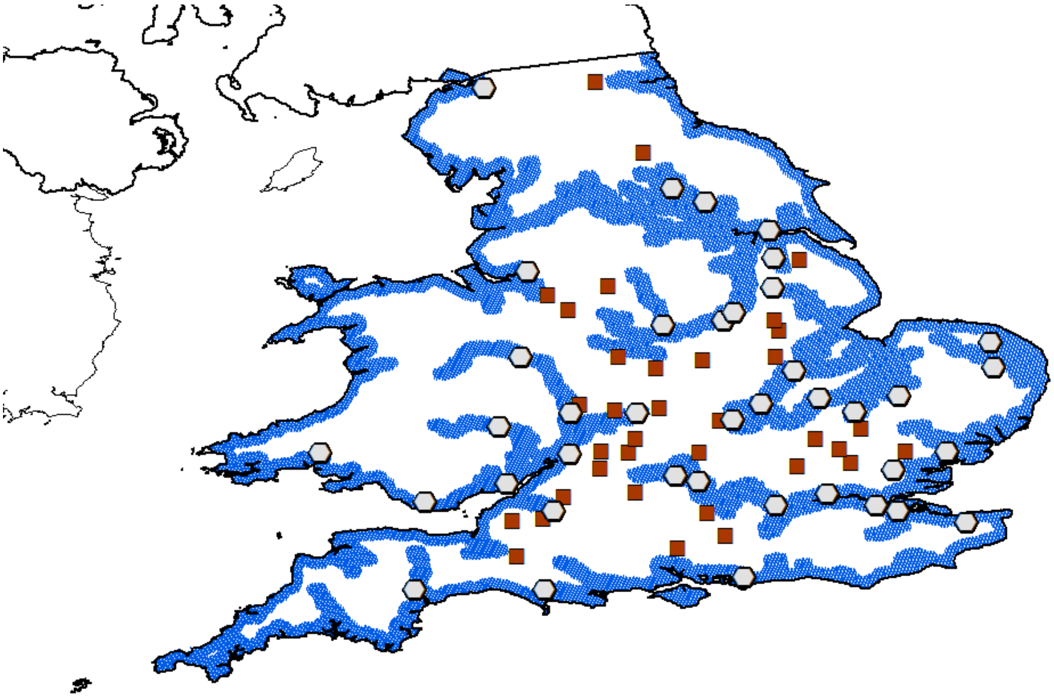
Panel D: Roman Baseline Towns (●) and Medieval Towns (1086-1200, ○)



Notes: The maps show the location of all the Roman Baseline Towns in our dataset and the location of later towns as specified in each panel for the Roman parts of Britain and France. See the data section for sources and definitions of towns.

Figure 2–Towns within and without 5km of navigable rivers and coasts in Britain

Panel A: Roman Baseline Towns



Panel B: Medieval Towns (1086-1200)

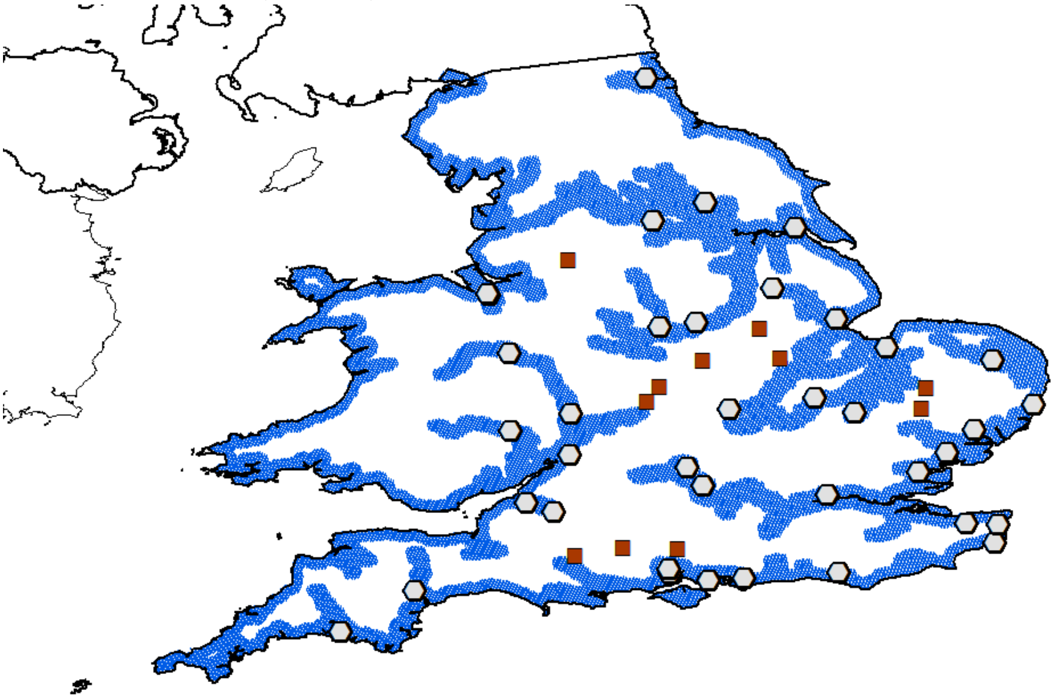
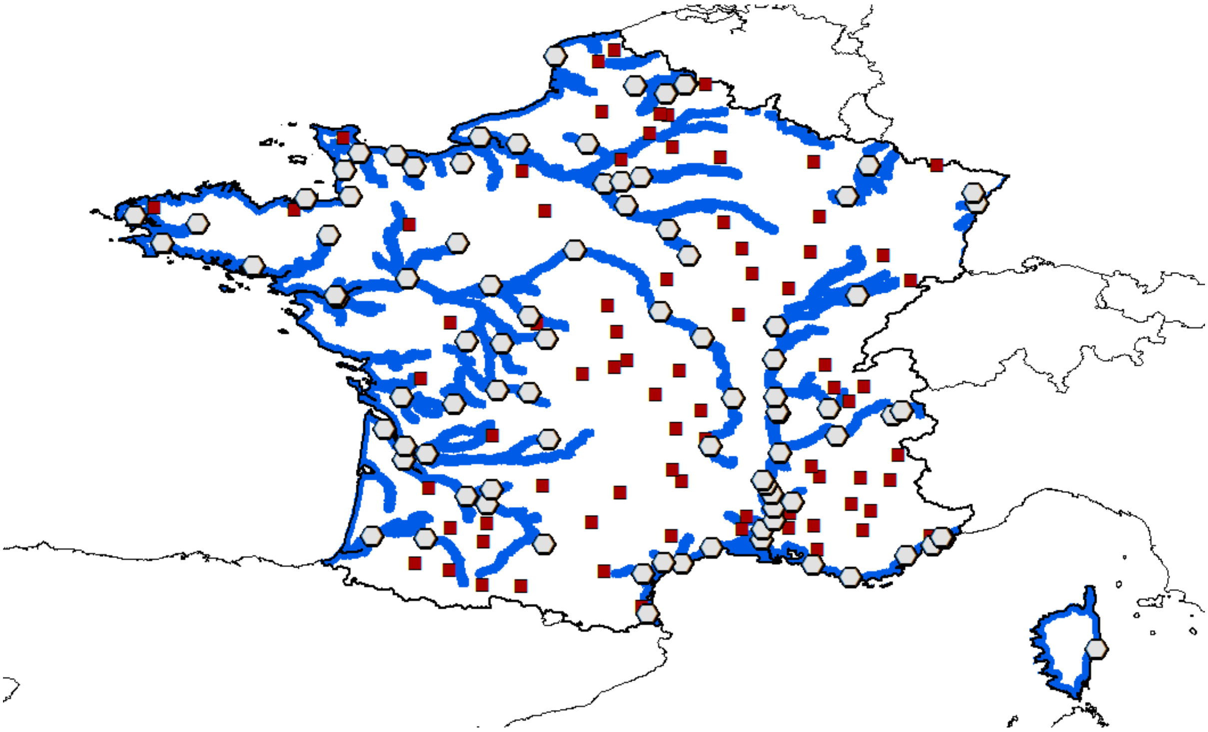


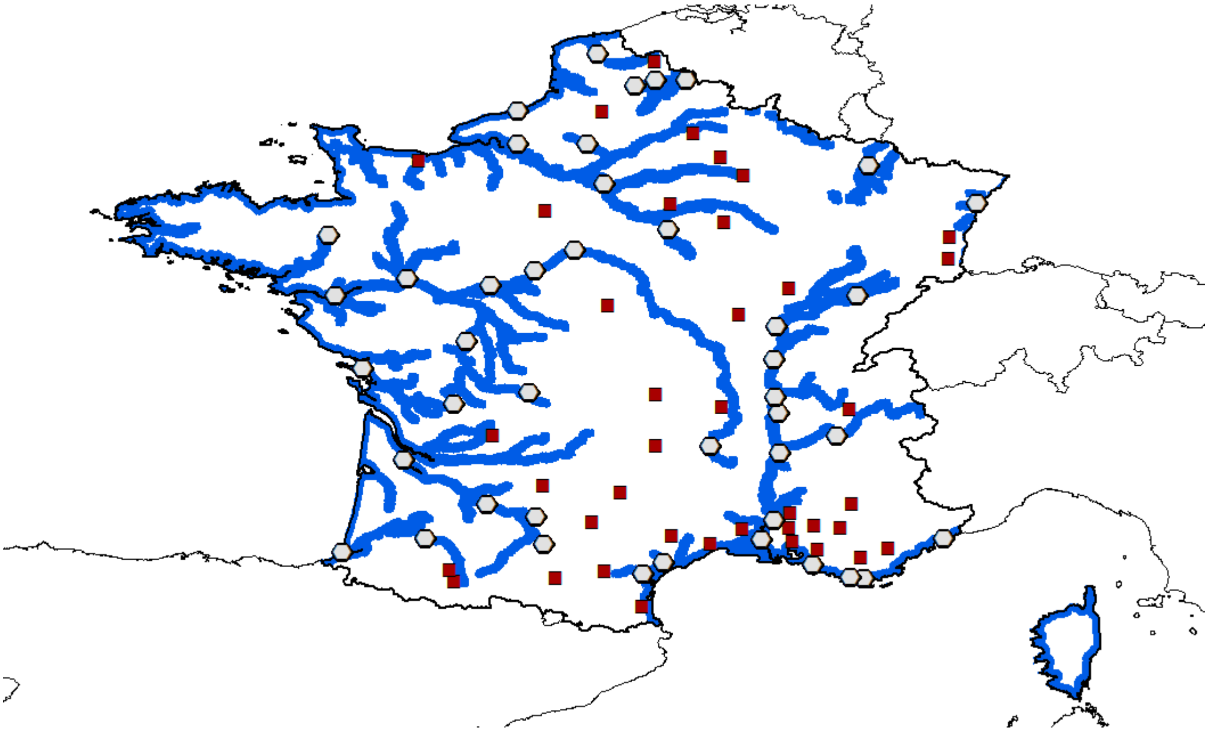
Figure continues overleaf

Figure 2 continued

Panel C: Roman Baseline Towns



Panel D: Medieval Towns (1086-1200)



Notes: The figures show towns that are or are not within 5km of the coast or navigable rivers (by the "Coastal access II" measure) for the Roman part of Britain and France for different years as indicated in the panel titles. The areas with navigable access are highlighted in blue.

Online Appendix for "Resetting the Urban Network: 117-2012"

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This is an online appendix for our paper "Resetting the Urban Network: 117-2012", and it contains three sections. First, Appendix A presents a simple model that explains how a town may become trapped in a bad location as result of historical accident. Second, Appendix B discusses in detail how we constructed our dataset. Finally, Appendix C examines a possible explanation for why France's towns survived in Roman era locations during the fifth and sixth centuries.

Appendix A. Model of Town Location

To frame our empirical analysis we construct a simple infinite-horizon discrete-time model of urban location. We assume that there is a population of measure one of identical, infinitely lived people. Each person maximizes the expected present discounted value of their consumption:

$$U_t = E\left[\sum_{s=0}^{\infty} \beta^t u\left(c_{t+s}\right)\right], \tag{8}$$

where the period utility function $u\left(c_t\right)$ is strictly increasing in consumption, c_t, and $\beta \in (0,1)$ is the discount factor.

People may live in one of two locations, which are indexed by $i \in \{1,2\}$.[1] The contribution of locational fundamentals to productivity in location i is $\theta_i \in \{0, \theta_F\}$. We assume that the two locations differ in their productivity ($\theta_1 \neq \theta_2$), and that in the first period $\theta_1 = \theta_F$ and $\theta_2 = 0$. In each subsequent period there is a probability $p_F \geq 0$ that the locational advantage changes, because either the fundamentals themselves change, or their productivity changes, or both.[2]

We call a location where a positive mass of people work a town, and we assume that working in a town provides an (additive) productivity adjustment θ_T, over and above that of the locational fundamentals.[3] If agglomeration forces make towns more productive then we expect that $\theta_T > 0$,

[1] Our model can be thought of as reflecting the choice of urban location within a given geographical region, which may be considerably smaller than a country. We assume only two locations for analytical tractability. In reality, of course, there may be many more, and the model can be extended to capture this, but without much gain in our economic intuition.

[2] In our model locational fundamentals affect only productivity, and do not affect utility directly. It would, however, be straightforward to add a difference in the utility of living in the two locations.

[3] Sunk investments may also increase productivity in an existing town location, and make path-dependence more likely. For a discussion of the consequences of durable housing in declining cities see Glaeser and Gyourko (2005). Modelling interdependence between towns in an urban network could similarly make path dependence more likely, since a town with poor first nature fundamentals may be complementary to an existent urban network. To keep the model simple and tractable, we do not include multiple towns or sunk costs in our model.

but our model also allows for cases where θ_T is zero or even negative, as long as $\theta_T + \theta_F \geq 0$.[4]

Since we are interested in cases where towns fail, we allow for an exogenous probability $p_T \in (0, 1)$ that a town ceases to function for one period. During that period, worker productivity is determined solely by locational fundamentals, and in the subsequent period a town re-emerges in the location with more productive locational fundamentals.

