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Divide et Praegressio: The Effects of Hadrian's Wall on Britain's Longlasting Development

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Did Roman presence have long-term impacts? I exploit plausibly exogenous differences across the Roman frontier in Northern England. Through a Regression Discontinuity Desing (RDD), I show that zones just South of the Roman wall still have significant advantage in luminosity and connectivity than those just at the North, and possible differences in population and human capital indicators. I argue that this is due to a legacy of infrastructure and urban centers left by the Romans, which influenced progress through all following centuries. To prove this, I show the effect of Roman rule on a number of intermediate outcomes from a rich amount of datasets. Almost all of them were statistically more positive South of the wall, although some differences appear to fade out after the Industrial Revolution period. All these results are robust to bandwidth, polynomial degree and numerous other tests.

Over the heather the wet wind blows,
I've lice in my tunic and a cold in my nose.

The rain comes pattering out of the sky,
I'm a Wall soldier, I don't know why.

The mist creeps over the hard grey stone,
My girl's in Tungria; I sleep alone.

Aulus goes hanging around her place,
I don't like his manners, I don't like his face.

Piso's a Christian, he worships a fish;
There'd be no kissing if he had his wish.

She gave me a ring but I diced it away;
I want my girl and I want my pay.

When I'm a veteran with only one eye,
I shall do nothing but look at the sky.

Roman Wall Blues by W. H. Auden (1937).

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1. Introduction

What was the impact of Roman rule over the countries held by the Empire? Did this influence persist over the years or did it fade away after centuries passed? If it did last, through what channels did the persistence occur? This thesis tries to answer these questions by studying the differences along one of the borders of the Empire, namely Hadrian's wall, in Northern Britain. It looks at modern and intermediate economic outcomes.

Figure 1: Map of Northern Britain with Hadrian's wall

Why was Hadrian's wall built where it was? By the time of Hadrian, the Roman Empire had expanded significantly and Rome was percieved to be too far from the newer conquests to properly rule them. The aforementioned emperor hence sought to establish a *limes*, a physical boundary where Roman rule finished to stop further expansions. Thus, after the conquest of Britain took place, the frontier was placed in the narrowest area of the island, and not because of political, cultural or ethnic reasons. In addition to historical arguments, I demonstrate that characteristics on the North and the South of the wall were identical before its construction.

Using a spatial Regression Discontinuity Design (RDD) and the Roman border as the "cutoff", I find that there is a discontinuity in outcomes around the wall measured in the last ten years. Specifically, the area South of the wall (SotW) has a higher degree of luminosity and a higher degree of connectivity.[1] On average, pixels have a 56% more luminosity and 10% more connectivity SotW. I also find that zones exposed discontinuously to Roman rule have larger population and higher school test scores (which are used as a proxy for human capital), but the difference is not statistically significant.[2]

But how did these effects come to be? From what point in history did the area SotW had this advantage? To test this, I gathered data on intermediate outcomes related to present ones. For luminosity I use other prosperity proxies, namely, presence of monasteries, when were they founded and wills left. Pixels SotW have a 2% higher probability of having a monastery and monasteries were founded 100 years earlier on average. I also find that parishes SotW leave on average 0.4 more wills out of a mean of 1.2 will per parish. Results for connectivity also appear to date back to earlier times: for every pixel around the wall there is a 10% more chance of having a road by 1675 and a railroad in 1851. All these results are significant to the 1%. For human capital measures, I extracted data of chapbooks licenses given in 1697 and soldiers' height between 1760-1870. As in modern data, results are too noisy to be conclusive, but include large potential differences in the case of chapbooks. This is similar for soldier height, however, in this case there are significant positive results for small bandwidths. The number of parishes in medieval times in that area is too small to be able to run an RDD, nevertheless, suggestive graphical evidence shows that initially SotW parishes had more population, but during and after the industrial revolution the Northern parishes caught up. This is confirmed using census data from 1801-1951, where no statistically significant difference in population is found.

What is interesting is that, unlike most places, the Romans were not pushed out from the island, but rather evacuated it in the year 410 C.E. This left most of their public goods untouched, in particular, their roads. This is clearly their biggest legacy, since they continued to be used in later centuries and many are still followed today by modern roads. However, additional analysis suggests that the impact I measure is linked to more than roads, as measured by Dalgaard et al. (2018). The Romans also built aqueducts (water supply), sanitation (baths) and wastewater (sewage) systems. Finally, since Romans founded cities which in turn were connected by their road network, my hypothesis is that even after the fall of Rome the settlements remained relevant urban centers, while also allowing for better market access to new cities founded near Roman roads. This

[1] Both using pixel level data, which is a thousand metres tall by five hundred metres wide, and connectivity measured by railroad density.

[2] All these results are measured using Calonico et al. (2014) optimal bandwidth, which is around 20 kilometres within the border. Depending on the bandwidth, results vary in magnitude.

would kick off an advantage given to the Southern half of the wall in comparison to the North, since after the post-Roman settlers went into Britain, some would have had access to these public goods, while other would not.

The rest of the paper is ordered as it follows. Section 2 assesses the literature that has reviewed similar topics. Section 3 explains the empirical and theoretical justification of the empirical strategy along with historical background. Section 4 depicts my models and data. Section 5 shows the results for modern times. Section 6 discusses intermediate outcomes and hypotheses, and Section 7 gives final remarks.

2. Related Literature

This paper contributes to two main literatures. First, it continues the research that assesses persistence in comparative development. In this line, several authors have already reported how history can affect the present, such as Dell et al. (2018), Michalopoulos & Papaioannou (2013) and Andersen et al. (2017). Dell et al. (2018) examine a similar case to mine, which is useful as a guide in the method to apply. Using an RDD to compare former North Vietnam (ruled by a strong, centralized state) and Southern Vietnam (which was a peripheral tributary of the Khmer -Cambodian- Empire), they find that the North has had a better performance in economic outcomes in the last 150 years, such as household consumption or schooling. Michalopoulos & Papaioannou (2013) make a similar argument, although they instead analyse economic development through the use of night luminosity as a proxy. Using pre-colonial ethnic political borders and the amount of centralization those states had, they compare light intensity between groups with different pre-colonial institutions, and find that groups with higher degree of complexity and hierarchical structure have better economic performance today (measured in light intensity).[3] Finally, Andersen et al. (2017) show that Cistercians (a monastic order) influenced comparative regional development across English counties, even after the monasteries were dissolved. While I cannot employ their data in my study since theirs are at county-level, the fact that monasteries were important in development shows that my geo-located dataset of them might prove useful to analyse prosperity around the wall.

[3]Although it is debatable if the same logic of light intensity as a proxy for prosperity also applies for a developed country as England, I use a number of other outcomes to measure economic and social performance to ensure the applicability of my conclusions.

This study would also expand the knowledge in another area of research, namely, understanding and evaluating the extent to which Roman influence affected future outcomes (Dalgaard et al., 2018; Michaels & Rauch, 2018; Wahl, 2017). However, not all studies reach the same conclusions regarding the impact of Roman rule. Dalgaard et al. (2018) show that in areas near Roman roads population and contemporary luminosity is higher. This provides evidence on the importance of Roman roads for long-run economic development. These results are consistent with my findings, although also imply that Roman rule may have had more benefits than only an established set of roads. Michaels & Rauch (2018) find that the Roman influence on city development may have been less in some countries (like England) but remained persistent in others (like France). In the latter country, Roman heritage may have even caused less development, preventing the relocation of cities to more favourable positions on the coast. My results suggest that this may depend on the region of England, but that there is still a visible influence within the British isle, contrary to the common consensus that Roman influence disappeared in England.

Lastly in this topic, but most importantly, is the work of Wahl (2017). In this paper, the author uses the frontier of the Roman empire between the Rhine and the Danube and -as Michalopoulos & Papaioannou's (2013)- light intensity as a proxy for economic progress, finding considerable advantage in the Roman area. While Wahl's work has arguments similar to mine for the use of an RDD, I argue that Hadrian's wall has advantages compared to the German frontier. The topography around the wall is much more similar than in the case of Germany. He argues that this frontier is optimal since "it is the only one that is not identical to an important contemporary political border (like that between England and Scotland)", while in fact, as seen in Figure 1, there is a big portion of England North of the wall.[4] Furthermore, the *limes germanicus* (the frontier in Germany analysed by the aforementioned author) changed its position several times through history.[5] The longest time a single frontier stood was for about a hundred years, giving less of a discontinuity than Hadrian's wall, which stayed immovable for almost three hundred years.[6] Nev-

[4]Nevertheless, it is important to note that, when using most bandwidths, some areas of Scotland are included in the regression, in particular for data at pixel level. This makes it likely that at least some of the effects I find are influenced by another discontinuity, which must be taken into consideration. However, a lot of my datasets -in particular those at parish level- correspond only to English territory, meaning the positive and significant effects I find are not dependent on Scottish discontinuity. As for the outcomes where both countries are included, I run an exercise in order to test if my results are robust to Scottish rule and find reassuring estimates (see Table A.2).

[5]From the Flavians who more or less formalized a long, unified wall, to the Antonines who stretched it even further.

[6]This is not to say Romans never ventured farther North. In fact, 15 years after the completion of the wall, Emperor Antoninus Pius built another wall near modern day Edinburgh and Glasgow. However, said wall was

ertheless our results are consistent with each other.