We assume that the sequence of events within each period is as follows. First, each person costlessly chooses their location, taking current town location as given.[5] Second, each person inelastically supplies one unit of labour, receives the output that they produce, and consumes it. Third, nature determines locational advantage for the next period, with locational advantage changing with probability p_F. Finally, with probability p_T the town is disrupted for one period.

Equilibrium

In equilibrium, if a town is located in the more productive location, or if there is no town, the entire population flocks to the more productive location. If a town exists in the less productive location, each person still chooses to locate in the most productive location, which may be the location with more productive fundamentals if $\theta_F \geq \theta_T$ or the one with less productive fundamentals if $\theta_F < \theta_T$.[6]

This result allows us to characterize the model's equilibrium using three exhaustive and mutually exclusive scenarios, each of which corresponds to a set of parameter values. Scenario 1, which we call "Fixed locational advantage", corresponds to the case where $p_F = 0$. In this scenario location 1 is always more productive, and when a town is disrupted it always reemerges in that location. This scenario may be applicable to a rocky island with a limited area suitable for a town, or to an inhospitable desert bordering on a narrow coastal area which is more habitable.

Scenario 2, which we call "Changing locational advantage with stronger fundamentals", corresponds to the case where $p_F > 0$ and $\theta_F \geq \theta_T$. In this case, locational fundamentals (or their value) may change over time, and they are more important for productivity than being in a town. Therefore, the town always locates in the more productive location, which changes over time. When locational fundamentals (or their value) change, the town simply moves to the more productive location. This scenario may describe a situation where initially a town is more productive inland, where it can serve a larger agricultural hinterland; but later it is more productive on the coast, where trade costs are lower. In this scenario, the town relocates to the coast.

Finally, Scenario 3, which we call "Changing locational advantage with stronger towns", corresponds to the case where $p_F > 0$ and $\theta_F < \theta_T$. In this case locational fundamentals or their value

[4]Our formulation implicitly allows for increasing returns ($\theta_T > 0$), constant returns ($\theta_T = 0$), or decreasing returns ($\theta_T < 0$) in towns. If returns are strongly decreasing such that $\theta_T + \theta_F < 0$, however, the model has no equilibrium. We could write a more general model where in this case employment all concentrates in a non-urban sector, which is presently unmodeled. But this would complicate the framework without yielding additional interesting testable predictions, so we have opted to keep the model leaner.

[5]If people can coordinate then they can all relocate to a better location whenever an opportunity arises. But coordination is often difficult to achieve an in practice people often take the status quo locations as given.

[6]We assume that in case of indifference people prefer the location with better fundamentals. Since people in the model are identical and move costlessly, they all co-locate in every period.

change, but the productivity advantage of being in a town is larger than that conferred by locational fundamentals. In this scenario, even if locational fundamentals change, the town will remain where it was. A town only relocates if it exogenously ceases to function, in which it reemerges the following period in the location that is then more productive.

In this scenario, a town may become "trapped" in a suboptimal location due to past decisions, which we refer to as "path dependence". Specifically, the utility from working in a town in the more productive location:

$$U_H = (\theta_F + \theta_T) + \beta \left\{ \begin{array}{c} (1-p_F)(1-p_T)U_H + (1-p_F)p_T(\theta_F + \beta U_H) + \\ p_F(1-p_T)(\theta_T + \beta U_L) + p_F p_T(\theta_F + \beta U_H) \end{array} \right\}$$

The utility from working in a town in the less productive location:

$$U_L = \theta_T + \beta \left\{ \begin{array}{c} (1-p_F)(1-p_T)U_L + (1-p_F)p_T(\theta_F + \beta U_H) + \\ p_F(1-p_T)(\theta_T + \theta_F + \beta U_H) + p_F p_T(\theta_F + \beta U_H) \end{array} \right\}$$

The difference in utility between locations is:

$$\Delta \equiv U_H - U_L = \theta_F + \beta \left\{ (1-p_F)(1-p_T)(U_H - U_L) - p_F(1-p_T)(\theta_F + \beta(U_H - U_L)) \right\},$$

which simplifies to:

$$\Delta = \theta_F + \beta(1-p_F)(1-p_T)\Delta - \beta p_F(1-p_T)(\theta_F + \beta\Delta),$$

which in turn simplifies to:

$$\Delta = \theta_F \left\{1 - \beta p_F(1-p_T)\right\} / \left\{1 - \beta(1-p_F)(1-p_T) + \beta^2 p_F(1-p_T)\right\} > 0.$$

This last expression implies that a central planner would have moved the town to the more productive location. Of course, this assumes that the (unmodeled) cost of moving a town is not too large.

We now distinguish between two variants of the third Scenario. In Scenario 3A, $\theta_F \approx 0$, so locational fundamentals barely affect productivity, and path dependence is inconsequential. In other words, a town may be "trapped" in an unfavourable location, but this location is so similar to the optimal location that this is of little consequence. One example of this scenario is a flat plain, in which every location is similar to the others. Another example is a flattish terrain with a slow-flowing river, where any locations along this river are similarly productive.

In Scenario 3B, $\theta_F \gtrapprox 0$, so locational fundamentals significantly affect productivity, and path dependence is consequential. This means that towns can get trapped in suboptimal locations. For example, consider the situation described above in the second scenario, where the coast becomes more productive, but the existing town is located inland. In Scenario 3B, as long as the town remains intact, it will not move to the coast.

The framework we outline is intentionally simple, but we can still relate some of the existing evidence on the locations of towns over time to the scenarios above. For example, Davis and Weinstein (2002) find high persistence in the location of economic activity over time in Japan, which corresponds to Scenario 1. Acemoglu, Johnson, Robinson (2005) show that Atlantic ports grow faster after the discovery of the new world, which may be interpreted as consistent with Scenario 2. Redding, Sturm, and Wolf (2011) and Bleakley and Lin (2012) both find evidence for path dependence, but their work suggests that the locations in which economic activity ended up concentrating are not significantly inferior to others, which is broadly consistent with Scenario 3A. Evidence for consequential path dependence, as in Scenario 3B, is rare, and typically comes from settings involving technology selection, rather than from economic geography (see for example David 1985).

Testable implications

Appendix Table A13 summarizes the parameter value combinations, theoretical implications and empirical implications of the different scenarios outlined above. The model is deliberately simple and stylized, and parameter values may vary across towns within each country, but we can draw some distinctions between the predictions of the different scenarios. If Scenario 1 is empirically relevant, then we expect a high persistence of town locations relative to their Roman counterparts in both France and Britain, because locational fundamentals pin towns to a fixed set of locations. If Scenario 2 is relevant, then we expect a lower persistence of town locations in both countries, because the changing value of fundamentals from the Roman to the medieval eras makes towns relocate to more favourable sites, regardless of whether the urban network was hit by a calamity. If Scenario 3 is relevant, however, then we expect higher persistence of locations relative to their Roman counterparts in France than in Britain. This is because the calamity that wiped out Britain's urban network allowed it to move to more favourable sites, while France's urban network is largely fixed to its Roman locations.

Another empirical prediction shared by Scenarios 1, 2, and 3A is that the improvement in suitability of locations from the Roman to the medieval eras (as judged by medieval economic conditions) should have been similar in Britain and France, although for different reasons. In Scenario 1 this is because a fixed set of locations is optimal for both eras. In Scenario 2 it is because the set of optimal locations changes, but towns everywhere follow. And in Scenario 3A it is because the best locations and the next-best locations are similarly suitable. In contrast, in Scenario 3B, Britain's towns will have relocated to sites that are more favourable given the prevailing medieval conditions, while in France there would not be much change in the suitability of locations from the Roman to the medieval eras.

Appendix B. Data Description

This data appendix contains a detailed description of our data construction process. To ensure that it is self-contained, this appendix includes explanations that are provided in the main text as well as additional details.

We construct our dataset around a grid of points, which allows us to consider all potential locations for towns within the areas we analyse. The small size of the squares of our grid, each covering an area of one square kilometre, enables us to differentiate locations that are close by and yet differ in their fundamentals or in their urban histories. Further reducing the size of the grid would not have substantially improved accuracy, since town location cannot be meaningfully measured with higher precision. And from a practical standpoint, our chosen grid size is computationally manageable. In our empirical analysis, we typically allow for 5km bands around locations, to account for possible measurement error.

Using Geographic Information System (GIS), we begin with a grid that covers the entire land area of the Roman Empire at the time of its greatest extent, around the death of Emperor Trajan in 117CE.[7] At the time the Roman Empire had a land area of about 5 million square kilometres (Taagepera 1979). The Roman Empire spanned the area around the Mediterranean (North Africa, the Levant, and southern Europe) and stretched as far north as the Danube and the Rhine, and in some cases (as in present-day Romania and Britain) even further. We focus most of our analysis on Britain and France, which had similar histories during the Roman and Norman eras.[8] This leaves us with a dataset of 697,198 grid points. In some of our robustness checks we also use data on all the northwestern provinces of the Roman Empire, which presently lie within the United Kingdom, France, Belgium, Luxembourg, Netherlands, Germany, and Switzerland.[9]

To this grid we add, using GIS, data on a number of locational fundamentals. These include a measure of elevation in meters using a 3x3km grid of elevation (ESRI 2010). We compute the elevation of each of our grid points using inverse distance weighted interpolation (IDW), a technique that computes local averages of elevation for points with unknown elevation using points with known elevation, giving smaller weight to input grid points further away. Thus every elevation point of the input map influences the local average that we compute, but the more distant points carry less weight in the computation. The power function that determines the weights is computed endoge-

[7] Data on the boundaries of the Roman Empire and its partition into provinces are from the Digital Atlas of Roman and Medieval Civilization (McCormick et al. 2013). The shapefiles with the location of the land and coastlines, and of present-day countries, are from the Economic and Social Research Institute (2010).

[8] We analyse Britain as far north as Hadrian's Wall, since Roman occupation north of that line was tenuous and did not lead to lasting urbanization. In both Britain and France we include proximate islands in Europe if they are either large enough (at least 1,000 square kilometres) or close enough (within 10km) to their respective mainlands. Thus in Britain we include two nearby islands (Isle of Wight and Anglesey) but not those further away (e.g. Isles of Scilly, Isle of Man, and the Channel Islands) or further north than Hadrian's Wall (e.g. Hebrides and the island groups of Orkney and Shetland). Although Corsica is further from France, we do include it in our data, since it is considerably larger than the other islands.

[9] We use modern country border shapefiles from Eurostat (2013). We do not analyse Italy, which lay at the heart of the Roman Empire and was therefore more heavily urbanized, and Spain and North Africa, whose subsequent histories differed due to the Muslim conquest.

nously in GIS by minimizing the root mean square prediction error. This is the standard technique for solving this type of problem, and its application to estimate elevation for unknown points from known points is explicitly given in the GIS help files. In coastal areas our calculation sometimes results in negative elevation numbers, since the Global GIS datasets records the elevation of the ocean floor; in these cases we convert negative elevation values to zero elevation.

Using this measure of elevation and our grid points, we compute a measure of ruggedness, following Nunn and Puga (2012) and Riley et al. (1999). Let $e_{r,c}$ denote elevation at a grid point located in row r and column c of a grid of elevation points. Then the ruggedness is computed as $\sqrt{\sum_{i=r-1}^{r+1}\sum_{j=c-1}^{c+1}(e_{i,j}-e_{r,c})^2}$. This measure considers squared deviations of elevations for each point with respect to the eight points that immediately surround it.[10]

We also calculate the closest distance from each grid point to the coast (using ESRI 2010) and to the nearest navigable river (using Historical GIS for European Integration Studies 2013). We use two different definitions of navigable rivers: the first covers rivers classified as "Commercial International", "Commercial Regional or National", and those suitable for "Large Motor Yacht" or "Cabin Cruisers"; the second covers all navigable rivers, adding to those above rivers accessible only to "Open Boats".[11] We also compute measures of distance to each of the two types of navigable rivers where we manually restrict the shapefiles of these rivers to those that flow into the ocean or a sea. The river maps we obtain are not GIS shapefiles, but images that we digitize. We georeference these images, and transform them into shapefiles using colour recognition features in GIS. This process has some limitations: (i) Rivers digitized that way from images tend to be wider than in reality. (ii) In a few instances the software misclassifies borders or names as rivers, and we corrected these mistakes manually. (iii) Georeferencing results in some imprecision, which we believe, however, to be minor. Based on these measures we use Stata to construct indicators for each grid point for whether it is within 5km of: (a) the coast or a (narrowly defined) navigable river, which flows into the ocean or a sea ("Coastal access I"); or (b) the coast or a navigable river (broadly defined), which flows into the ocean or a sea ("Coastal access II").

Having discussed the measurement of the terrain, we now move on to the human aspects of geography. Our main source of data on modern towns (including cities) is the World Gazetteer (2012), which compiles population data from official national statistical agencies.[12] Based on these official data the website provides an estimate of each town's 2012 population. We focus our analysis of modern towns on those with estimated populations of 10,000 or more in 2012. For the vast majority of towns, the World Gazetteer also provides the coordinates of each town, typically quite close to its

[10]Where a grid point falls at the edge of a map and some of its neighbours are missing, we assume the elevations in these missing locations to be zero.

[11]We acknowledge that the shapes of some rivers have changed since the Middle Ages (or the Roman era for that matter), but accounting for changes in navigability is difficult in practice. For example, see debates discussed in Blair (2007) regarding the extent of navigability of British rivers in the early and late Middle Ages. We therefore use present-day navigability to proxy for historical navigability.

[12]For example, the site contains 1,000 such units in the United Kingdom and 1,000 in France. The smallest of the towns in each of the countries we use (listed above) are estimated to have had fewer than 10,000 people in 2012.

centre.[13] We use these coordinates to assign each town to the grid point that is closest to it.[14] To avoid the inclusion of towns that lie outside the grid, we restrict the match to towns that are within a distance of 1km from the grid point that they are matched with. Because of minor mismeasurement problems in our data, some coastal towns appear to be further away than 1km from their nearest grid point. This problem pertains to 19 towns in Britain, 2 in Belgium and 15 in France. In these cases, we manually match these towns to the nearest grid point to ensure that our data spans all the modern towns in the area we analyse. Finally, in four cases, towns appeared just across national borders from their actual countries, and in these cases we corrected the country identifier of each town.

The resulting dataset with modern towns (and their names and locations) provides the basis for matching into the grid the locations of earlier towns and sites, most of which are only identified by name and locality (typically from maps). The combination of name and locality allows us to match most of our historical data. Where no matches were possible, we used other sources, including the Getty Thesaurus of Geographic Names (Getty 2013), a gazetteer that includes many antique and old spelling versions of many town names. For locations that we still cannot match, we turn to Bairoch et al. (1988), which includes coordinates of the towns it lists.[15] We also use the Ordnance Survey Historical Map Roman Britain (2011) and the Catholic Encyclopedia (1907), which contain useful information on old places in Europe. We track the few remaining units that do not show up in any of these sources using a general search on the internet. After obtaining coordinates for these towns we create a map for each of these data sources and merge that map with our 1km grid using GIS software.

In reconstructing the historical populations of towns we use (like many researchers before us) the estimates provided by Bairoch et al. (1988). Unfortunately, this source covers French towns from 800CE and Britain towns only from 1000CE, so to look further back in time we required other sources of data.[16] In tracing the origins of western European urbanization back into the first millennium, we tried to balance a number of criteria. First, we wanted measures that capture the spatial concentrations of economic activity, which typically characterize towns. Second, we sought where possible to obtain estimates made in recent years, reflecting knowledge that has been built up by historians and archaeologists. Third, we looked for town definitions that were as comparable as possible for the areas that make up present-day Britain and France. Fourth, when considering post-Roman urbanization in particular, we searched for measures of urbanization dating back as early as possible in the medieval era, even if in some cases the locations can only be thought of as proto-towns, rather

[13] We cross-checked a sample of the coordinates against Google Maps website and typically the coordinates were within fewer than 5km of each other, although towns are clearly not points and some measurement error is unavoidable. In cases where coordinates were missing from the World Gazetteer, we added them in manually using additional sources listed below.

[14] In four cases a single grid point is matched to more than one town, in which case we select the largest matched town, as ranked by population. We thus lose Vosselaar due to its proximity to Beerse, Bourg-la-Reine because of Sceaux, Saint-Ouen-l'Aumone due to Pontoise and Voisins-le-Bretonneux due to Montigny-le-Bretonneux.

[15] In a few cases we identified inaccuracies with some of the coordinates data in Bairoch et al. (1988), which is why we preferred to rely on the sources above where possible.

[16] Chandler (1987) provides earlier population estimates for some towns, but unfortunately too few in for statistical analysis in present-day Britain and France.

than fully-fledged ones. Finally, wherever possible, we aimed for definitions that covered more than a handful of sites in both Britain and France, in order to facilitate a meaningful statistical analysis, starting with the pre-Roman era.

Some scholars (e.g. Wacher 1978 and Woolf 1998) conclude that pre-Roman northwestern Europe was largely a pre-urban world. Nevertheless, this world, which was largely populated by Celtic tribes, had some settlements with features that we might recognize as urban (or proto-urban), such as the use of coins. To identify the location of these pre-Roman settlements, we use data from Fichtl (2005) on Iron Age *oppida*.[17] This source lists 107 *oppida* in France, but only 11 *oppida* in Britain, so we also use map 3:3 from Jones and Mattingly (1990) to locate other important Iron Age settlements in Britain, which may be viewed as harbingers of British urbanization.[18]

When it comes to measuring Roman-era towns, we face the challenge that different authors define Roman towns differently, and arrive at different lists of towns. To mitigate this problem, we do not rely on just one particular definition a "Roman town", but instead use three different definitions. Our first (baseline) measure is an indicator for Roman towns using classical references: Wacher (1995) for the main towns of Britain, Burnham and Wacher (1990) for the "small towns" of Britain, and Bedon (2001), for Roman towns of various sizes in France.[19] Each of these sources describes every town in considerable detail, using both historical and archaeological records.[20] These sources reveal many similarities between the Roman towns in Britain and France, as one might expect from neighbouring areas within the empire. In particular, larger Roman towns in both Britain and France had civil, commercial, and residential buildings that served a broad range of economic functions, whereas smaller towns typically had a more limited range of buildings, mostly residential and commercial. As Appendix Table A1 shows, our baseline sample includes 74 Roman towns in Britain and 167 Roman towns in France. Panel C of the table also reports separately the number of Roman towns in northern France, defined using the two Trajan provinces of the Roman Empire (Belgica and Lugdunensis). The table also shows that the Roman towns in Britain were quite similar to their counterparts in France in their origins (pre-Roman or Roman) and their coastal access, although towns in France were generally located in higher elevations and in more rugged terrain.[21] Our empirical methodology allows us to control for pre-existing differences in locational fundamentals.

Our second measure of towns uses the size of defended (walled) area of towns. Since precise population estimates for towns are unavailable, there is a long tradition of using walled areas to con-

[17] According to www.oppida.org, which contains a list of oppida similar to Fichtl (2005): "*Oppidum* (plural *oppida*) was the name used by Caesar to describe the Celtic towns that he discovered during his conquest of Gaul. In archaeology, the term is now used to describe all fortified Celtic sites covering a minimum area of 15ha and dating back to the second half of the 2nd and 1st centuries BC (the late La Tène period). These towns were both economic and political centres."

[18] In all but one of the cases, the oppida that Fichtl (2005) reports in Britain are also covered in Jones and Mattingly (1990).

[19] We are grateful to Greg Woolf and Penelope Goodman for advice on these data sources.

[20] Other sources, such as Millet (1990) and Ordnance Survey (2011), contain even longer lists of towns for Roman Britain but with less detail on each than Wacher (1995) and Burnham and Wacher (1990). Tassaux (1994) and Petit et al. (1994) include longer lists of agglomerations in parts of France, but they do not cover the entire country, nor do they provide as much detail as Bedon (2001).

[21] For more details on the origins of the Roman towns, see below.

struct estimates of population, and this methodology is still widely used.[22] We apply a specific cutoff - having at least 5 hectares of walled area - for selecting the larger Roman towns. One advantage of this approach is that it allows us to cover not on Britain and France, but also other parts of northwestern Europe, as we explain below. This approach also has limitations: some Romans lived outside the walls (see Goodman 2007); even within the walls population densities may have differed; and some important Roman towns, especially in France (e.g. Marseille) did not have town walls. Nonetheless, this approach provides a useful complement to our baseline definition of Roman towns. The data we use on the size of walled areas come from recent estimates for Britain (Mattingly 2006), France (Bedon 2001), and the rest of northwestern Europe (Esmonde-Cleary 2003).[23] It is probable that each town with 5 hectares or more of defended area had at least of 500-1000 people (see for example Bowman and Wilson, eds., 2011) and at most tens of thousands of people.[24] The specific size cutoff we apply is due partly to data limitations (Mattingly 2006 does not list smaller towns), but also because coverage of walled areas for smaller towns might not be as complete (see for example Millet 1990 and Bowman and Wilson, eds., 2011). As Table A1 shows, Roman towns with walled areas of 5 hectares or more number 49 in Britain (with an average log walled area in hectares of 2.93) and 82 in France (with an average log walled area in hectares of 2.96), of which 29 are in northern France (with an average log walled area in hectares of 2.78). The similarity of these figures suggests that in terms of their population, the towns of Roman Britain were not too dissimilar from those of France. Moreover, a comparison of the walled areas of Roman towns in Britain and northern France suggests that it is highly improbable that urbanization survived in northern France and not in Britain because Britain's towns were vastly inferior.

Our third definition of Roman towns relies on administrative usage of the Romans themselves. Each Roman administrative towns was classified as either *colonia, municipium* or "*civitas* capital".[25] *Colonia* was originally the name for Roman towns for retired soldiers, and this term was later used for the highest rank of Roman cities in the provinces. *Municipium* was a Roman town with some administrative functions, which was in principal not as prestigious as a colonia. Lastly, a *civitas* capital was a regional administrative town, which often served a particular local tribe. While these definitions had some relevance, they became less important over time, as more people within the Roman Empire became Roman citizens. One drawback of using the administrative definitions, is the imperfect correlation between these definitions and towns' actual size and economic importance. Another limitation is that while a fairly comprehensive list of administrative towns in the late Roman Empire in France - the *Notitia Galliarum* - appears to have survived (see for example Harris 1978), we have no comparable list for Britain. The list of administrative towns that have been identified in

[22] For a recent discussion of this methodology and its applications, see Bowman and Wilson (2011).

[23] We cross-checked a sample of the estimated size of defended areas against earlier estimates, for example by Millet (1990) for Britain and Lot (1945) for France, and found that they were quite similar.

[24] Fleming (2010) argues that the population of Roman London may have reached 30,000, and Bowman and Wilson (2011) estimate that a few Roman-era French towns exceeded 10,000 people.

[25] At the very bottom of the Roman administrative hierarchy were local centers known as *pagi*, but our evidence on the location of *pagi* in Britain is almost nonexistent, so we do not use the *pagi* classification in our analysis.

Britain (even including towns with possible administrative roles) is shorter, and may be incomplete. In total our dataset includes 24 administrative Roman towns in Britain and 110 in France, of which 46 are in northern France, as defined above (we use Mattingly 2006 for Britain and Bedon 2001 for France).

We complement the data on the location of Roman towns using these three definitions with additional information. We use data from Bedon (2001) to identify Roman towns that had bishops in the fourth century.[26] To identify whether the Roman towns had pre-Roman origins, we use Millet (1990) for Britain and again Bedon (2001) for France.[27]

During its post-Roman period, from 450-600CE, Britain had no functional towns (as discussed in Ward-Perkins 2001, Palliser 2001, Fleming 2010, Mattingly 2006, and Nicholas 1997), while in France many towns survived. From the seventh century onwards, trading settlements known as emporia (or "wics") began to emerge in Britain (Fleming 2010). These emporia had some urban features (and are sometimes described as "proto-urban"), but only few such sites have been identified in Britain, and they have almost no counterpart in France (Quentovic being a rare exception), making a quantitative analysis impractical.

Our first measure of post-Roman urbanization identifies the seats of bishops (including archbishops), known as bishoprics, from 700-900 (Reynolds 1995). From these locations bishops exercised power at a time when the church was central for many aspects of life. The bishops and their followers also produced and consumed various products and services, sustaining a spatial concentration of economic activity (Fleming 2010 and Nicholas 1997). The bishoprics thus provide a window into early post-Roman (proto) urbanization.

Our next measure of (proto) urbanization is more directly related to the location of economic activity in early medieval Europe, namely the minting of coins. While the size and importance of early mints varied considerably, their presence suggests a concentration of local economic activity for a period where good measures of economic activity in both Britain and France are difficult to come by. We use data from Spufford (1988), who describes the location of mints in Carolingian and post-Carolingian France and in pre-Norman Britain (from 768-1066).

The main advantage of using bishoprics and mints is that they allow us to track the early stages of urbanization in Britain and France. For later years, however, we have more direct and conventional measures of urban activity in the form of population estimates. As discussed above, Bairoch et al. (1988), which is a standard reference, reports town population estimates for Britain only from 1000 onwards, and in the first few centuries of the second millennium the number of British towns it covers is very low - only 14 in 1000 and 5 in 1100. In contrast, Holt (2000), when discussing Britain's urban population in 1086, writes that "Estimates of the size of individual towns based on the recorded

[26]We include towns where Bedon specifies that the existence of a fourth-century bishop is uncertain. There is, however, much greater uncertainty on the location of Roman-era bishops in Britain, so we use the Roman bishop identifier for France only.

[27]Note that this measure of pre-Roman origins may include relatively minor settlements, and is therefore different from the measures of main Iron Age settlements described above (which also include Iron Age settlements that did not develop into Roman towns).

number of houses or of tenants (as presented in Appendix 2) must of necessity be cautious, producing minimal figures; even by that reckoning, however, some thirty-six towns had a population greater than 1,000." Given our focus on the location of towns, albeit small, we construct an indicator for towns with 1,000 people or more in Britain or France, using any town with estimated population in this range from Bairoch et al. (1988) for 1000-1200 or Dyer (2000) - the above mentioned appendix, which is based on the Domesday Book.[28] While this approach has its drawbacks (it may for example miss small towns in France if they are excluded from Bairoch et al. 1988) it permits a quantitative analysis of the location of early towns in both Britain and France.

Despite its limitations, Bairoch et al. (1988) is our main source for the population of towns for each century from 1200-1800. Because of the selection problems related to smaller towns, we focus on towns with at least 5,000 inhabitants. Since town populations grew rapidly during the industrial revolution, we use an additional population threshold of 10,000 inhabitants or more for towns in 1800.

Because the medieval era is important for our analysis, we also use Russell (1972) as alternative estimate of town populations circa 1300, before the onset of the Black Death. From Russel's estimates we again construct an indicator for towns with 5,000 people or more, as we do using the estimates of Bairoch et al. (1988) for that period.

For the period following the Black Death we construct an indicator for the 50 most populous towns in Britain and France. This measure takes the largest 50 towns as reported by Bairoch for 1400, and adds the 50 largest town in Britain as measured by the number of taxpayers based on the poll taxes of 1377-1381, as reported in Dyer (2000).[29] While the size of towns included in this measure most likely differs between Britain and France, this measure helps us understand the location of towns up to a fixed threshold in the town size hierarchy.

Finally, to examine individual towns that are locally important, irrespective of their absolute or relative size within a country, we compute arbitrary grid cells of 100 kilometres by 100 kilometres using an equal area projection in GIS. We then compute indicators for the largest towns within each of these cells for each century from 1200-1800 (using Bairoch et al. 1988) and for 2012 (using the World Gazetteer 2012). We also use these same cells to cluster the standard errors in our empirical analysis.

Appendix C. Why France's Urban Network Stayed

We have found that many French towns remained in Roman-era town sites that were suboptimal in terms of their (first nature) locational fundamentals. This result is perhaps unsurprising in periods when towns are highly productive ($\theta_T \gg 0$). But this description is probably ill-suited for the

[28] In Britain we include all towns listed by Dyer (2000) as towns of categories I, II, III and IV. These include 36 towns mentioned in the Domesday Book, plus London and Bristol, which are included in Dyer (2000) despite their omission from the Domesday Book.