Finally, this paper sheds light on another key issue: the differences in development between the North and South of the British main island. There are not only differences in economic prosperity, but also in voter's behaviour, religion and language,[7] that could be explained in part by the Roman's presence (or lack of it). Authors Fritsch et al. (2020) investigate cultural and social issues in the Roman and non-Roman parts of Germany. They find that people living in the ex Roman area of Germany "score indeed higher on certain personality traits, have higher life and health satisfaction, longer life expectancy, generate more inventions and behave in a more entrepreneurial way." While this work lacks the type of identification strategy I use, it is particularly useful for future research and expansion of the present work. In the next section, I will explain in detail the empirical strategy of my work and illustrate why it may be particularly valid.

3. Justification of the Empirical Strategy

The history of Rome expands for over two thousand years.[8] In those years she goes from Monarchy, through Republic to Empire. It is not the purpose of this work to describe all of Rome's history, but it is still necessary to understand some of her past. Roman possessions covered modern France, England, Spain, northern Africa, Egypt, Turkey, Syria, the Balkans, and more.

The conquest of Great Britain took place around the year 43 A.D., by Emperor Claudius. Though the island had already been invaded several times (most notably by Julius Caesar), it was not until Claudius that some actual control was enforced, but only in the South-East as a formal province. During the next twenty years the island was explored and small tribes were annexed for different reasons, such as open rebellion (as the one of the famous queen-warrior Bouddicca). While Nero was emperor, his general Gnaeus Julius Agricola successfully finished dominating Southern Britannia, and was recalled from the province by the new emperor Domitian when Nero died, even though Caledonia (today Scotland) was not put under Roman rule. The province was left like this for about fifty years, and although some incursions were made further North, the distance from the capital made it hard to coordinate.

abandoned after only 8 years because of the problems mentioned before. After that, the wall remained the border until the collapse of the Empire.

[7]See The Economist article Britain's great divide: https://www.economist.com/leaders/2013/04/20/britains-great-divide.

[8]From it's mythical foundation in 753 B.C. until the fall of Constantinople in 1453.

This is what is key in my empirical strategy. There are several reasons why the wall was constructed, and most importantly, why it was built in that location. By far, the element that stands out is the distance from Rome. When Hadrian came into power in 117 C.E., his policy of stopping the expansion of the Empire was mandatory. After him, no more provinces were created until the Empire's fall,[9] and instead of conquering belligerent people near the frontier, Rome would simply protect it instead of expanding it. The Empire we remember today has the borders Hadrian created, called *limes*. Since a frontier was to be made in Great Britain, Hadrian chose the northernmost point in the island with the shortest length possible, therefore leaving any tribe from the North outside of Roman rule. Rome had good cartographers and knew that this was exactly where this stood.

Since the wall was in a possibly random place North of Roman rule, it can be assumed (to some level) to be exogenous or arbitrary. Thus, this gives me exemplary conditions to run a geographic RDD, for there is a sharp, semi-arbitrary difference, that separates potentially similar tribes, to which some of them Roman rule was provided, and to others it was not. As Haskett (2009) says: "Hadrian chose to locate the wall between the Tyne and Solway Rivers. It was built quickly, it was built of permanent material, and it was built to secure the province and Romanize the Britons." He also states that the wall divided part of the Brigantes[10] tribal territory, "placing a portion of their territory within the [Roman] province." This goes to show that the placement of the wall is "as good as" random, guaranteeing the key assumption of an RDD: those who just barely received treatment are comparable to those who just barely did not receive treatment.[11]

Another proof of the random placement comes from a key section of Bede's *Historia Ecclesiastica*[12] written in 730 A.D., where he says "[the Romans] constructed a strong stone wall from sea to sea, in a straight line between the towns that had been there". This is important because -according to Bede- it truly was exogenous, which can be seen in the fact that the wall went through towns that "had been there". After the separation and collapse of the Western Empire, the Legions were withdrawn for England, not to be seen again by Britons.[13] Although most of

[9]Except for a small one in Africa by the Severus dynasty.

[10]A tribe of Northern England.

[11]Another advantage of my study case is that the sample cannot manipulate their treatment status, since it was the Romans -and not the locals- who decided who stayed in and out.

[12]Book I Chapter 12.

[13]This is also relevant! Unlike other provinces, Roman Brittania was **evacuated**, not pillaged or destroyed, as Mommsen & Dickson (1832) say.

Roman government forms disappeared, the infrastructure her architects built did not. Today only a few sections of the wall still stand, but for at least six hundred years it remained erected.[14]

This, however, is not enough to assert that whatever discontinuity to be observed is due to the wall. If the wall was located on a location that, while random, had significant discontinuity in some variable, one would not be able to isolate the impact of the wall itself. Therefore, I provide evidence that there are no discontinuities around the wall in observable characteristics. This is important, since these characteristics show that Romans built the wall in a rather arbitrary spot and not because lands North or South were better for settlers (e.g. in terms of crop quality). Here I provide a spatial RDD in order to check for difference in both elevation and soil quality:[15]

Table 1: Balance Checks

	Elevation		Soil Quality		Crop Yield 1801	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Roman	-10.039	-7.540	.209	-.018	-.143	.265
	(7.928)	(8.105)	(.166)	(.234)	(.667)	(.972)
Mean	113	128	32	32	4.863	4.863
Obs	2816	5592	7078	6943	54	54
Bandwidth in km	5	11	14	13	22	22

Note: Columns one to four are at pixel level. Columns five and six at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$ Bandwidths reported are using Calonico et al. (2014) optimal bandwidth

As seen in Table 1, there are no statistically significant discontinuities between the North and the South of Hadrian's wall, neither in altitude, soil quality (both at pixel level) or crop yield in 1801 (parish level). Furthermore, the magnitudes are relatively small compared to the mean values, suggesting that both sides of the wall were similar before the arrival of Rome.[16]

[14] It is important to note (though it would deserve another paper) that Roman roads and buildings were incredibly durable, created to sustain all kind of weathers with barely any maintenance.

[15] Since soil quality is usually unobservable, I proxy it by the amount of silt on the pixel's earth. "Silty soil is usually more fertile than other types of soil, meaning it is good for growing crops. Silt promotes water retention and air circulation. Too much clay can make soil too stiff for plants to thrive. In many parts of the world, agriculture has thrived in river deltas, where silt deposits are rich, and along the sides of rivers where annual floods replenish silt." National Geographic Enciclopedia: https://www.nationalgeographic.org/encyclopedia/silt/. I also use crop yield in 1801 as a second measure of soil quality.

[16] Plots of these results are available on the online appendix available on my webpage

Continuing with the timeline, after being evacuated, all of Britannia was occupied by Saxons and Jutes. For about 500 years the island was at peace with the outside (save for some Viking raids), until William the Conqueror invaded with his Norman army. After a quick sweep through the country, the island was under Norman control. This marked another period of peace where differences in infrastructure and development in each side of the wall could have been crucial. During this period most monasteries were founded, revealing or confirming which areas were more developed.

Although England was now unified under a king, this did not mean that it had a centralized power. This is relevant because the fact that noblemen and craftsmen SotW had autonomy means they could take advantage of what Romans left, making it a plausible reason as to why the studied area was and is more developed. There are numerous examples of this autonomy. Some of them would be the noblemen rebellion against King John[17] (1215), which would end in him signing the *Carta Magna*, a document that gave more local power to the noblemen. The War of the Roses is another example (1455-1487), since it was a war mostly between the landowner aristocracy and the feudal warlords.

But what happened to the wall? After Hadrian built it in 122, the wall stood as a Roman frontier until the evacuation of the island in 410. As said before, some incursions were made North of it, and also attempts to move the frontier farther North. This is the case of the Antonine wall, a much less imposing structure made of turf, abandoned eight years after its construction, having the garrisons later relocated again to Hadrian's wall.[18] Unlike its little brother to the North, most of Hadrian's wall was made of stone, making it possible for it to survive for centuries. Having justified that Hadrian's wall can be used as an exogenous source of variation to Roman exposure, the following section presents the data and empirical models to be employed.

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https://jtquiroga3.wixsite.com/personalpage. All following results have extra plots for every polynomial and varying bandwidths tests that are not shown here but are present in the aforementioned webpage.

[17]Successor to Richard Lionheart.

[18]This should not go unnoticed. What I'm comparing is a heavily romanized area against a very lightly so. This happens because it's impossible -specially for old societies- to be completely isolated. Some of Rome's influence was transferred to the North, and even Roman roads can be found there. That doesn't mean that there's no effect to analyse. As simply as Roman infrastructure goes, in Section 6 I show that there are considerably more Roman roads SotW.

4. Data and Models

To measure the difference in outcomes between the North and the South of the wall, I use a non-parametric RDD, namely, a local linear regression. This means I only use observations under a certain threshold, which is determined using the optimal bandwidth and bias correction of Calonico et al. (2014). Its general form is:

$$Y_i = \alpha + \beta D_i + \tau S_i + \gamma D_i S_i + \eta_i$$

Where Y_i is the outcome of interest, D_i is the running or forcing variable, which in my study is always distance from the wall normalized to be positive when South of it and negative otherwise, S_i a dummy equal to one if the observation is SotW, τ the coefficient of the treatment, γ the coefficient for an interaction that shows the intensity of the effect of distance and η_i the error. Given that I use several datasets, units of observations vary. For luminosity, modern and intermediate connectivity, monasteries, chapbook licenses, altitude and soil quality, i corresponds to a pixel. For schools and monastery foundation, instead, i correspond to the school or the monestary. Finally, for modern and intermediate population, wills, soldier height and soil quality in 1801, i corresponds to a parish. In order to have robustness in my results, I also run every experiment twice, using a second degree polynomial. Therefore, the second model is:

$$Y_i = \alpha + \beta_1 D_i + \beta_2 D_i^2 + \tau S_i + \gamma_1 S_i D_i + \gamma_2 D_i^2 S_i + \eta_i$$

One important issue is that all these geographic RDD are uni-dimensional. Unlike most cited studies, the wall has the advantage of being (mostly) a straight line in the same latitude. This makes the possibility of a two dimensional analysis futile, since most pixels or data points do not even "touch" the wall if projected East or West. In the following section I run robustness tests to make sure that a straight, almost perfectly horizontal artificial wall has similar effects.