[29] Bairoch et al. (1988) list only 21 towns in Britain for that year, including 10 of 5,000 people or more. For France it lists 60 towns, including 38 with 5,000 people or more.

towns in France following the fall of the Western Roman Empire, in the fifth and sixth centuries. To complete the picture and explain why many French towns' location persisted through this difficult period, we examine the possible role of bishops. As Nicholas (1997) and Wickham (2009) discuss, bishops played important roles in town life in France after the fall of the Western Roman Empire. In addition to their religious duties, bishops often also had administrative and political roles. The bishops and their followers also provided services for the surrounding countryside, so towns remained important focal points. Finally, the goods and services consumed by the bishops and their followers meant that towns in France continued to concentrate economic activity even when urbanization reached a nadir after the fall of Rome.

Nicholas (1997), quoted above, suggests that bishops may have instrumental in the survival of towns in France after the fall of the Roman Empire. While the location choice of bishops in the late Roman Empire was potentially endogenous, we examine, at least descriptively, the hypothesis that Roman towns in France with bishops survived better than others. To examine this hypothesis, we estimate regressions as in specification (1), but this time adding as a control an indicator for fourth-century bishoprics in France. The results in Table A14 suggest that Roman-era towns with fourth-century bishops were significantly more likely to have survived throughout the Middle Ages and up until the present-day.

What is perhaps even more interesting, however, is that Roman-era towns in France without fourth-century bishops were quite similar to their counterparts in Britain in terms of their survival rate, at least until the dawn of the Industrial Revolution. In Appendix Tables A15 and A16 we present a set of robustness checks for this result, using different definitions of proximity, Roman towns, areas in continental Europe, and geographic controls. The general picture that emerges is that in the post-Roman era towns in France without a late-Roman bishop displayed fairly low survival rates, which were typically comparable to those in Britain.

Appendix Table A1. Descriptive statistics for Roman and later towns

	(1) Number of towns	(2) Coastal access I	(3) Coastal access II	(4) Coast	(5) Eleva-tion in meters	(6) Rugg-edness	(7) Pre-Roman origin	(8) Iron Age settle-ment	(9) Roman towns with walled area ≥ 5ha	(10) Ln(walled area) in towns with walled area ≥ 5ha
A. Britain										
Roman baseline town	74	0.41	0.50	0.09	77	117	0.38	0.11	38	2.93
Town with 1k+ people, 1086-1200	49	0.67	0.78	0.29	50	96	0.17	0.10	-	-
Town with 5k+ people in 1200	15	0.80	0.80	0.33	41	99	0.20	0.13	-	-
Town with 5k+ people in 1700	44	0.66	0.77	0.27	64	126	0.11	0.05	-	-
B. France										
Roman baseline town	167	0.33	0.51	0.13	251	563	0.37	0.10	58	2.96
Town with 1k+ people, 1086-1200	82	0.35	0.55	0.12	193	566	0.32	0.14	-	-
Town with 5k+ people in 1200	62	0.37	0.58	0.10	185	481	0.35	0.16	-	-
Town with 5k+ people in 1700	169	0.36	0.53	0.13	183	463	0.17	0.09	-	-
C. Northern France: Belgica and Lugdunensis only										
Roman baseline town	63	0.40	0.57	0.10	136	268	0.32	0.16	30	2.78
Town with 1k+ people, 1086-1200	29	0.47	0.69	0.06	103	280	0.31	0.22	-	-
Town with 5k+ people in 1200	26	0.42	0.65	0.04	100	230	0.27	0.19	-	-
Town with 5k+ people in 1700	87	0.43	0.60	0.11	108	220	0.13	0.11	-	-

Notes: Columns (1) and (9) report counts, columns (2), (3), (4), (5), (6), (7), (8), and (10) report means. Coastal access measure I: within 5km of the coast or of a major navigable river which leads to the coast. Coastal access measure II: within 5km of the coast or of any navigable river which leads to the coast. See the text for a description of the dataset and the sources for each of the other variables.

Appendix Table A2. Largest 20 cities in Britain, France and Northern France

Britain		France		Northern France		Britain		France		Northern France	
Ranked by Bairoch 1700 population	5km of Roman town	Ranked by Bairoch 1700 population	5km of Roman town	Ranked by Bairoch 1700 population	5km of Roman town	Ranked by 2012 population	5km of Roman town	Ranked by 2012 population	5km of Roman town	Ranked by 2012 population	5km of Roman town
London	1	Paris	1	Paris	1	London	1	Paris	1	Paris	1
Bristol	0	Lyon	1	Rouen	1	Birmingham	0	Marseille	1	Nantes	1
Norwich	0	Marseille	1	Lille	0	Liverpool	0	Lyon	1	Lille	0
Newcastle	0	Rouen	1	Nantes	1	Leeds	0	Toulouse	1	Rennes	1
Birmingham	0	Lille	0	Versailles	0	Sheffield	0	Nice	1	Reims	1
Liverpool	0	Bordeaux	1	Orleans	1	Manchester	0	Nantes	1	Angers	1
Manchester	0	Nantes	1	Amiens	1	Bristol	0	Strasbourg	1	Le Havre	0
Exeter	1	Versailles	0	Caen	0	Cardiff	0	Lille	0	Amiens	1
Leeds	0	Toulouse	1	Dijon	1	Leicester	1	Montpellier	0	Tours	1
Plymouth	0	Strasbourg	1	Rennes	1	Bradford	0	Bordeaux	1	Dijon	1
Chester	0	Orleans	1	Metz	1	Hull	0	Rennes	1	Le Mans	1
Coventry	0	Amiens	1	Brest	1	Coventry	0	Reims	1	Brest	1
Nottingham	0	Caen	0	Angers	1	Plymouth	0	Angers	1	Orleans	1
Sheffield	0	Montpellier	0	Reims	1	Derby	1	Le Havre	0	Metz	1
York	1	Dijon	1	Nancy	0	Stoke-on-Trent	0	Toulon	1	Rouen	1
Great Yarmouth	0	Rennes	1	Douai	0	Nottingham	0	Saint-Etienne	0	Boulogne	0
Worcester	1	Metz	1	Troyes	1	Wolverhampton	0	Grenoble	1	Argenteuil	0
Sunderland	0	Brest	1	Valenciennes	0	Southampton	0	Aix-en-Provence	1	Saint-Denis	0
Bath	1	Nîmes	1	Abbeville	0	Portsmouth	0	Nîmes	1	Nancy	0
Portsmouth	0	Avignon	1	Arras	1	Dudley	0	Limoges	1	Caen	0

Notes: Top 20 most populated cities ranked by 1700 (left half) and 2012 (right half) populations. Northern France consists of the Roman provinces of Lugdunensis and Belgica. To rank towns with identical 1700 population we use 1600 population. No towns with equal populations to those displayed in a given year are excluded.

Appendix Table A3. Robustness checks for the probability of towns (700-1500) within 5km of Roman towns

	Bishopric or Arch-bishopric 700-900	Coin Mint 768-1066	Town with 1k+ people 1086-1200	Town with 5k+ people in 1200	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	Largest 50 towns 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500
Panel A: Same as baseline, but using 10km radius instead of 5km radius									
Ratio Britain	4.46	2.52	3.27	3.58	2.99	2.63	2.95	3.72	3.13
Ratio France	10.06	8.30	8.09	8.55	10.47	8.28	8.06	7.69	7.43
Ratio Britain / France	0.44	0.30	0.41	0.42	0.29	0.32	0.37	0.48	0.42
p-value[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.001
Panel B: Same as baseline, but using 0km radius instead of 5km radius									
Ratio Britain	1,403	464	744	1,336	1,145	859	633	1,432	1,169
Ratio France	19,712	8,761	7,076	8,696	31,210	8,064	6,377	5,706	4,380
Ratio Britain / France	0.07	0.05	0.11	0.15	0.04	0.11	0.10	0.25	0.27
p-value[1]	0.003	0.000	0.000	0.008	0.043	0.017	0.015	0.054	0.018
Panel C: Same as baseline, but using only Trajan provinces of Britannia, Belgica, and Lugdunensis									
Ratio Britain	13.12	6.52	9.79	10.93	9.78	8.08	8.62	10.93	9.91
Ratio France	42.91	30.73	32.56	30.45	39.92	29.46	28.26	27.27	24.58
Ratio Britain / France	0.31	0.21	0.30	0.36	0.25	0.27	0.31	0.40	0.40
p-value[1]	0.000	0.000	0.002	0.013	0.000	0.008	0.008	0.044	0.014
Panel D: Same as baseline, but using only Roman towns with defended areas of 5ha or more									
Ratio Britain	19.14	10.79	15.68	21.29	19.04	15.74	12.58	21.29	13.77
Ratio France	59.59	61.58	54.24	61.63	76.47	58.58	68.50	65.80	50.39
Ratio Britain / France	0.32	0.18	0.29	0.35	0.25	0.27	0.18	0.32	0.27
p-value[1]	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Panel E: Same as baseline, but using only Roman towns with defended areas of 5ha or more in all Northwest Europe									
Ratio Britain	19.14	10.79	15.68	21.29	19.04	15.74	12.58	21.29	13.77
Ratio France	62.72	59.71	41.84	49.49	60.15	35.23	79.88	38.69	32.62
Ratio Britain / France	0.31	0.18	0.38	0.43	0.32	0.45	0.16	0.55	0.42
p-value[1]	0.000	0.000	0.000	0.003	0.001	0.069	0.000	0.112	0.040
Panel F: Same as baseline, but using only Roman administrative towns									
Ratio Britain	25.23	12.05	17.72	28.07	30.16	24.93	16.59	33.71	21.80
Ratio France	52.59	43.67	42.21	45.18	55.99	44.74	44.21	42.47	35.13
Ratio Britain / France	0.48	0.28	0.42	0.62	0.54	0.56	0.38	0.79	0.62
p-value[1]	0.009	0.000	0.001	0.186	0.075	0.127	0.001	0.530	0.266
Panel G: Same as baseline, but using only Roman towns with pre-Roman origins									
Ratio Britain	21.63	8.60	13.66	14.41	6.44	11.51	9.95	11.52	14.94
Ratio France	43.66	40.86	38.00	44.57	54.92	42.57	42.62	40.94	39.56
Ratio Britain / France	0.50	0.21	0.36	0.32	0.12	0.27	0.23	0.28	0.38
p-value[1]	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005
Panel H: Same as baseline, but with geographic controls and their Britain interactions									
Ratio Britain	9.60	5.27	8.66	11.20	10.49	9.09	8.38	9.50	10.35
Ratio France	56.11	43.24	41.99	44.02	59.56	38.59	30.45	28.47	28.86
Ratio Britain / France	0.17	0.12	0.21	0.25	0.18	0.24	0.28	0.33	0.36
p-value[1]	0.000	0.000	0.000	0.001	0.000	0.011	0.001	0.011	0.010

Notes: The number of observations is 697,198, except in Panel C in which it is 396,228 and in Panel E in which it is 906,076. Robust standard errors are clustered to account for spatial correlation.
[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A4. Robustness checks for the probability of towns (1600-2012) within 5km of Roman towns

	Town with 5k+ people in 1600	Town with 5k+ people in 1700	Town with 10k+ people in 1700	Town with 5k+ people in 1800	Town with 10k+ people in 1800	Town with 10k+ people in 2012	Town with 20k+ people in 2012	Town with 50k+ people in 2012	Town with 100k+ people in 2012
Panel A: Same as baseline, but using 10km radius instead of 5km radius									
Ratio Britain	2.45	2.72	2.79	1.96	2.32	1.39	1.51	1.83	1.74
Ratio France	5.79	5.23	7.60	4.19	7.38	3.20	4.63	7.32	8.99
Ratio Britain / France	0.42	0.52	0.37	0.47	0.31	0.44	0.33	0.25	0.19
p-value[1]	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel B: Same as baseline, but using 0km radius instead of 5km radius									
Ratio Britain	668	590	668	268	321	74	97	184	297
Ratio France	2,738	2,380	5,256	1,529	4,487	365	692	2,160	7,392
Ratio Britain / France	0.24	0.25	0.13	0.18	0.07	0.20	0.14	0.09	0.04
p-value[1]	0.000	0.000	0.001	0.000	0.000	0.007	0.033	0.057	0.024
Panel C: Same as baseline, but using only Trajan provinces of Britannia, Belgica, and Lugdunensis									
Ratio Britain	7.54	7.42	7.01	4.55	5.62	2.07	2.54	3.44	4.15
Ratio France	18.85	18.83	25.83	14.28	27.22	7.20	11.96	21.04	30.34
Ratio Britain / France	0.40	0.39	0.27	0.32	0.21	0.29	0.21	0.16	0.14
p-value[1]	0.007	0.001	0.001	0.000	0.000	0.001	0.004	0.013	0.000
Panel D: Same as baseline, but using only Roman towns with defended areas of 5ha or more									
Ratio Britain	11.73	10.83	10.91	6.07	6.96	2.30	2.70	4.36	6.28
Ratio France	34.20	34.99	57.08	22.20	48.86	12.03	20.77	43.44	70.36
Ratio Britain / France	0.34	0.31	0.19	0.27	0.14	0.19	0.13	0.10	0.09
p-value[1]	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel E: Same as baseline, but using only Roman towns with defended areas of 5ha or more in all Northwest Europe									
Ratio Britain	11.73	10.83	10.91	6.07	6.96	2.30	2.70	4.36	6.28
Ratio France	28.95	28.46	42.45	18.33	38.58	6.46	10.02	21.39	34.75
Ratio Britain / France	0.41	0.38	0.26	0.33	0.18	0.36	0.27	0.20	0.18
p-value[1]	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel F: Same as baseline, but using only Roman administrative towns									
Ratio Britain	16.25	13.33	12.95	8.13	7.87	2.58	2.85	4.77	8.52
Ratio France	27.09	24.76	39.51	18.03	36.28	9.39	16.33	31.98	44.22
Ratio Britain / France	0.60	0.54	0.33	0.45	0.22	0.27	0.17	0.15	0.19
p-value[1]	0.115	0.026	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Panel G: Same as baseline, but using only Roman towns with pre-Roman origins									
Ratio Britain	11.93	9.79	7.40	5.70	8.10	2.47	3.67	4.09	3.65
Ratio France	28.42	22.96	44.14	16.36	37.02	9.30	15.86	31.99	46.91
Ratio Britain / France	0.42	0.43	0.17	0.35	0.22	0.27	0.23	0.13	0.08
p-value[1]	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel H: Same as baseline, but with geographic controls and their Britain interactions									
Ratio Britain	8.08	9.27	8.92	4.11	5.91	1.73	2.06	2.73	3.60
Ratio France	21.64	21.12	37.40	15.70	36.86	8.28	15.09	29.51	48.76
Ratio Britain / France	0.37	0.44	0.24	0.26	0.16	0.21	0.14	0.09	0.07
p-value[1]	0.002	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.002