The outcomes of interest are all those that are related to progress or development. That is why this study combines several datasets. Economic prosperity or general wealth is the first outcome I will explain. To measure it in present times, I use nighttime luminosity from 2013.[19] The data were provided by the Defense Meteorological Program (DMSP) Operational Line-Scan System (OLS).[20] This has been previously used as a measure of prosperity for both developed and not

[19]Using pixel level data, which is a thousand metres tall by five hundred metres wide.
[20]All data that is available online will be provided with a link in the Appendix.

developed countries by Wahl (2017) and Michalopoulos & Papaioannou (2013) For intermediate outcomes, I use monasteries and wills as proxies for general well-being of society. Monasteries, abbeys, friaries and priories foundations and placements were obtained through Historic England's webpage "Pastscape". As the section *about* of the page says, "The information on PastScape is derived from the National Record of the Historic Environment (NRHE) which holds records on the architectural and archaeological heritage of England." Using this, a GIS dataset was created from scratch. The Prerogative Court of Canterbury (PCC) wills were extracted from the UK data service and converted into dta. files. The PCC was "a church court under the authority of the Archbishop of Canterbury, which was responsible for the probate of wills and trials of testamentary causes where the value of the goods involved was greater than five pounds." Data are by parish, from 1450 to 1850.

The second outcome of interest is connectivity. Proxies related to this are rather straightforward. For present times, I use the modern railroad lines from 2020. These are available at the OpenStreetMap project. The GIS data on Roman roads were obtained in the Digital Atlas of Roman and Medieval Civilization Dataverse, by Harvard University. Intermediate outcomes are similar on format. The first measure are Ogilby's roads. These are roads published in *Britannia*, an atlas produced by John Ogilby, royal cosmographer, in 1675.[21] I obtained the digital map of the roads from the work of "The Cambridge Group for the History of Population and Social Structure", geo-referenced the image and extracted all roads, creating the GIS file myself. I also measure whether a pixel had a railroad in 1851 or not. These data were obtained from the UK data service.

Thirdly, we want to measure differences along the wall in human capital. The modern proxy for this is school scores in 2018, which was obtained in the Central Government Open Data. GIS of schools are available at the ArcGIS Hub databases. For past times data are less easily available and proxies are less straightforward. I use Licenses to sell Chapbooks in 1697. These were obtained from the work of Spufford (1985). In her book, she located every license given and provided a map showing this (see Figure B.1). Chapbooks were "cheap, popular books typically retailing for 2 pence in the second half of the 1600s. Chapbooks included almanacs, pamphlets, political and religious tracts, nursery rhymes, and poetry. Chapbook sellers were licensed by the government.

[21] "Ogilby's atlas is rightly celebrated in the history of cartography. The pre-turnpike road network is not depicted with any accuracy until Ogilby published his atlas of "principal roads" of England and Wales in 1675. Britannia consisted of strip maps at 1:63360 scale of 85 routes on 100 copper plates which mapped over 7500 miles of road."

Government records on licensed chapbooks sellers survive from the mid-1690s" ((Dittmar, 2011)). In a similar way as with Ogilby's roads, I geo-referenced the map and measured each dot (license) to create the GIS file. I also use soldier height as another proxy documented by the work of Floud (1986) which spans from 1760 to 1879.

The last outcome of interest is population. Modern population by parish in 2011 can be found at the Office for National Statistics and GIS of modern parishes is available at the ArcGIS Hub databases. For older observations, Census data from 1801 to 1951 for every decade was made available by Ell et al. (2004), Parish data on baptisms, burials and marriages from 1530 to 1800 stem from the work of Schofield & Wrigley (2003) and population is measured following Antman (2020). Finally, GIS of the Ancient Parishes of England and Wales between 1500-1850 were created by Burton & Southall (2004), and are available at the UK data service.

To confirm the identification assumptions, data regarding characteristics before the wall was erected was needed. I employ altitude and two proxies for soil quality. Altitude data were released by NASA and distributed by the United States Geological Survey (USGS). Regarding soil quality, I used the amount of silt in the ground and crop yields in 1801. The former was obtained from the International Soil Reference and Information Centre (ISRIC). The latter are available in the UK Data Service.

5. Modern Impacts

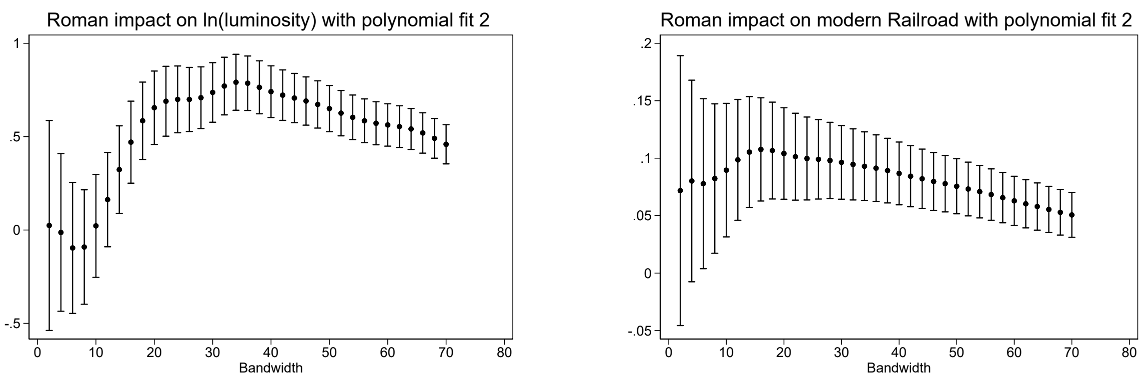
I now employ the strategy described in the previous section to measure the impact of Roman rule on present day outcomes. My first proxy for development is light intensity. The first two columns of Table 2 show that pixels SotW have 56% more luminosity and that the difference is significant at the one percent. Depending on the polynomial and bandwidth, the effects vary from 20-80% more luminosity, almost always significant at least at 10%, most times more. See Figure 2 for the effects varying bandwidth. The Roman "treatment" within the island could have also affected connectivity and physical capital investments. The next two columns of Table 2 show this is also true. Pixels SotW have on average a 10% higher probability of having a modern railroad in present days, also significant at the 1%.

Table 2: Modern Effects

	Luminosity		Connectivity		Human Capital		ln(Population)	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Roman	.2108*	.5681***	.104***	.104***	11.12	11.38	.5324	.6520
	(.1249)	(.1122)	(.019)	(.019)	(8.35)	(8.60)	(.3730)	(.4241)
Mean	2.9624	2.3425	.09066	.06270	45.17	45.59	6.8801	6.8422
Obs	3,576	9,829	7247	16141	72	97	178	256
Bandwidth in km	6.9	18.5	13	28	18	41	21	30

Note: Columns one to four are at pixel level, columns five and six account for every school in England, and columns seven and eight are at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

Figure 2: Varying Bandwidth on Statistically Significant Outcomes



As seen in the next four columns, estimates for human capital and population are noisier, and therefore non-statistically significant. The 95% confidence intervals in school scores suggests that we cannot reject a difference of 29 points from a mean of 45.59. For population, the point estimate is smaller but still corresponding to 10% of the mean, implying that we cannot reject possibly considerable differences in population.

In Appendix figures B.2-B.5 the plot for the results and the estimates for varying bandwidths with other polynomials for all modern outcomes are shown. Results for luminosity and connectivity are robust to bandwidth and polynomial selection. Results for human capital and population remain noisy for all choices of bandwidth.

To show the robustness of these results, I conducted five additional exercises. First, I run a placebo test on those outcomes that were statistically significant, by changing the cutoff to 20km (around the usual optimal bandwidth) either North or South. Reassuringly, I find no effect, meaning the discontinuity is in fact on the wall and not somewhere else. This is shown in Table 3. I also run the same experiment for those outcomes not statistically significant, with similar results (see Table A.1).

Table 3: Placebo

	20km South				20km North			
	Luminosity		Connectivity		Luminosity		Connectivity	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
South	.026	.053	.002	.003	.0073	-.031	-.001	-.002
	(.154)	(.155)	(.011)	(.013)	(.140)	(.123)	(.010)	(0.011)
Mean	3.018	2.769	.097	.086	3.055	2.597	.076	.060
Obs	2951	5307	7289	8977	2474	7121	10929	17739
Bandwidth in km	6	10	12	14	5	14	19	30

Note: All columns are at pixel level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

Second, I run the RDD controlling for altitude for every pixel, as seen in Panel A of Table 4. The estimates remain positive for all outcomes, and luminosity and connectivity keep their statistical significance, except for column two. Third, I represent the wall as a straight line, and not the correctly projected GIS shape, as seen in Figure B.6. With it, I test if there is still a discontinuity in this case. The logic of this is that Romans built the wall where the island was narrowest, trying to make it as straight as possible. Thus, by looking at the discontinuity around the straight line, I am testing for a discontinuity around a more exogenous "frontier" but I am also losing precision as the wall is not exactly where I am testing for its presence. Panel B of Table 4 shows the estimates for all modern effects. Luminosity loses all significance, suggesting that settlements or investments present in the specific areas SotW were tremendously relevant in initial and following development. However, connectivity remains strong and significant, which is probably because the effect Romans had on roads is so big that adding noise to the regression does not affect the results.