Notes: The number of observations is 697,198, except in Panel C in which it is 396,228 and in Panel E in which it is 906,076. Robust standard errors are clustered to account for spatial correlation.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France $\neq$ 0

Appendix Table A5. Robustness checks for the probability of towns (1200-2012) within 5km of Roman towns, using the largest town in each cluster

	Largest town in cluster in 1200	Largest town in cluster in 1300	Largest town in cluster in 1400	Largest town in cluster in 1500	Largest town in cluster in 1600	Largest town in cluster in 1700	Largest town in cluster in 1800	Largest town in cluster in 2012
Panel A. Using all of Britain and France								
Ratio Britain	8.59	7.20	8.57	8.05	6.51	7.29	5.92	4.74
Ratio France	35.07	31.64	35.46	30.29	29.71	27.45	29.68	27.39
Ratio Britain / France	0.25	0.23	0.24	0.27	0.22	0.27	0.20	0.17
p-value[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel B. Using only Trajan provinces of Britannia, Belgica, and Lugdunensis								
Ratio Britain	8.59	7.20	8.55	8.05	6.51	7.29	5.92	4.74
Ratio France	37.97	29.60	32.05	27.23	28.25	27.07	29.83	28.24
Ratio Britain / France	0.23	0.24	0.27	0.30	0.23	0.27	0.20	0.17
p-value[1]	0.000	0.003	0.001	0.004	0.000	0.002	0.000	0.000

Notes: This table is similar to the lower part of Table 4, except for the left hand side variable.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A6. First stage regressions

Sample:	France	Britain	Britain	Britain
Iron Age settlement (Fichtl 2005)	0.159 (0.036)	0.272 (0.134)		-0.049 (0.164)
Iron Age settlement (Jones and Mattingly 1990)			0.333 (0.106)	0.353 (0.110)

Notes: These first stage regressions complement Table A7. The dependent variable is Roman town (baseline). “Iron Age settlement (Fichtl 2005)” is an indicator for Iron Age *oppida* from Fichtl (2005). “Iron Age settlement (Jones and Mattingly 1990)” is an indicator for major Iron-Age settlements in Britain from Jones and Mattingly (1990). Robust standard errors are clustered to account for spatial correlation.

Appendix Table A7. IV: Probability of towns (700-2012) within 5km of Roman towns

	Bishopric or Arch-bishopric 700-900	Coin Mint 768-1066	Town with 1k+ people 1086-1200	Town with 5k+ people in 1200	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	Largest 50 towns 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500
Roman town	0.996	1.011	0.735	0.725	0.647	0.437	0.470	0.558	0.468
	(0.191)	(0.178)	(0.148)	(0.174)	(0.170)	(0.148)	(0.129)	(0.139)	(0.143)
Britain	-0.006	0.031	0.012	-0.001	-0.000	-0.000	0.018	-0.001	0.001
	(0.002)	(0.008)	(0.003)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
Roman town	-0.520	-0.259	-0.055	-0.497	-0.539	-0.452	0.206	-0.327	-0.121
x Britain	(0.246)	(0.270)	(0.236)	(0.176)	(0.177)	(0.148)	(0.224)	(0.141)	(0.311)
Intercept	0.015	0.010	0.011	0.009	0.006	0.005	0.007	0.007	0.008
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Ratio Britain	60.10	19.24	30.19	32.06	20.73	-2.00	28.19	39.00	37.82
Ratio France	69.47	98.16	66.14	86.22	114.30	85.15	71.08	81.32	56.31
Ratio Britain/France	0.87	0.20	0.46	0.37	0.18	-0.02	0.40	0.48	0.67
p-value[1]	0.678	0.001	0.045	0.029	0.004	0.003	0.062	0.100	0.570
First stage F	9.780	9.780	9.780	9.780	9.780	9.780	9.780	9.780	9.780
Underid. test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Town with 5k+ people in 1600	Town with 5k+ people in 1700	Town with 10k+ people in 1700	Town with 5k+ people in 1800	Town with 10k+ people in 1800	Town with 10k+ people in 2012	Town with 20k+ people in 2012	Town with 50k+ people in 2012	Town with 100k+ people in 2012
Roman town	0.996	1.258	0.709	1.270	0.850	1.539	1.189	0.387	0.369
	(0.191)	(0.233)	(0.181)	(0.223)	(0.159)	(0.358)	(0.241)	(0.143)	(0.141)
Britain	-0.006	-0.001	0.001	0.016	0.014	0.186	0.132	0.065	0.024
	(0.002)	(0.003)	(0.003)	(0.007)	(0.005)	(0.026)	(0.023)	(0.012)	(0.004)
Roman town	-0.520	-0.948	-0.739	-0.439	-0.554	-0.194	-0.331	0.003	-0.082
x Britain	(0.246)	(0.309)	(0.182)	(0.353)	(0.254)	(0.693)	(0.386)	(0.286)	(0.246)
Intercept	0.015	0.023	0.009	0.041	0.013	0.074	0.040	0.013	0.005
	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)	(0.009)	(0.006)	(0.002)	(0.001)
Ratio Britain	26.14	15.23	-2.00	15.84	12.23	6.17	5.97	5.97	10.83
Ratio France	48.65	56.03	83.54	32.68	67.06	21.75	30.42	30.65	73.77
Ratio Britain/France	0.54	0.27	-0.02	0.48	0.18	0.28	0.20	0.19	0.15
p-value[1]	0.242	0.006	0.000	0.027	0.001	0.012	0.005	0.052	0.026
First stage F	9.780	9.780	9.780	9.780	9.780	9.780	9.780	9.780	9.780
Underid. test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: This table is the same as Table 3, except that the estimates use limited information maximum likelihood (LIML) instead of OLS. First stage estimates are reported in Table A6. The reported first stage F-statistic is the Kleibergen-Paap statistic. The underidentification test reports the p-value from the Kleibergen-Paap LM test. The number of observations is 697,198. Robust standard errors are clustered to account for spatial correlation.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A8. Probability of towns (1300-2012) within 5km of towns with 5,000+ people in 1200

	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	Largest 50 towns, 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500	Town with 5k+ people in 1600	Town with 5k+ people in 1700
Town with 5k+ people in 1200	0.655	0.479	0.638	0.638	0.556	0.837	0.880
	(0.068)	(0.066)	(0.065)	(0.065)	(0.067)	(0.049)	(0.037)
Britain	-0.000	-0.000	0.018	-0.001	0.0010	-0.000	-0.001
	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)	(0.004)
1200 town x	0.072	0.183	0.203	-0.111	0.101	-0.188	-0.035
Britain	(0.126)	(0.123)	(0.102)	(0.151)	(0.146)	(0.138)	(0.093)
Intercept	0.006	0.005	0.007	0.007	0.009	0.018	0.023
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Ratio Britain	133.8	134.2	34.54	86.6	70.0	37.2	39.7
Ratio France	113.3	91.7	95.27	91.5	66.1	47.2	39.0
Ratio Britain / France	1.18	1.46	0.36	0.95	1.06	0.79	1.02
p-value[1]	0.573	0.235	0.000	0.830	0.785	0.172	0.918

	Town with 10k+ People in 1700	Town with 5k+ People in 1800	Town with 10k+ People in 1800	Town with 10k+ People in 2012	Town with 20k+ People in 2012	Town with 50k+ People in 2012	Town with 100k+ people in 2012
Town with 5k+ people in 1200	0.717	0.943	0.777	0.877	0.863	0.664	0.414
	(0.056)	(0.016)	(0.052)	(0.028)	(0.036)	(0.068)	(0.058)
Britain	0.001	0.016	0.013	0.186	0.132	0.066	0.024
	(0.002)	(0.007)	(0.005)	(0.026)	(0.023)	(0.012)	(0.004)
1200 town x	-0.127	0.000	-0.070	-0.138	-0.035	-0.010	0.156
Britain	(0.131)	(0.018)	(0.13)	(0.037)	(0.043)	(0.116)	(0.151)
Intercept	0.009	0.040	0.013	0.075	0.041	0.013	0.005
	(0.001)	(0.003)	(0.001)	(0.009)	(0.006)	(0.002)	(0.001)
Ratio Britain	62.4	17.7	27.8	3.8	5.8	9.3	20.5
Ratio France	83.1	24.4	60.6	12.8	22.2	51.8	81.6
Ratio Britain / France	0.75	0.73	0.46	0.30	0.26	0.18	0.25
p-value[1]	0.133	0.013	0.000	0.000	0.000	0.000	0.000

Notes: This table is similar to Table 3, except that it analyzes locational persistence relative to 1200 towns instead of Roman towns. The number of observations is 697,198. Robust standard errors are clustered to account for spatial correlation.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A9. Coastal access and the location of Roman and later towns using only Trajan provinces of Britannia, Belgica, and Lugdunensis

	Later town:							
Dependent variable: Roman town (baseline) or later town	Town with 1k+ people in 1086-1200		Town with 5k+ people in 1200		One of largest 50 towns in 1377-1400		Town with 5k+ people in 1700	
Coastal access measure:	I	II	I	II	I	II	I	II
Roman period	0.00020	0.00016	0.00020	0.00016	0.00020	0.00016	0.00020	0.00017
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Roman period x Britain	0.00019	0.00022	0.00019	0.00022	0.00019	0.00022	0.00019	0.00022
	(0.00008)	(0.00009)	(0.00008)	(0.00009)	(0.00008)	(0.00009)	(0.00008)	(0.00009)
Roman period x Coastal access	0.00054	0.00046	0.00054	0.00046	0.00054	0.00046	0.00054	0.00046
	(0.00011)	(0.00008)	(0.00011)	(0.00008)	(0.00011)	(0.00008)	(0.00011)	(0.00008)
Roman period x Britain x Coastal access	-0.00012	-0.00013	-0.00012	-0.00013	-0.00012	-0.00013	-0.00012	-0.00013
	(0.00017)	(0.00012)	(0.00017)	(0.00012)	(0.00017)	(0.00012)	(0.00017)	(0.00012)
Later period	0.00008	0.00005	0.00008	0.00005	0.00007	0.00005	0.00027	0.00021
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00004)	(0.00003)
Later period x Britain	0.00006	0.00006	-0.00005	-0.00002	0.00009	0.00006	-0.00013	-0.00011
	(0.00004)	(0.00004)	(0.00002)	(0.00002)	(0.00004)	(0.00004)	(0.00006)	(0.00005)
Later period x Coastal access	0.00034	0.00029	0.00025	0.00024	0.00037	0.00046	0.00083	0.00069
	(0.00009)	(0.00006)	(0.00008)	(0.00005)	(0.00009)	(0.00008)	(0.00017)	(0.00012)
Later period x Britain x Coastal access	0.00039	0.00031	0.00005	-0.00004	0.00033	0.00035	-0.00018	-0.00013
	(0.00016)	(0.00012)	(0.00011)	(0.00008)	(0.00016)	(0.00012)	(0.00021)	(0.00016)
Coastal access effects in Britain:								
on Roman towns (=C1)	2.08	1.87	2.08	1.87	2.08	1.87	2.08	1.87
on later towns (=C2)	6.28	6.47	12.18	7.49	5.41	6.64	5.89	6.37
Change in effect: C2/C1-1	2.03	2.46	4.87	3.00	1.61	2.55	1.84	2.40
Test H0:C2/C1≤1 vs. H1:C2/C1>1, p-value:	0.012	0.028	0.061	0.078	0.003	0.003	0.028	0.043
Coastal access effects in France:								
on Roman towns (=C3)	3.68	3.79	3.68	3.79	3.68	3.79	3.68	3.79
on later towns (=C4)	5.22	6.31	4.10	5.37	5.99	6.31	4.14	4.22
Change in effect: C4/C3-1	0.42	0.67	0.12	0.42	0.62	0.67	0.13	0.11
Test H0:C4/C3≤1 vs. H1:C4/C3>1, p-value:	0.192	0.111	0.389	0.177	0.120	0.134	0.348	0.356
Differential change, Britain minus France: (C2/C1)-(C4/C3)	1.51	1.70	4.75	2.58	0.98	1.88	1.71	2.29
Test H0:(C2/C1)-(C4/C3)≤0 vs. H1:(C2/C1)-(C4/C3)>0, p-value:	0.071	0.087	0.058	0.103	0.137	0.036	0.073	0.067

Notes: This table is the same as Table 4, except that the sample is restricted to the Roman provinces of Britannia, Belgica and Lugdunensis. Robust standard errors are clustered to account for spatial correlation.