Table 4: Robustness Tests

	Luminosity		Connectivity		Human Capital		ln(Population)	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Panel A: Controlling for Altitude								
Roman	.222**	.041	.082***	.094***	11.184	11.162	.509	.510
	(.019)	(.021)	(.019)	(.021)	(8.266)	(8.632)	(.367)	(.399)
Mean	2.842	2.657	.092	.073	45.384	45.564	6.802	6.818
Obs	6986	11451	6986	11451	217	231	142	225
BW (km)	9	12	13	20	26	27	17	26
Panel B: Straight Line								
South	.039	-.032	.057***	.052***	7.533	10.811	.557	.806*
	(.090)	(.092)	(.017)	(.020)	(11.561)	(13.309)	(.383)	(.452)
Mean	2.680	2.279	.070	.057	38.589	38.589	6.763	6.781
Obs	5730	10008	12469	18425	75	108	153	217
BW (km)	11	19	23	33	19	47	20	28

Note: Columns one to four are at pixel level, columns five and six account for every school in England, and columns seven and eight are at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

Fourth, one may be worried because the wall is relatively close to the frontier with Scotland. For the parish-level outcomes, the data is already restricted only to England. However, for pixel-level outcomes, for most bandwidths, some areas of Scotland are included in the analysis. This may be worrisome since the modern border between Scotland and England may generate a discontinuity. In order to be sure that my results are not dependent on this second discontinuity, I present a small exercise in Table A.2, where I run the same RDD but excluding all Scottish pixels. Connectivity results remain strong and significant. The results for luminosity with the second polynomial (my main specification) are almost identical to the one including Scottish pixels. However, the estimate with a polynomial of degree 1 loses its significance and even switches sign.

As a last robustness test, I run the RDD again for luminosity and connectivity, but using as observations not the pixels but the schools and parishes geo-locations (see Table A.3). This was done in order to check if the lack of significance of human capital and population was because of low number of observations. Reassuringly, I find that all estimates remain positive (except one using a specific polynomial), but lose all significance. This suggests that there may be a significant effect on human capital and population, yet it remains hidden due to insufficient statistical power.

In general, the robustness checks suggest that the connectivity results are extremely strong and consistent no matter which specification is employed. Results on luminosity are generally consistent but more fragile in some specifications. The positive and non-significant impact on the parish and school level outcomes persists under alternative methods.

6. Intermediate Outcomes and Discussion

Having shown that modern outcomes display a marked discontinuity around Hadrian's wall, I now turn to exploring intermediate outcomes. Was the impact of the Romans larger in earlier periods, fading away through history? Or instead it became even more important as time passed? In order to test this, I take each outcome presented in the past section, and run the same exercises with intermediate outcomes (i.e. after the fall of Rome but before modern days) that relate to them. As proxies for prosperity (luminosity) I gathered data on monasteries (1000-1300) and wills (1450-1850). Table 5 shows the results, where the first two columns include as an outcome the year monasteries were founded, the next two if the pixel has a monastery on it and the last two wills left by parish.

Table 5: Prosperity Intermediate Outcomes

	Foundation of Monasteries		Presence of Monastery		Wills	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Roman	-90.4**	-112.6***	.022***	.018**	.458***	.412***
	(37.3)	(42.3)	(.005)	(.008)	(.116)	(.122)
Mean	1,170.3	1,170.3	0.00815	0.00783	1.258	1.243
Obs	25	25	19140	20566	390	572
Bandwidth in km	25	24	33	35	14	23

Note: Columns one and two account only for geo-located monasteries. Columns three and four are at pixel level. Columns five and six are at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

As can be seen in the first four columns of the table, monasteries were founded on average a hundred years earlier SotW, and every pixel had a 2% higher probability of having a monastery if it was located SotW. The results are again very statistically significant: for all specifications at least at the 5%. As for wills, the last two columns of Table 5 show that parishes SotW leave on average 0.43 more wills out of a mean of 1.2 will per parish, significant at the 1%. The effect sizes are around 10-250%, thus implying that there is not a large decline in magnitude between these historical and modern measures of prosperity. In Appendix figure B.7 we can see that the effects are robust to varying bandwidths. In Table A.4 of the Appendix we can see that the effect of wills is not driven by a certain time (given such a long period of centuries), but instead the effect is always positive and significant pre and post Industrial Revolution (it does become even stronger after it). This suggests that at the start of the second millennium there was still a large and positive influence left by the Romans that affected the formation of rich, urban (and potentially cultural) centers. In the same way, it impacted general prosperity, as more wills were left SotW through 1450 and 1850.

The second outcome to analyse is connectivity. Finding a proxy for this is easier than with prosperity, since any form of general roads can be used. For intermediate outcomes I gathered Roman roads, Ogilby's roads and the 1851 railroad. As can be seen in the first two columns of Table 6, there is a 16% more chance of the pixel having a Roman road near itself SotW, significant at the 1%. That more Roman roads are found SotW seems tautological, since we are comparing Roman with not Roman. However, it is useful to test if the area was indeed more "Romanized" than NotW. We also see in the next two columns that pixels SotW also have around 12% more chance of being near any of Ogilby's roads. This is smaller in absolute and relative term than the coefficient from Roman roads, suggesting that Roman influence faded slightly over time. Finally, all pixels SotW has a 12-13% more chance of having a railway near it in 1851. The similar magnitude between the middle and the last columns suggest that, while less marked than originally, the difference between North and South remained constant in the post Roman times. In Appendix Figure B.8 we can see that the effects are robust to varying bandwidths.

Table 6: Connectivity and Physical Capital Intermediate Outcomes

	Roman Roads		Ogilby		1851 Railroad	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Roman	.168***	.161***	.137***	.096***	.120***	.132***
	(.021)	(.019)	(.021)	(.027)	(.020)	(.019)
Mean	.07884	.05743	.09841	.09701	.08694	.06703
Obs	4376	11300	9928	10329	7465	15753
Bandwidth in km	8	20	18	19	14	27

Note: All columns are at pixel level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

The third modern outcome presented in Section 5 that I will analyse here is human capital. By far, this is the hardest one to find proxies for. In the past section I used school scores. Here, I use two very different ones: chapbook licenses and soldier height. The first one is more straightforward: locations where more licenses to sell chapbooks were given were more likely to have a higher demand for them, and in turn were more likely to have a higher level of human capital (such as the ability to read). On the other hand, the second one is somewhat less clear. Height is very dependent on nutrition in infancy, so it is a measure of how much care did children receive South and North of the wall. In Table 7 I show the results, where the first two columns show the number of chapbooks licenses given by pixel in 1697. In the same way as in the modern age, for chapbook licenses I find that results are not small, however, they are too noisy to be able to identify an effect in human capital. The coefficient is large and positive, even more so considering the small mean. For soldier height, instead, it is negative. However, I could reject effects larger than 1 inch out of a base of 68, which is proportionally small. Interestingly, as seen in Figure B.9, soldiers SotW were significantly taller when using small bandwidths and a polynomial of order 1. This suggests that there might be a discontinuity in terms of height in the immediate neighbourhood surrounding the wall. Nevertheless, this effect must be analysed with caution, since there is a limit to what I can measure with the data. The effects for varying bandwidths are reported in the Appendix Figure B.9.

Table 7: Human Capital Intermediate Outcomes

	Chapbooks Licenses		Soldier Height	
	Poly 1	Poly 2	Poly 1	Poly 2
Roman	.042	.068	-0.184	-0.360
	(.045)	(.073)	(.680)	(.735)
Mean	.00299	.00277	68.17350	67.76489
Obs	23762	29278	103	174
Bandwidth in km	40	48	35	48