Appendix Table A10. Coastal access and the location of Roman and later towns, Roman towns with defended area of 5ha or more

	Later town:							
Dependent variable: Roman town with defended area of 5ha+, or later town	Town with 1k+ people in 1086-1200		Town with 5k+ people in 1200		One of largest 50 towns in 1377-1400		Town with 5k+ people in 1700	
Coastal access measure:	I	II	I	II	I	II	I	II
Roman period	0.00008	0.00006	0.00008	0.00006	0.00008	0.00006	0.00008	0.00006
	(0.00002)	(0.00001)	(0.00002)	(0.00001)	(0.00002)	(0.00001)	(0.00002)	(0.00001)
Roman period x Britain	0.00009	0.00008	0.00009	0.00008	0.00009	0.00008	0.00009	0.00008
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Roman period x Coastal access	0.00037	0.00029	0.00037	0.00029	0.00037	0.00029	0.00037	0.00029
	(0.00010)	(0.00006)	(0.00010)	(0.00006)	(0.00010)	(0.00006)	(0.00010)	(0.00006)
Roman period x Britain x Coastal access	-0.00002	0.00003	-0.00002	0.00003	-0.00002	0.00003	-0.00002	0.00003
	(0.00014)	(0.00010)	(0.00014)	(0.00010)	(0.00014)	(0.00010)	(0.00014)	(0.00010)
Later period	0.00008	0.00005	0.00008	0.00005	0.00007	0.00005	0.00027	0.00021
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00004)	(0.00004)
Later period x Britain	0.00006	0.00006	-0.00005	-0.00002	0.00009	0.00006	-0.00013	-0.00011
	(0.00004)	(0.00004)	(0.00002)	(0.00002)	(0.00004)	(0.00004)	(0.00006)	(0.00005)
Later period x Coastal access	0.00034	0.00029	0.00025	0.00024	0.00037	0.00029	0.00083	0.00069
	(0.00009)	(0.00006)	(0.00008)	(0.00005)	(0.00009)	(0.00006)	(0.00017)	(0.00012)
Later period x Britain x Coastal access	0.00039	0.00031	0.00005	-0.00004	0.00034	0.00035	-0.00018	-0.00013
	(0.00016)	(0.00012)	(0.00011)	(0.00008)	(0.00016)	(0.00012)	(0.00021)	(0.00016)
Coastal access effects in Britain:								
on Roman towns (=C1)	3.04	3.21	3.04	3.21	3.04	3.21	3.04	3.21
on later towns (=C2)	6.09	6.30	12.18	7.49	5.41	6.64	5.89	6.37
Change in effect: C2/C1-1	1.00	0.96	3.00	1.33	0.78	1.07	0.93	0.98
Test H0:C2/C1≤1 vs. H1:C2/C1>1, p-value:	0.046	0.062	0.072	0.109	0.011	0.005	0.080	0.102
Coastal access effects in France:								
on Roman towns (=C3)	5.59	5.68	5.59	5.68	5.59	5.68	5.59	5.68
on later towns (=C4)	5.22	6.31	4.10	5.37	5.99	6.31	4.14	4.22
Change in effect: C4/C3-1	-0.07	0.11	-0.27	-0.06	0.07	0.11	-0.26	-0.26
Test H0:C4/C3≤1 vs. H1:C4/C3>1, p-value:	0.583	0.372	0.787	0.568	0.422	0.387	0.778	0.798
Differential change, Britain minus France: (C2/C1)-(C4/C3)	1.07	0.85	3.27	1.39	0.71	0.96	1.19	1.24
Test H0:(C2/C1)-(C4/C3)≤0 vs. H1:(C2/C1)-(C4/C3)>0, p-value:	0.076	0.114	0.038	0.079	0.102	0.051	0.074	0.080

Notes: This table is the same as Table 4,, except that it uses a different definition of Roman towns, which only considers Roman-era towns with walled area of 5 hectares or more. Robust standard errors are clustered to account for spatial correlation.

Appendix Table A11. Access to canals and the growth of towns with 5,000 people or more in 1200, for towns with reduced market access (Coastal Access Type I measure = 0)

Sample:	Britain and France	Britain and France	Britain and France	Britain and France	Britain and France	Britain and France, only areas ≤25km of coast or navigable river	Britain and France, only Britannia, Belgica, and Lugdunensis	Northwestern Europe, all Roman provinces	Britain and France
Dependent variable is population growth from:	1200-1800	1200-1800	1200-1800	1200-1700	1200-2012	1200-1800	1200-1800	1200-1800	1200-1800
Canal access	0.302	0.458	0.461	0.446	0.66	0.461	0.693	0.407	0.433
	(0.170)	(0.191)	(0.192)	(0.202)	(0.227)	(0.380)	(0.276)	(0.165)	(0.208)
Log population in 1200		-0.404	-0.401	-0.355	-0.368	-0.414	-0.676	-0.429	-0.396
		(0.159)	(0.160)	(0.187)	(0.207)	(0.310)	(0.255)	(0.113)	(0.163)
Britain			-0.471	-0.235	0.0821	-0.868	-0.543	-0.516	-0.586
			(0.212)	(0.197)	(0.340)	(0.311)	(0.233)	(0.204)	(0.283)
Canal access x Britain									0.349
									(0.323)
Observations	42	42	42	38	39	15	18	80	42

Notes: Coastal access measure I: within 5km of the coast or of a major navigable river which leads to the coast. Canal access: within 5km of a canal.

Robust standard errors are clustered to account for spatial correlation.

Appendix Table A12. `Locally Suboptimal' Coastal Access and the location of Roman and later towns

	Later town:							
Dependent variable: Roman town (baseline) or later town	Town with 1k+ people in 1086-1200		Town with 5k+ people in 1200		One of largest 50 towns in 1377-1400		Town with 5k+ people in 1700	
Coastal access measure:	I	II	I	II	I	II	I	II
Roman period	0.00033	0.00041	0.00033	0.00041	0.00033	0.00041	0.00033	0.00041
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Roman period x Britain	0.00021	0.00020	0.00021	0.00020	0.00021	0.00020	0.00021	0.00020
	(0.00010)	(0.00011)	(0.00010)	(0.00011)	(0.00010)	(0.00011)	(0.00010)	(0.00011)
Roman period x Suboptimal location	-0.00011	-0.00024	-0.00011	-0.00024	-0.00011	-0.00024	-0.00011	-0.00024
	(0.00006)	(0.00004)	(0.00006)	(0.00004)	(0.00006)	(0.00004)	(0.00006)	(0.00004)
Roman period x Britain x suboptimal location	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
	(0.00011)	(0.00012)	(0.00011)	(0.00012)	(0.00011)	(0.00012)	(0.00011)	(0.00012)
Later period	0.00016	0.00020	0.00012	0.00015	0.00009	0.00012	0.00034	0.00041
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00004)	(0.00005)
Later period x Britain	0.00032	0.00040	0.00006	0.00004	0.00039	0.00049	0.00013	0.00013
	(0.00008)	(0.00009)	(0.00006)	(0.00006)	(0.00008)	(0.00011)	(0.00007)	(0.00008)
Later period x Suboptimal location	-0.00005	-0.00011	-0.00003	-0.00009	-0.00000	-0.00006	-0.00013	-0.00024
	(0.00004)	(0.00003)	(0.00003)	(0.00002)	(0.00003)	(0.00003)	(0.00006)	(0.00005)
Later period x Britain x Suboptimal location	-0.00029	-0.00037	-0.00015	-0.00008	-0.00030	-0.00044	-0.04376	-0.00020
	(0.00010)	(0.00010)	(0.00007)	(0.00007)	(0.00009)	(0.00011)	(0.00010)	(0.00009)
Coastal access effects in Britain:								
on Roman towns (=C1)	0.85	0.66	0.85	0.66	0.85	0.66	0.85	0.66
on later towns (=C2)	0.30	0.19	0.08	0.13	0.37	0.18	0.23	0.18
Change in effect: C2/C1-1	-0.64	-0.72	-0.91	-0.81	-0.56	-0.73	-0.72	-0.72
Test H0:C2/C1≥1 vs. H1:C2/C1<1, p-value:	0.004	0.000	0.000	0.000	0.004	0.000	0.001	0.001
Coastal access effects in France:								
on Roman towns (=C3)	0.67	0.42	0.67	0.42	0.67	0.42	0.67	0.42
on later towns (=C4)	0.71	0.43	0.79	0.40	0.95	0.49	0.63	0.43
Change in effect: C4/C3-1	0.06	0.02	0.18	-0.05	0.43	0.16	-0.05	0.016
Test H0:C4/C3≥1 vs. H1:C4/C3<1, p-value:	0.575	0.541	0.681	0.424	0.808	0.664	0.401	0.532
Differential change, Britain minus France: (C2/C1)-(C4/C3)	-0.70	-0.75	-1.10	-0.76	-0.99	-0.89	-0.67	-0.74
Test H0:(C2/C1)-(C4/C3) ≥0 vs. H1:(C2/C1)-(C4/C3)<0, p-value:	0.027	0.003	0.005	0.005	0.032	0.011	0.003	0.001

Notes: This table is the same as Table 4 except that it considers measures of suboptimal location instead of the coastal access measures. These measures of suboptimality indicate locations that are within more than 5 kilometers but fewer than 25 kilometers from locations with corresponding coastal access (according to definitions I and II). Robust standard errors are clustered to account for spatial correlation.

Appendix Table A13. Model overview

Scenario	1. Fixed locational advantage	2. Changing locational advantage with stronger fundamentals	3A. Changing locational advantage with stronger towns and inconsequential fundamentals	3B. Changing locational advantage with strong towns and consequential fundamentals
Parameter values				
• Probability that value of fundamentals changes	$p_F=0$	$p_F>0$	$p_F>0$	$p_F>0$
• Productivity parameters	$\theta_F>0$	$\theta_F>\theta_T$	$\theta_T>\theta_F\approx 0$	$\theta_T>\theta_F\not\approx 0$ ($\theta_F>0$)
Theoretical implications				
• Do town locations change over time?	No	Yes	Yes	Yes
• Are town locations path-dependent (affected by history)?	No	No	Yes	Yes
• Are some town badly located?	No	No	No	Yes
Empirical predictions				
• Persistence of town locations relative to Roman period in France	High	Low	High	High
• Persistence of town locations relative to Roman period in Britain	High	Low	Low	Low
• Improved suitability to medieval economy of town locations from Roman to Medieval period in France	Low	High	Low	Low
• Improved suitability to medieval economy of town locations from Roman to Medieval period in Britain	Low	High	Low	High

Notes: Summary of parameter values, theoretical implications and empirical predictions of the different scenarios in the model.

Appendix Table A14. Probability of towns (700-1600) within 5km of Roman towns with and without 4th century bishoprics

	Bishopric or Arch-bishopric in 700-900	Coin Mint in 768-1066	Town with 1k+ people in 1086-1200	Town with 5k+ people in 1200	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	Largest 50 towns 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500
Roman_town	0.238	0.167	0.140	0.093	0.070	0.058	0.056	0.056	0.067
	(0.050)	(0.043)	(0.042)	(0.033)	(0.028)	(0.025)	(0.026)	(0.026)	(0.027)
Britain	-0.006	0.031	0.012	-0.001	-0.000	-0.000	0.018	-0.001	0.001
	(0.002)	(0.008)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Roman_town x Britain	-0.139	0.062	0.066	-0.019	-0.022	-0.023	0.135	0.005	0.018
	(0.062)	(0.063)	(0.058)	(0.043)	(0.040)	(0.033)	(0.048)	(0.040)	(0.048)
Roman Bishopric in the 4th	0.622	0.334	0.394	0.353	0.310	0.198	0.278	0.278	0.299
century	(0.065)	(0.087)	(0.073)	(0.059)	(0.052)	(0.052)	(0.061)	(0.061)	(0.059)
Intercept	0.015	0.011	0.011	0.009	0.006	0.005	0.007	0.007	0.009
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Ratio Britain	13.12	6.52	9.76	10.93	9.78	8.08	8.62	10.93	9.91
Ratio France (non-bishopric)	17.25	16.71	13.32	11.72	13.01	11.99	9.33	8.96	8.904
Ratio Britain / France (non-bishopric)	0.76	0.39	0.73	0.93	0.75	0.67	0.92	1.22	1.11
p-value[1]	0.361	0.020	0.391	0.873	0.606	0.505	0.862	0.728	0.831

	Town With 5k+ people in 1600	Town With 5k+ people in 1700	Town With 10k+ people in 1700	Town with 5k+ people in 1800	Town with 10k+ people in 1800	Town with 10k+ people in 2012	Town with 20k+ people in 2012	Town with 50k+ people in 2012	Town with 100k+ people in 2012
Roman_town	0.172	0.268	0.118	0.365	0.227	0.381	0.326	0.139	0.084
	(0.047)	(0.051)	(0.034)	(0.048)	(0.045)	(0.056)	(0.047)	(0.041)	(0.030)
Britain	-0.000	-0.001	0.001	0.016	0.013	0.186	0.132	0.065	0.024
	(0.003)	(0.004)	(0.002)	(0.007)	(0.005)	(0.026)	(0.023)	(0.012)	(0.004)
Roman_town x Britain	-0.055	-0.128	-0.060	-0.164	-0.105	-0.101	-0.067	0.053	0.009
	(0.068)	(0.063)	(0.043)	(0.063)	(0.056)	(0.083)	(0.082)	(0.062)	(0.048)
Roman Bishopric in the 4th	0.367	0.311	0.248	0.379	0.237	0.306	0.337	0.303	0.161
century	(0.077)	(0.079)	(0.064)	(0.076)	(0.075)	(0.080)	(0.072)	(0.068)	(0.053)
Intercept	0.018	0.023	0.009	0.040	0.013	0.075	0.041	0.013	0.005
	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)	(0.009)	(0.006)	(0.002)	(0.001)
Ratio Britain	7.54	7.42	7.01	4.56	5.62	2.08	2.50	3.44	4.15
Ratio France (non-bishopric)	10.49	12.60	14.49	10.05	18.48	6.12	9.04	11.62	17.26
Ratio Britain / France (non-bishopric)	0.72	0.59	0.48	0.45	0.30	0.40	0.27	0.30	0.24
p-value[1]	0.409	0.060	0.122	0.000	0.001	0.000	0.000	0.029	0.028

Notes: This table is that same as Table 2, except that the estimated specification includes an additional right hand side indicator for 4th century bishoprics in France.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A15. Robustness checks for the probability of towns (700-1500) within 5km of Roman towns with and without 4th century bishoprics