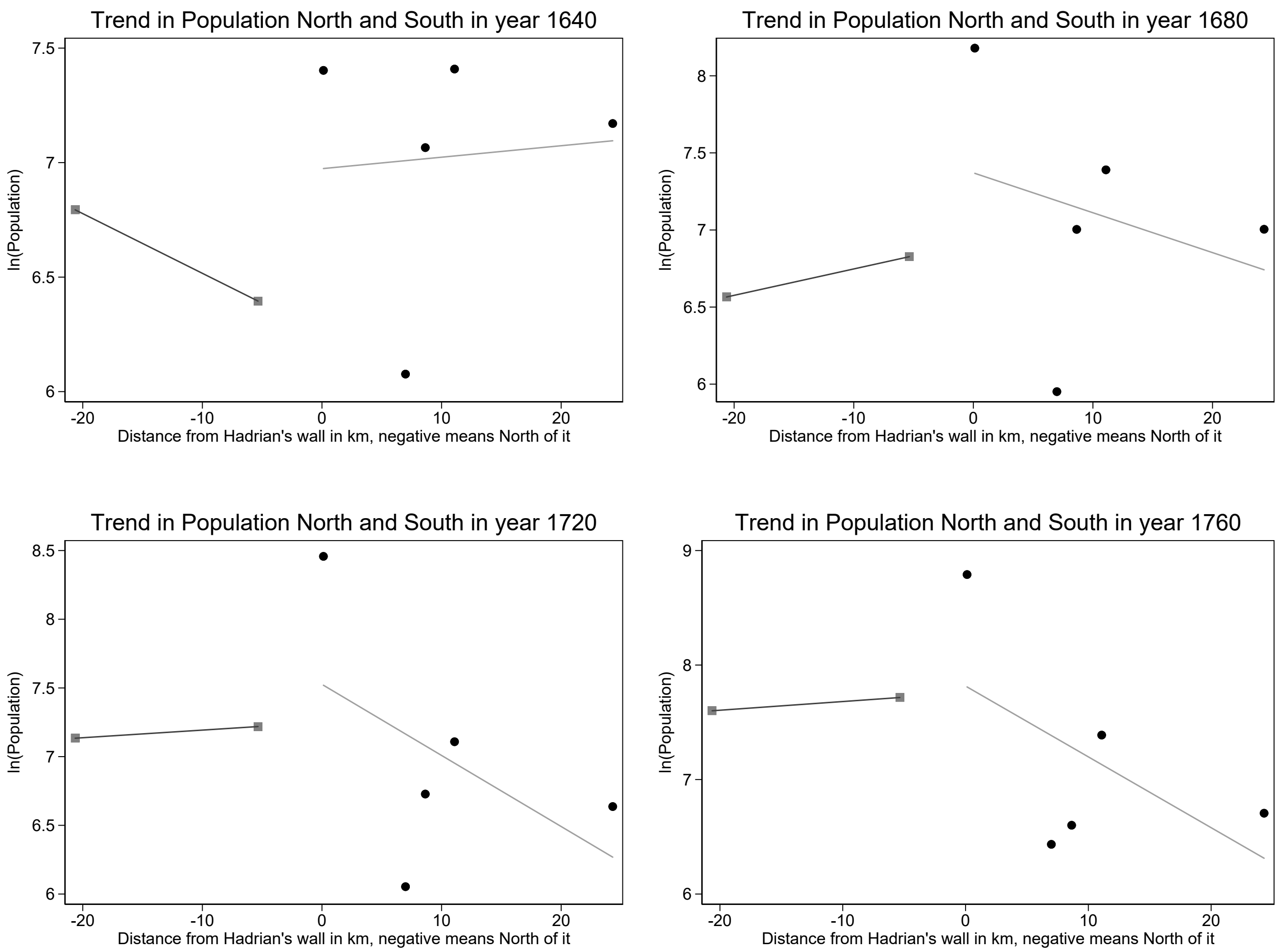
Note: Columns one and two are at pixel level, columns three and four at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

The final outcome to analyse is population. Unfortunately, data on population around the wall is scarce, particularly as we look further past. In Figure 3, I show the estimated population for parishes around the wall for years 1640-1760. The graphs suggest that before the industrial revolution, there was somewhat of a discontinuity in parish population, although after it it disappears.[22] The lack of discontinuity holds true when looking forward. I run an RDD for every decade that had a census from 1801-1951, and find out there's no effect in $ln(population)$ given by the wall's discontinuity, as can be seen in Appendix figures B.11-B.12. This also holds true when looking at baptisms, as seen in Figure B.13.

There is still the question remaining of the origin of these effects. In other words, through which channels did the differences shown before appear and persist? As Dalgaard et al. (2018) show, part of the Roman influence was that a road network was built, which until today shapes the

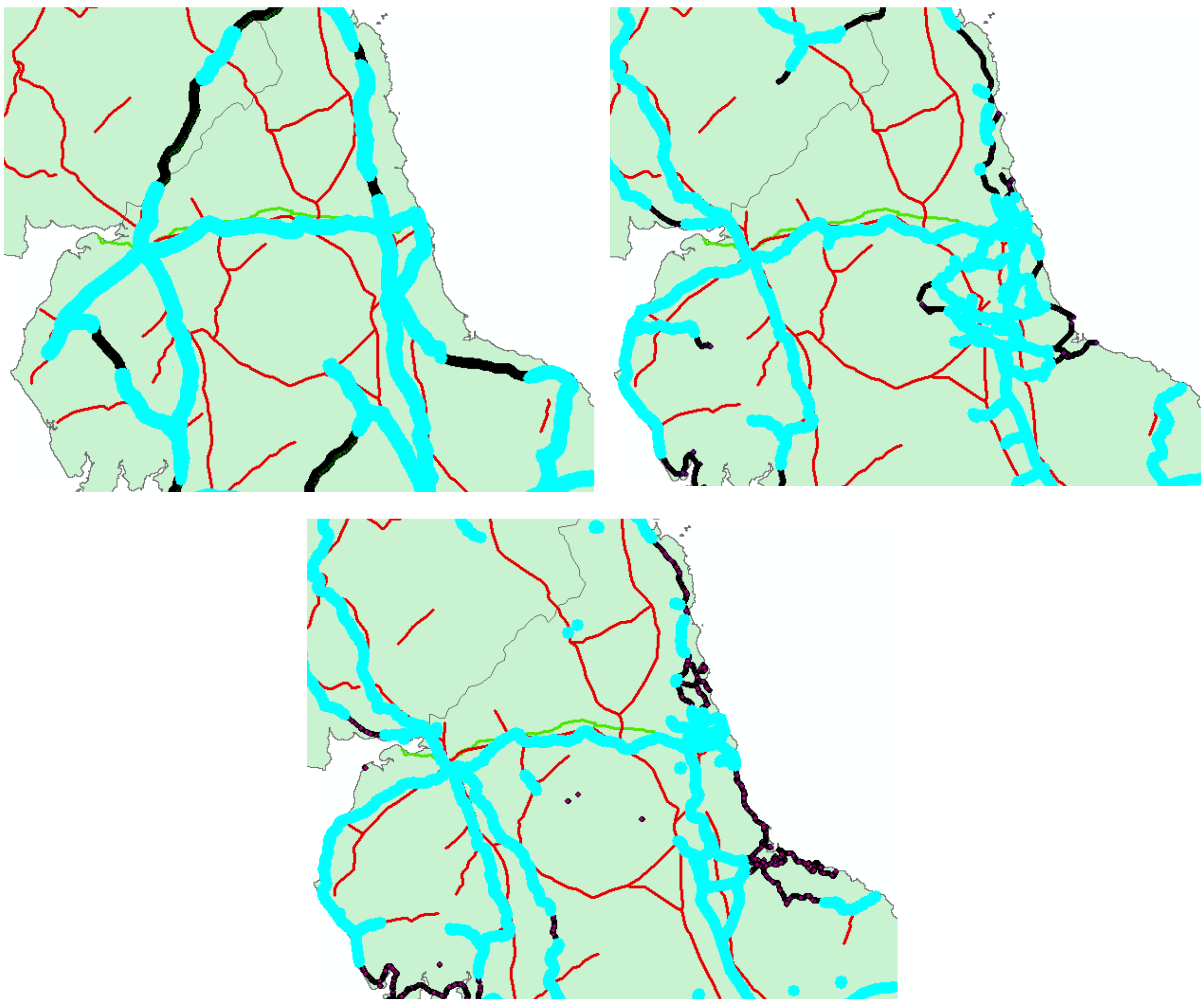
[22]Data is also available for 1800, but it is not shown, because the lack of discontinuity is still there. Nevertheless I added it in the Appendix figure B.10.

Figure 3: Evolution of Parish Population Around the Wall



way roads or railroads are done. Clearly there are more Roman roads SotW, but that determined that a larger number of roads in 1675, railroads in 1851 and railroads today were built SotW. This suggests that the higher connectivity SotW is due to the construction of roads by Romans, and that said influence affected until today the way roads are made in Northern Britain. As a way of showing this in Figure 4 I present the Roman highway and all roads analysed in this work. It is clear that most roads followed the Roman ones, which strengthens my point.[23]

Figure 4: Roman Roads with Other Sources of Connectivity



Note: In red Roman roads, in black other sources of connectivity, in green Hadrian's wall and in blue points of roads that are near Roman ones. The first quadrant shows Ogilby's roads, the second the 1851 railroad and the third the modern one.

[23]Here I use a similar approach as Wahl (2017), where I highlight any road in a 10km radius of the Roman highway. A more conservative approach of 5km shows similar results, as seen in Figure B.16.

But is connectivity alone the legacy left by Romans to Britain? We can measure the effect of Roman roads on luminosity by using a Wald estimator.[24] This means we calculate:

$$\beta = \frac{\delta}{\gamma}$$

Where β is the effect of Roman roads, δ is the impact of the wall (my "instrument") on luminosity, and γ the impact of the wall over Roman roads. By this logic, the impact of Roman roads on luminosity in my scenario would be:

$$\beta = \frac{.5681}{.161} = 3.5285$$

By comparison, Dalgaard et al. (2018) results are 1.635 using no controls, and 0.524 when using all controls. Their effects, however, are mostly driven by Europe. The results for only Europe are 0.760, using all controls (they do not report results for Europe with no controls). The effect that I am seeing is two to five times larger than what Daalgard et al. found, suggesting that in fact it is not only (at least in this local environment) the Roman road network that promoted a higher level of these outcomes, but instead just **being** Roman is the effect seen here. And this effect is relevant, since it is seen almost immediately after the Romans leave, and it is still seen today. Although an important channel through which this effect is transmitted is probably the Roman highway (as Figure 4 suggests), the fact of the matter remains that there might be more than just roads involved in the persistence of overall development SotW.