	Bishopric or Arch-bishopric in 700-900	Coin Mint in 768-1066	Town with 1k+ people in 1086-1200	Town with 5k+ people in 1200	Town with 5k+ people c.1300 (Russell)	Town with 5k+ people in 1300	One of largest 50 towns in 1377-1400	Town with 5k+ people in 1400	Town with 5k+ people in 1500
Panel A: Same as baseline, but using 10km radius instead of 5km radius									
Ratio Britain	4.46	2.52	3.27	3.58	2.99	2.63	2.95	3.72	3.13
Ratio France	4.51	4.16	3.86	3.62	3.78	4.09	3.22	3.08	3.65
Ratio Britain / France	0.99	0.61	0.85	0.99	0.79	0.64	0.92	1.21	0.86
p-value[1]	0.972	0.153	0.586	0.978	0.641	0.418	0.824	0.683	0.716
Panel B: Same as baseline, but using 0km radius instead of 5km radius									
Ratio Britain	1,403	465	744	1,336	1,145	859	633	1,432	1,169
Ratio France	7,408	3,638	2,404	2,451	8,681	3,157	1,226	1,097	1,286
Ratio Britain / France	0.19	0.13	0.31	0.55	0.13	0.27	0.52	1.31	0.91
p-value[1]	0.015	0.024	0.087	0.419	0.165	0.161	0.461	0.774	0.890
Panel C: Same as baseline, but using only Trajan provinces of Britannia, Belgica, and Lugdunensis									
Ratio Britain	13.12	6.52	9.79	10.93	9.78	8.08	8.62	10.93	9.91
Ratio France	18.77	13.66	9.62	3.53	6.55	8.92	6.55	6.32	7.64
Ratio Britain / France	0.70	0.48	1.02	3.10	1.49	0.91	1.32	1.73	1.30
p-value[1]	0.374	0.127	0.980	0.132	0.681	0.895	0.663	0.448	0.652
Panel D: Same as baseline, but using only Roman towns with defended areas of 5ha or more									
Ratio Britain	19.14	10.79	15.68	21.29	19.04	15.74	12.58	21.29	13.77
Ratio France	22.18	40.80	28.79	35.00	42.12	33.96	49.79	47.85	27.39
Ratio Britain / France	0.86	0.26	0.55	0.61	0.45	0.46	0.25	0.45	0.50
p-value[1]	0.749	0.002	0.106	0.177	0.101	0.198	0.002	0.050	0.191
Panel E: Same as baseline, but using only Roman towns with defended areas of 5ha or more in all Northwest Europe									
Ratio Britain	19.14	10.79	15.68	21.29	19.04	15.74	12.58	21.29	13.77
Ratio France	28.85	19.15	43.93	36.20	64.47	31.52	40.72	39.31	19.11
Ratio Britain / France	0.66	0.56	0.36	0.59	0.30	0.50	0.31	0.54	0.72
p-value[1]	0.510	0.399	0.029	0.283	0.027	0.374	0.05	0.232	0.662
Panel F: Same as baseline, but using only Roman administrative towns									
Ratio Britain	25.23	12.05	17.72	28.07	30.16	24.93	16.59	33.71	21.80
Ratio France	26.71	25.56	21.50	19.37	21.37	25.86	22.02	21.15	7.073
Ratio Britain / France	0.95	0.47	0.82	1.45	1.41	0.96	0.75	1.59	3.08
p-value[1]	0.886	0.061	0.685	0.542	0.608	0.951	0.562	0.384	0.238
Panel G: Same as baseline, but using only Roman towns with pre-Roman origins									
Ratio Britain	21.63	8.60	13.66	14.41	6.44	0.00	9.95	11.52	14.94
Ratio France	11.63	16.84	13.32	18.34	21.48	18.10	17.55	16.88	18.44
Ratio Britain / France	1.86	0.51	1.03	0.79	0.30	0.00	0.57	0.68	0.81
p-value[1]	0.092	0.146	0.957	0.631	0.120	0.090	0.432	0.604	0.697
Panel H: Same as baseline, but with geographic controls and their Britain interactions									
Ratio Britain	18.14	9.82	15.92	29.94	34.66	30.71	16.71	30.07	23.86
Ratio France	37.35	32.63	28.21	24.93	30.08	30.99	21.43	20.05	6.88
Ratio Britain / France	0.49	0.30	0.56	1.20	1.15	0.99	0.78	1.50	3.47
p-value[1]	0.088	0.025	0.362	0.786	0.866	0.991	0.633	0.479	0.192

Notes: The number of observations is 697,198, except in Panel C in which it is 396,228 and in Panel E in which it is 906,076. Robust standard errors are clustered to account for spatial correlation.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Table A16. Robustness checks for the probability of towns (1600-2012) within 5km of Roman towns with and without 4th century bishoprics

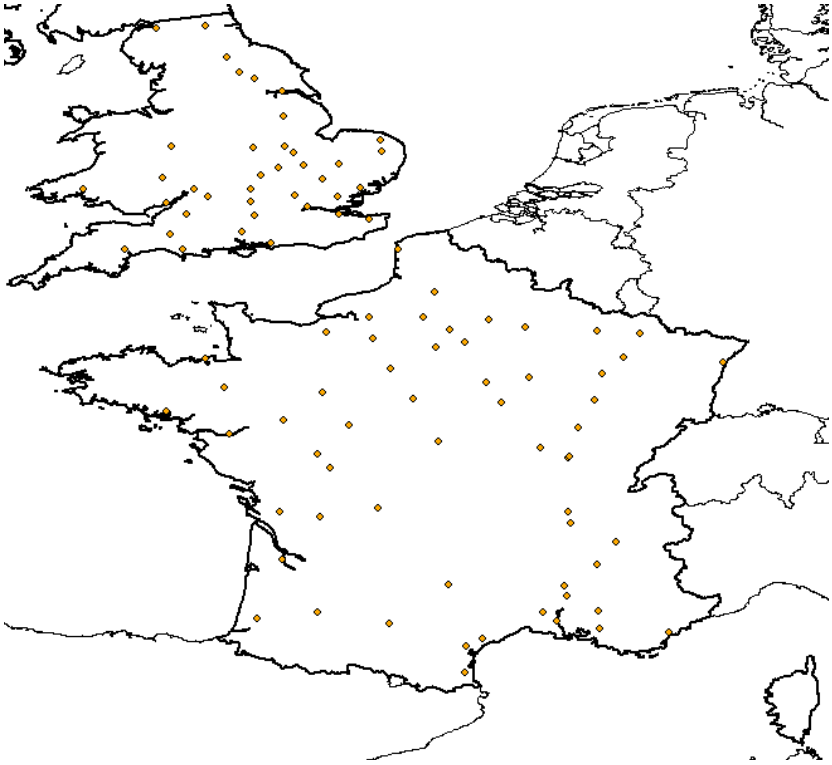
	Town with 5k+ people in 1600	Town with 5k+ people in 1700	Town with 10k+ people in 1700	Town with 5k+ people in 1800	Town with 10k+ people in 1800	Town with 10k+ people in 2012	Town with 20k+ people in 2012	Town with 50k+ people in 2012	Town with 100k+ people in 2012
Panel A: Same as baseline, but using 10km radius instead of 5km radius									
Ratio Britain	2.45	2.72	2.79	1.96	2.32	1.39	1.51	1.83	1.74
Ratio France	3.15	3.60	4.29	3.01	5.12	2.66	3.43	3.87	5.07
Ratio Britain / France	0.78	0.76	0.65	0.65	0.45	0.53	0.44	0.47	0.34
p-value[1]	0.500	0.325	0.315	0.015	0.010	0.000	0.000	0.033	0.046
Panel B: Same as baseline but using 0km radius instead of 5km radius									
Ratio Britain	668	590	668	268	320	74	97	184	297
Ratio France	1,254	1,417	2,500	963	2,710	232	435	951	3,472
Ratio Britain / France	0.53	0.42	0.27	0.28	0.12	0.32	0.22	0.19	0.09
p-value[1]	0.210	0.030	0.055	0.000	0.001	0.034	0.064	0.171	0.095
Panel C: Same as baseline, but using only Trajan provinces of Britannia, Belgica, and Lugdunensis									
Ratio Britain	7.54	7.42	7.01	4.55	5.62	2.07	2.54	3.44	4.15
Ratio France	9.62	10.90	10.71	9.15	16.63	5.06	8.28	9.86	13.78
Ratio Britain / France	0.78	0.68	0.66	0.50	0.34	0.41	0.31	0.35	0.30
p-value[1]	0.626	0.276	0.444	0.012	0.009	0.017	0.020	0.220	0.178
Panel D: Same as baseline, but using only Roman towns with defended areas of 5ha or more									
Ratio Britain	11.73	10.83	10.91	6.07	6.96	2.30	2.70	4.36	6.28
Ratio France	17.53	25.21	40.22	12.27	34.63	7.36	12.67	27.88	55.09
Ratio Britain / France	0.67	0.43	0.27	0.49	0.20	0.31	0.21	0.16	0.11
p-value[1]	0.376	0.004	0.002	0.012	0.000	0.000	0.001	0.003	0.001
Panel E: Same as baseline, but using only Roman towns with defended areas of 5ha or more in all Northwest Europe									
Ratio Britain	11.73	10.83	10.91	6.07	6.96	2.30	2.70	4.36	6.28
Ratio France	17.86	23.12	33.36	14.29	34.17	9.07	17.27	25.96	55.28
Ratio Britain / France	0.66	0.47	0.33	0.42	0.20	0.25	0.16	0.17	0.11
p-value[1]	0.438	0.038	0.053	0.016	0.010	0.001	0.004	0.047	0.004
Panel F: Same as baseline, but using only Roman administrative towns									
Ratio Britain	16.25	13.33	12.95	8.13	7.87	2.58	2.85	4.77	8.52
Ratio France	13.70	17.88	24.94	11.81	30.12	5.99	11.42	20.10	26.23
Ratio Britain / France	1.19	0.75	0.52	0.69	0.26	0.43	0.25	0.24	0.33
p-value[1]	0.740	0.445	0.268	0.221	0.003	0.011	0.002	0.016	0.136
Panel G: Same as baseline, but using only Roman towns with pre-Roman origins									
Ratio Britain	11.93	9.79	7.40	5.70	8.10	2.47	3.67	4.09	3.65
Ratio France	14.01	10.43	25.40	6.86	20.84	4.75	7.84	15.58	24.55
Ratio Britain / France	0.85	0.94	0.29	0.83	0.39	0.52	0.47	0.26	0.15
p-value[1]	0.704	0.862	0.045	0.539	0.023	0.032	0.019	0.046	0.032
Panel H: Same as baseline, but with geographic controls and their Britain interactions									
Ratio Britain	18.11	17.37	17.41	7.38	8.34	2.06	2.20	3.68	7.47
Ratio France	13.74	19.06	31.46	12.19	39.75	5.86	12.79	24.81	37.35
Ratio Britain / France	1.32	0.91	0.55	0.61	0.21	0.35	0.17	0.15	0.20
p-value[1]	0.597	0.828	0.407	0.142	0.004	0.008	0.002	0.009	0.090

Notes: The number of observations is 697,198, except in Panel C in which it is 396,228 and in Panel E in which it is 906,076. Robust standard errors are clustered to account for spatial correlation.

[1] Test H0: Ratio Britain - Ratio France = 0 vs. H1: Ratio Britain - Ratio France ≠ 0

Appendix Figure A1

Panel A: Roman Baseline Towns (●)



Panel B: Roman Baseline Towns (●) and Medieval Bishoprics and Archbishoprics, (8th and 9th century, ○)

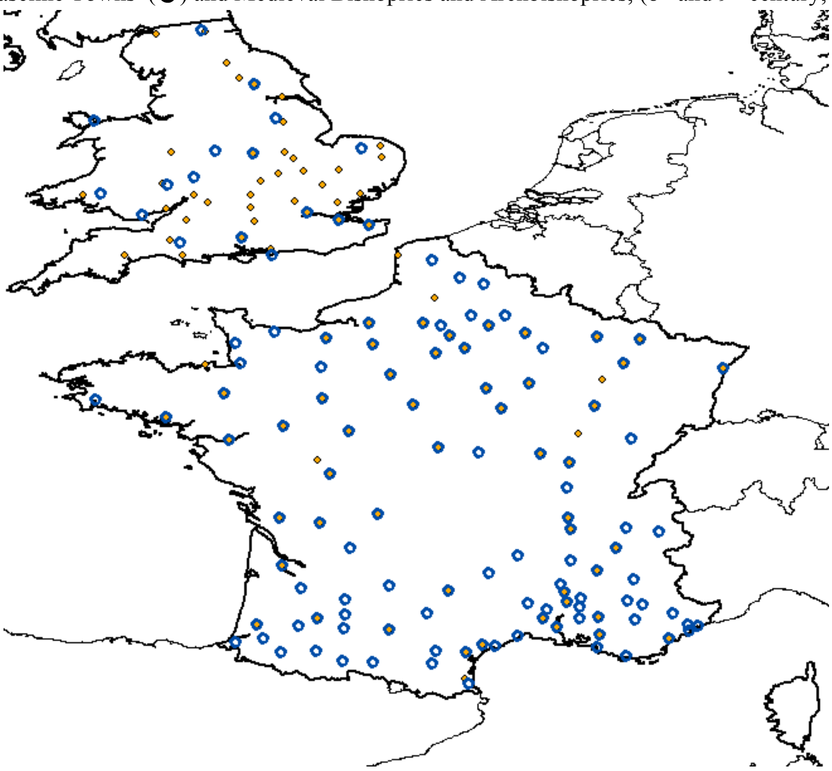
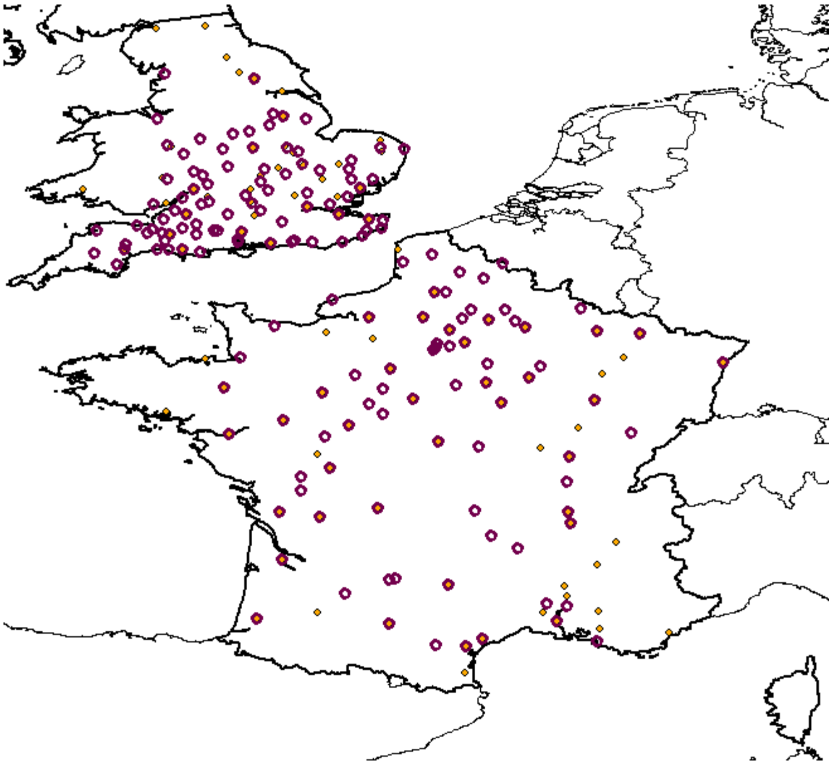