With the information from intermediate outcomes, I can venture a few hypotheses. I believe the Roman presence forged the landscape of the island, by founding cities, creating a road network and building infrastructure that would impact future growth. The cities founded would remain important trade and commerce centres, and cities would be built where there already was a connected way of transport and infrastructure, beginning a domino effect that would preserve an over development SotW until nowadays. This would explain why monasteries are founded earlier and are more numerous SotW, and also why more wills are left in that area. As explained before, the Roman highway made it possible for all following roads to be constructed in the same way. It is also possible that Romanized Britons had a higher level of sophistication that could have been passed down through generations (very correlated with the fact that they had a higher level of prosperity) and therefore making it likely that there could have been now and before an effect on human capital. Finally, after the Roman evacuation, Anglo-Saxon settlements were more likely to

[24]See Wald (1940).

be established in well connected areas, giving the Roman side of the wall an advantage in early population. As an interesting exercise related to Roman influence on population, I use the calculated parish population for 1600-1800 and run OLS regressions with Roman roads and general public goods, such as aqueducts, theatres and *thermae* (baths) on all the island. I find that getting one kilometre away from a Roman road makes your parish population 0.2-0.4% lower on average, significant at the 1%. The same goes for Roman infrastructure (see Table A.5). This is not a causal effect but a mere correlation, but it does shed light on the Roman influence on population, since it compares area heavily romanized against less ones, and is robust to a number of controls. These results also hold true when looking at every twenty years period, as figures B.14-B.15 show. A last branch of what Rome may have left to the island is a connection with the European continent, which would remain relevant until the industrial revolution and the divergence of the U.K.

7. Final Remarks

Exploiting a plausibly exogenous variation in Hadrian's wall in Northern England, I run a Spatial Regression Discontinuity Design in order to find local effects of having been occupied by the Romans. Using luminosity, connectivity, human capital and population, I find robust positive effects of Roman occupation on the first two, and non statistically significant effects on the second two. The reason behind this unequal growth is due to a Roman wall built two thousand years ago, which I argue to be exogenous by empirical and historical reasoning.

I then use an abundant number of different datasets that represent intermediate outcomes between the Roman evacuation of the island and present day. I find that almost immediately after the fall of Rome, the area SotW already had an advantage in economic development and connectivity, and possible differences in human capital and population. However, not all of them evolve in the same way. Some tend to develop even stronger differences, while others appear to fade out after the industrial revolution. Results are robust to various checks and suggest that the impact goes beyond the simple influence of Roman road networks. Identifying the exact channels is left for future work.

Another aspect that could be studied in the future is health. Since this correlates with physical investments or infrastructure (number of hospitals), it is likely the impact (if any) of Roman rule could have persisted until today. Proxies that could help to analyse this would be child mortality or life expectancy.

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I had always imagined myself as a loner, and it only struck me how wrong I was when I was struggling with whom to thank, for I had too many people to do so and little space. This thesis is the product of a far longer time than these last months writing it, and during that process I have been lucky enough to have met the right people for my life. I would like to write a few paragraphs thanking everyone who made this possible. I am not the most prone person to mellow words, but it is not good for them to be left unsaid.

The ones who naturally come to mind first are my parents. My father, who through his hard work and dedication made my life as easy and happy as it could possibly get. Some of my fondest memories are with you beside my bed, waiting for me to fall asleep after a hard day at work. This small example represents well how far your love and sacrifice can reach. Furthermore, words cannot describe how perfect my mother is. I cannot imagine being born to someone more caring, loving and kind. A lot of people believe their mother to be the best. But they are all wrong. My mother is. Thank you for accepting all my little quirks in the most patient way I've seen. In that same aspect, I thank both my brothers: Rodrigo, for his unconditional love and support, and Sebastián, for taking me out of my confort zone, pushing me forward by believing in me and overall working as a life mentor. I hope you are all proud of what the baby of the family has done, for it wouldn't have been possible without **any** of you.

My friends are also an invaluable part of my life, and therefore, of this work. I thank you Paulo, for your joyful companionship; Calvert, for your constant presence; Ian for understanding as few and teaching me to loosen up; and Alejandro, for *being the Shawn to my Gus*. You all kept me sane in moments I wanted to throw everything away. Just talking or playing with you was therapeutic, and I hope our longlasting friendship survives all tests. Moreover, I want to thank Salchi and his laid back, non judging friendship and reading of this thesis; Max for simply being awesome; Benja, for although you appeared late in my life, we have bonded in a way I have with few and hope to continue to do so; and Bastien, for his unquestioning loyalty, help, understanding and fun in my last years of Uni. Lastly, I want to thank each and every one of the Otop crew. To a boy who never really felt that he belonged anywhere, you have all been a group I am immensely proud and happy to be a part of, and you have done more good than you can imagine by accepting me. In particular, Gonzalo, thank you for being the first one to include me, I shall not forget. Dayz, you have kept me with my feet on the ground and given me encouragement by simply having fun. Bego, your energy, happiness and support has only made my life better and I hope I can give back merely half of it. Finally, Nine: you may feel that you didn't intervene as much as you wanted in these four months, but your care, thoughtfulness and concern were present throughout our four years of friendship. I am so lucky our paths crossed and hope that you remain on it forever.

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Appendix

A. Tables

Table A.1: Placebo for Statistically Insignificant Modern Outcomes

	20km South				20km North			
	School Scores		Population		School Scores		Population	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
South	4.386	6.460	-.392	-.593	-	-	-.091	-.479
	(4.475)	(6.829)	(.385)	(.452)	-	-	(1.175)	(1.433)
Mean	45.217	45.272	6.865	6.817	-	-	6.746	6.867
Obs	140	153	295	420	-	-	71	108
Bandwidth in km	51	63	23	33	-	-	14	20

Note: Columns one, two, five and six account for every school in England. Columns three, four, seven and eight are at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$. There is not enough data North of the placebo border to be able to compute the fifth and sixth columns.

Table A.2: Effects or Roman Occupation on Luminosity and Connectivity without Scottish Pixels

	Luminosity		Connectivity	
	Poly 1	Poly 2	Poly 1	Poly 2
Roman	-.009	.253**	.096***	.094***
	(.146)	(.121)	(.019)	(.023)
Mean	3.054	2.482	.07802	.07022
Obs	2470	7360	8293	11037
Bandwidth	5	15	16	22

Note: All columns are at pixel level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$.

Table A.3: Effects of Roman Occupation Using Parishes and Schools as Outcome Units

	Luminosity				Connectivity			
	Parish		School		Parish		School	
	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2	Poly 1	Poly 2
Roman	.496	.369	-.008	.038	.030	.038	.081	.094
	(.486)	(.636)	(.183)	(.206)	(.090)	(.095)	(.067)	(.071)
Mean	2.973	3.006	4.004	4.007	.07547	.06683	.25506	.23790
Obs	217	231	816	996	212	404	741	971
Bandwidth in km	26	27	23	34	25	44	18	33

Note: Parish columns are at parish level. School columns account for all school in England. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

Table A.4: Wills Left pre and post 1775

	Pre 1775		Post 1775	
	Poly 1	Poly 2	Poly 1	Poly 2
Roman	.197***	.162**	.564***	.559***
	(.072)	(.082)	(.139)	(.153)
Mean	1.071	1.094	1.11224	1.08527
Obs	154	190	294	390
Bandwidth in km	25	30	14	20

Note: All columns are at parish level. Robust standard errors and bias-corrected estimates are reported. $***p < 0.01, **p < 0.05, *p < 0.1$

Table A.5: Overall effects of Roman rule on parishes $ln(population)$

	Roads			Other Infrastructure		
	No controls	PAT	All controls	No controls	PAT	All controls
Effect in parish	-0.00291***	-0.00257***	-0.00444***	-0.00405***	-0.00436***	-0.0043875***
population	(0.0005250)	(0.0005181)	(0.0005255)	(0.0002417)	(0.0002394)	(0.0002442)
Mean		6.44343			6.47318	
Obs		86,470			66,661	

Note: All columns are at pixel level. Robust standard errors are reported, $***p < 0.01, **p < 0.05, *p < 0.1$. PAT columns control for the parish average altitude, distance to nearest port and distance to nearest commerce trade route. All controls cover whether said trade routes or ports were active at different moments in time.

B. Figures

There are a number of figures that are not shown in this Appendix for the sake of brevity. This include plots for every polynomial and every table here presented, and varying bandwidths tests for all exercises. They can be found in the online appendix on my webpage:

https://jtquiroga3.wixsite.com/personalpage

Figure B.1: Licensed Vendors of Popular "Chapbooks"

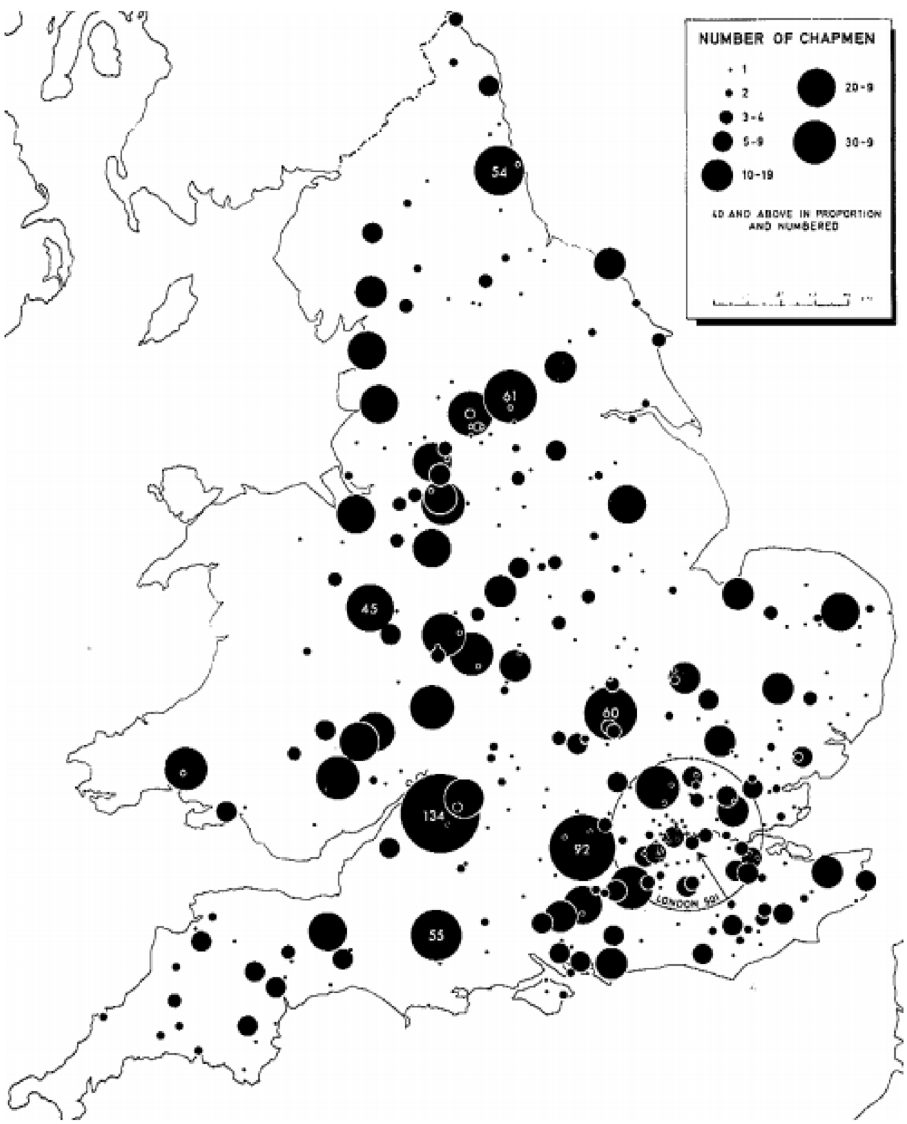
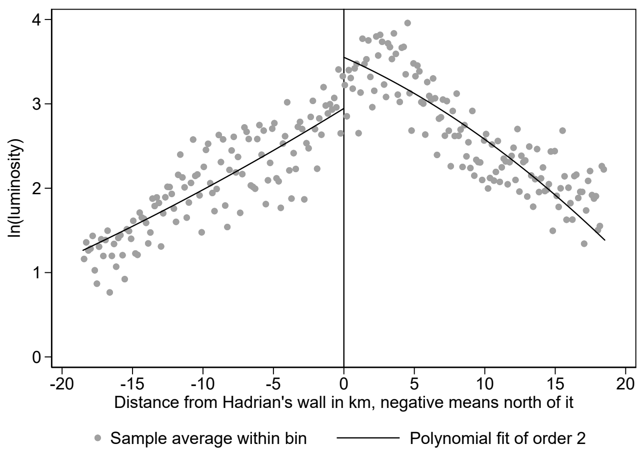


Figure B.2: Modern Prosperity Plot and Varying Bandwidth



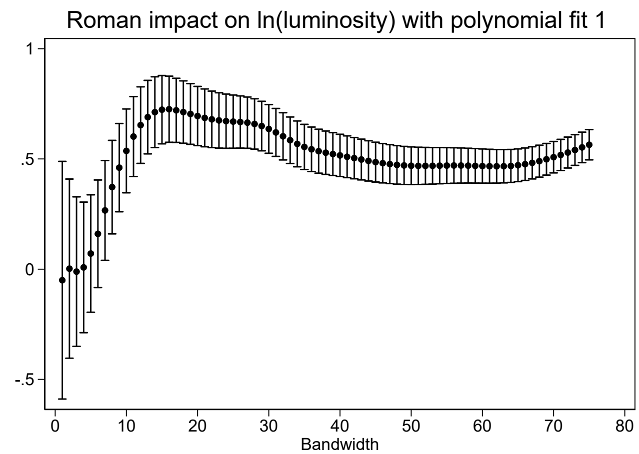
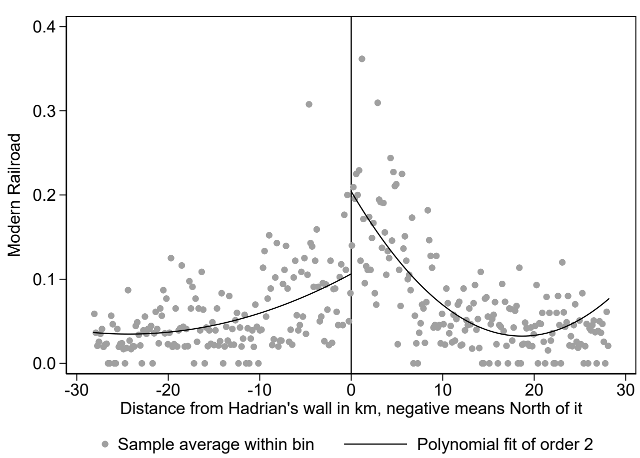