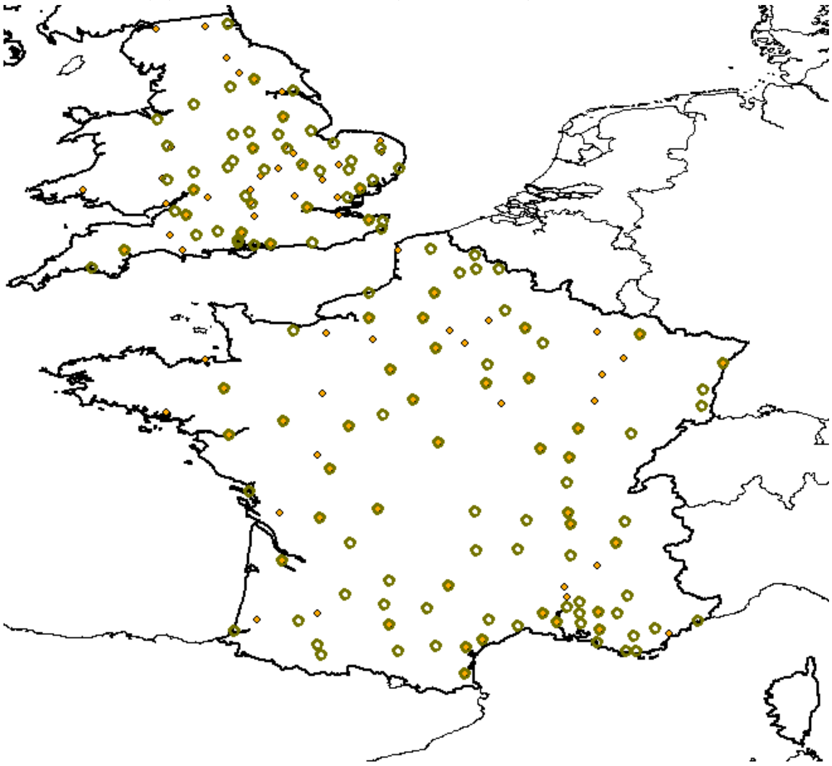
Figure continues overleaf

Appendix Figure A1 continued

Panel C: Roman Baseline Towns (◉) and Medieval Mints (768-1066, ◯)



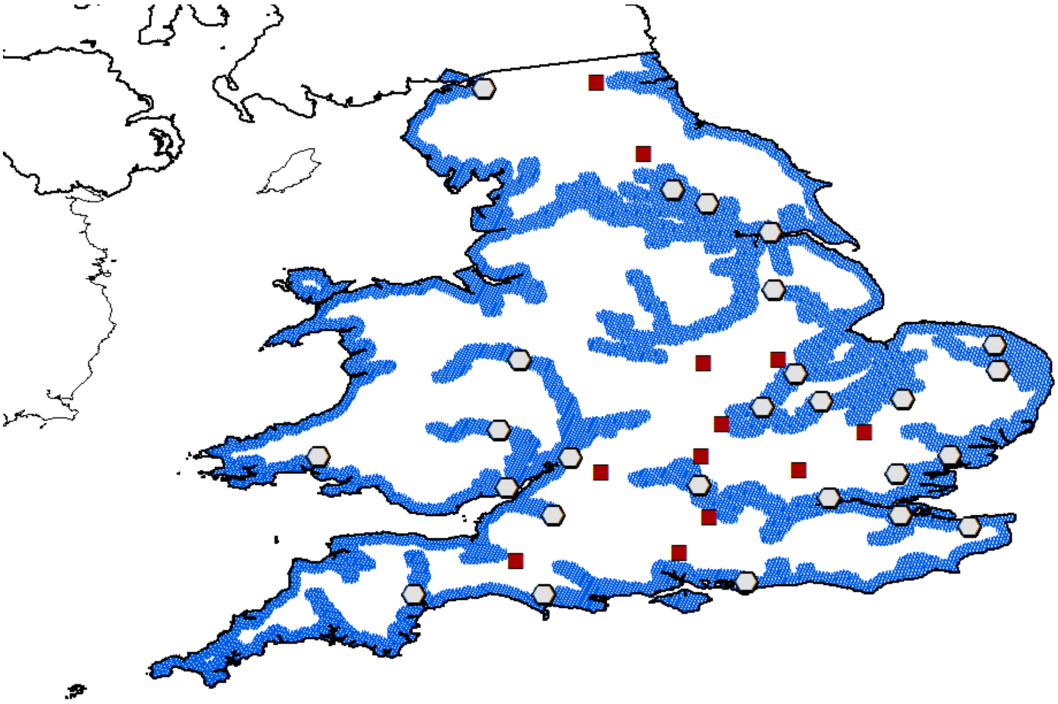
Panel D: Roman Baseline Towns (◉) and Medieval Towns (1086-1200, ◯)



Notes: The maps show the location of all the Roman towns with walled areas of at least 5 hectares and the location of later towns as specified in each panel for the Roman parts of Britain and France. See the data section for sources and definitions of towns.

Appendix Figure A2–Towns within and without 5km of navigable rivers and coasts in Britain

Panel A: Roman Baseline Towns, 5ha of defended area or more



Panel B: Medieval Towns (1086-1200)

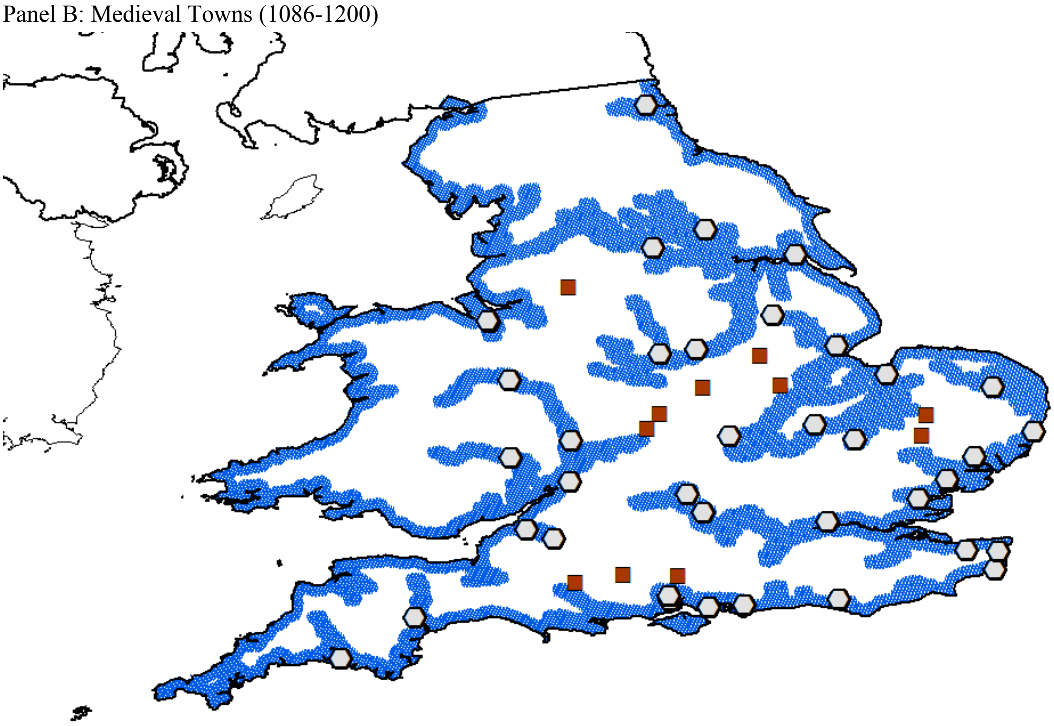
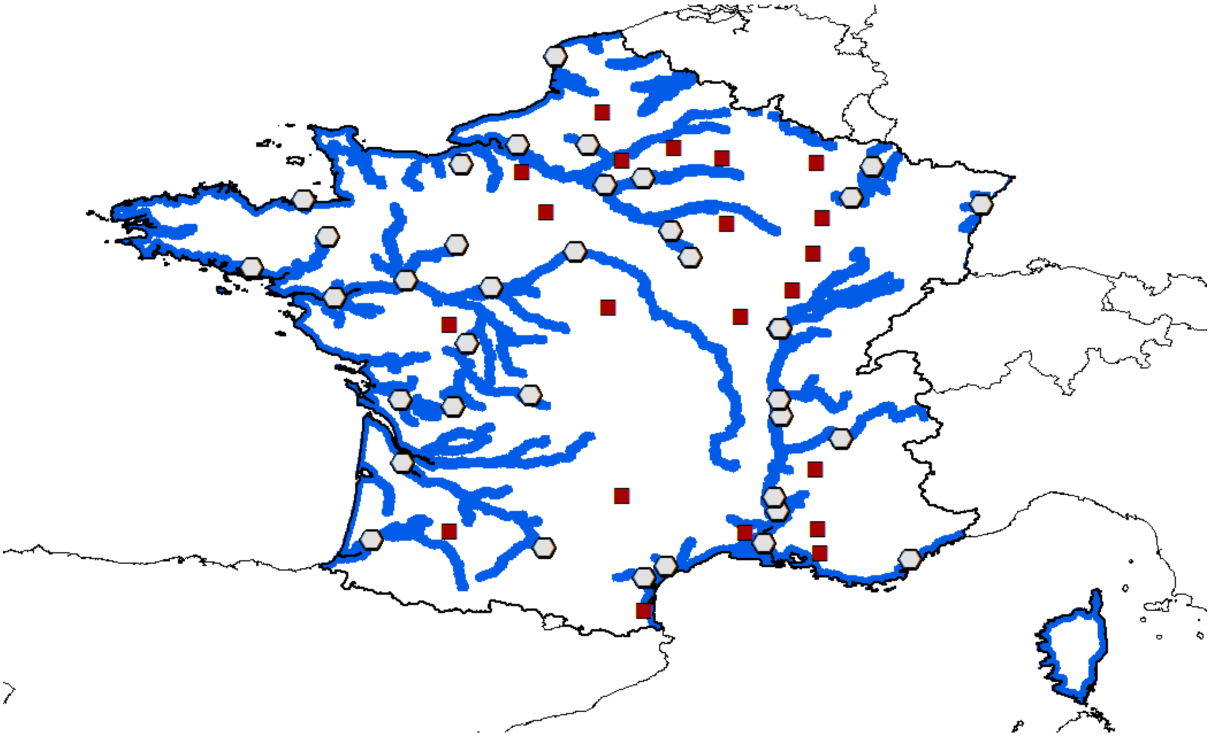


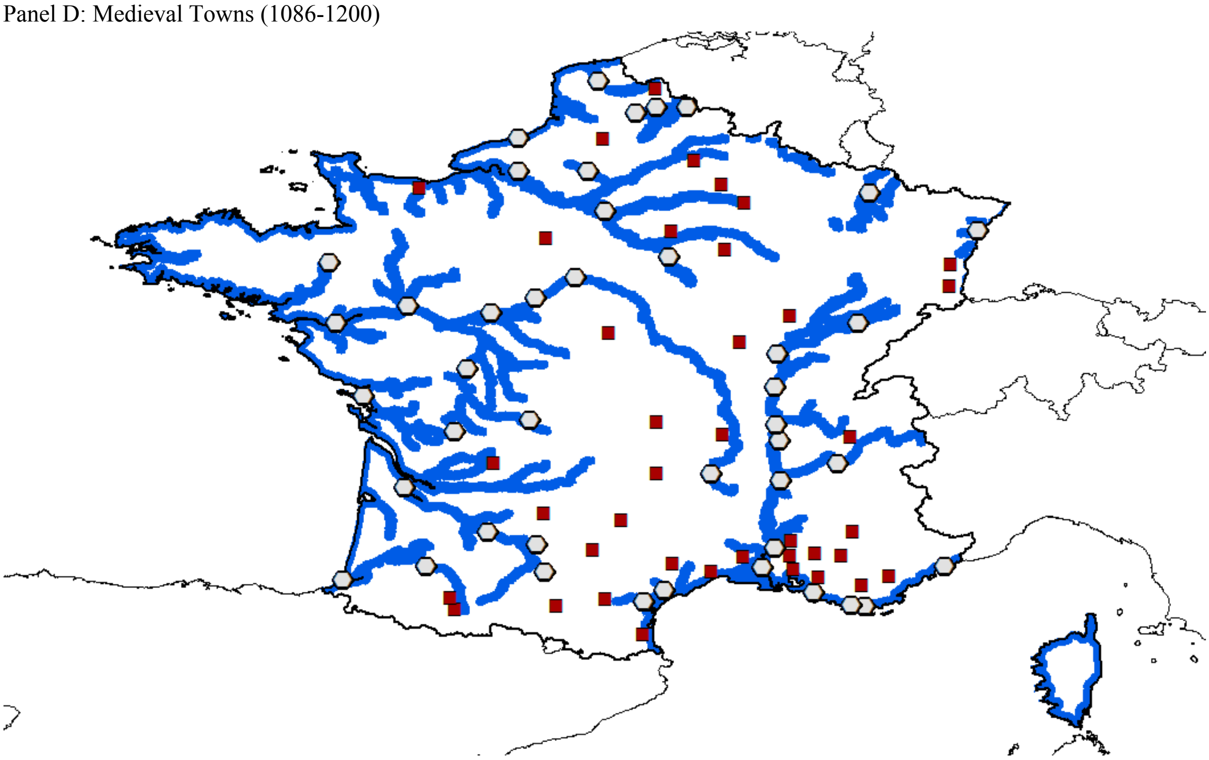
Figure continues overleaf

Appendix Figure A2 continued

Panel C: Roman Baseline Towns, 5ha of defended area or more



Panel D: Medieval Towns (1086-1200)



Notes: The figures show towns that are or are not within 5km of the coast or navigable rivers (by the "Coastal access II" measure) for the Roman part of Britain and France for different years as indicated in the panel titles. The areas with navigable access are highlighted in blue.