Figure B.3: Modern Connectivity Plot and Varying Bandwidth



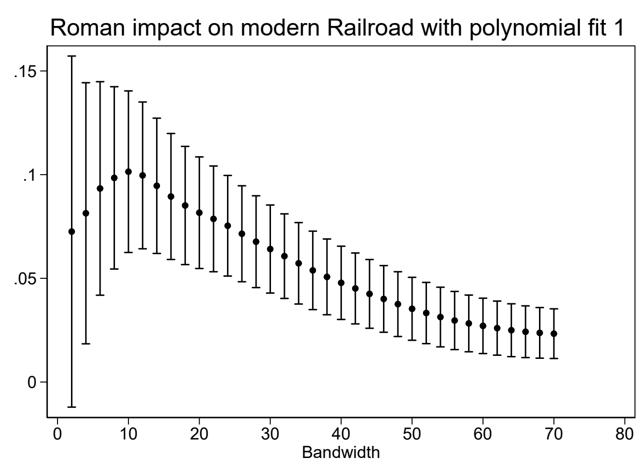


Figure B.4: Modern Human Capital Plot and Varying Bandwidth

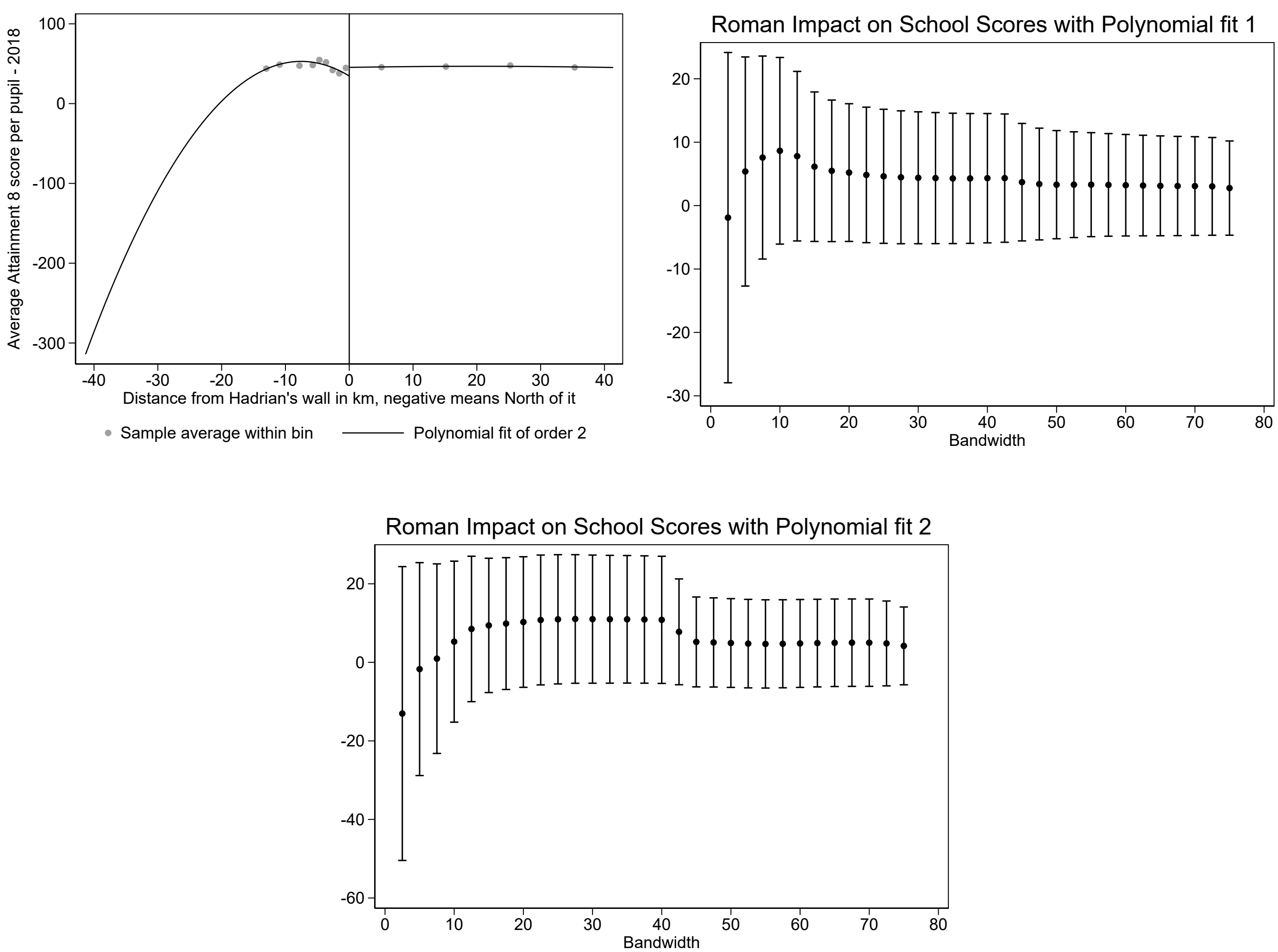


Figure B.5: Modern Population Plot and Varying Bandwidth

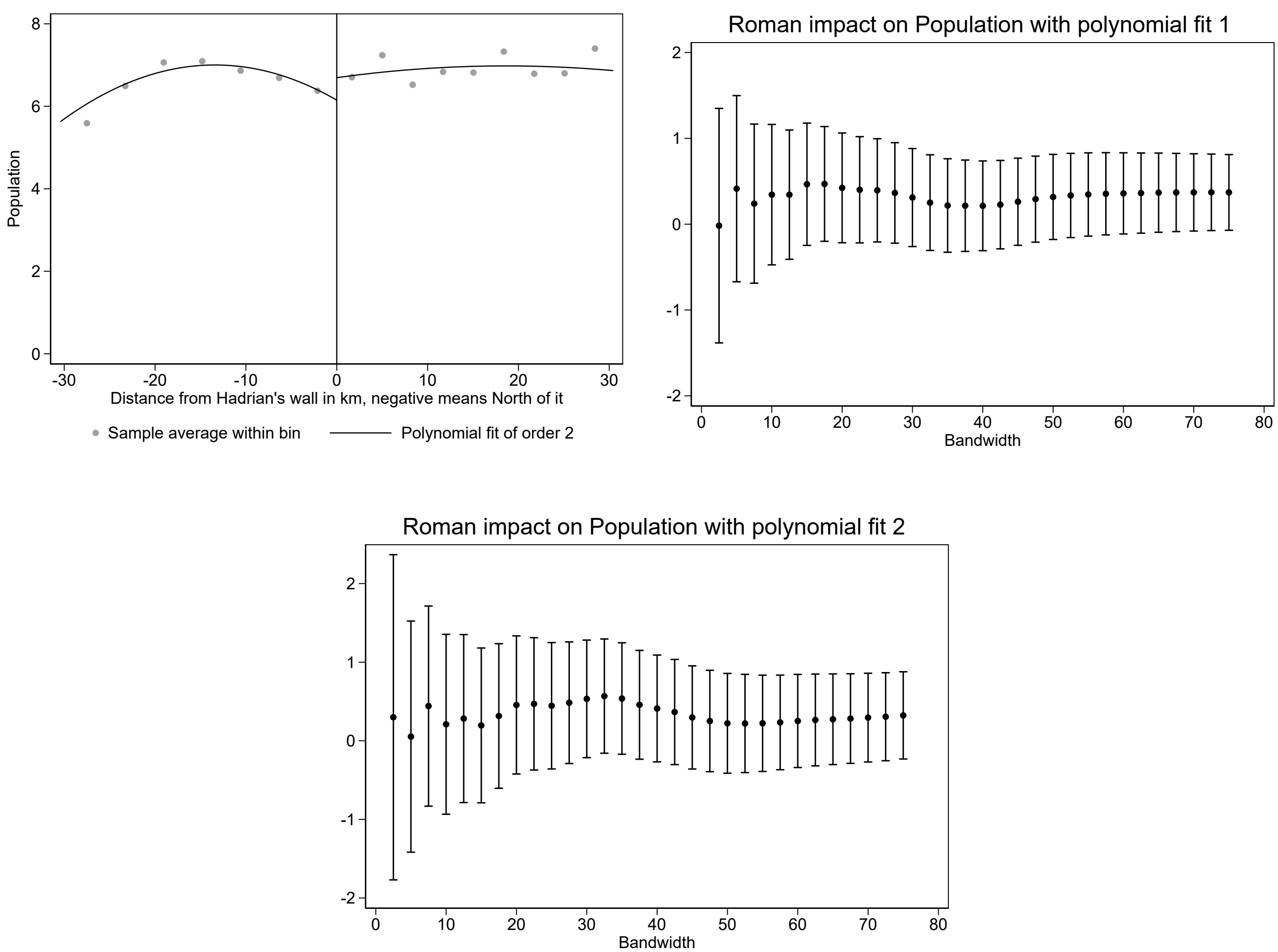
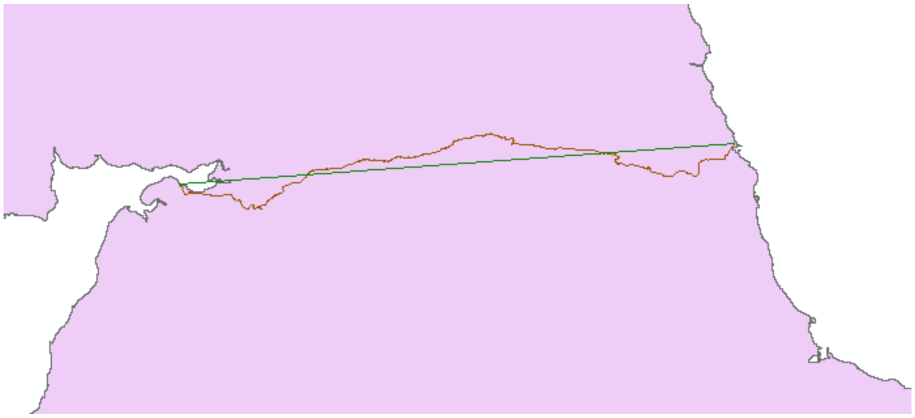


Figure B.6: How a Straight Line Looks on a Projected Map of Northern England with Hadrian's Wall



Note: In red Hadrian's wall and green the straight line.

Figure B.7: Intermediate Prosperity Varying Bandwidth

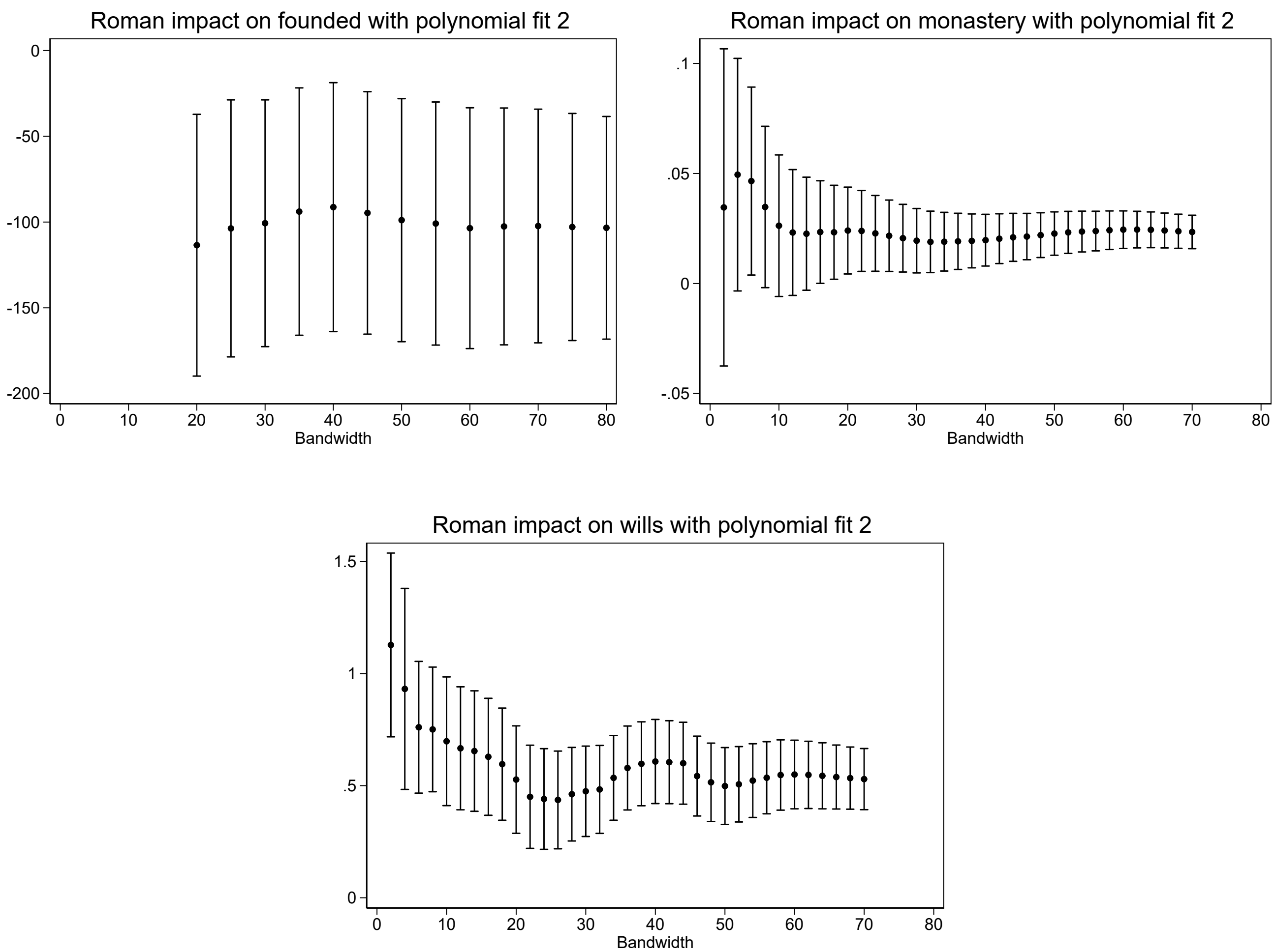


Figure B.8: Intermediate Connectivity Varying Bandwidth

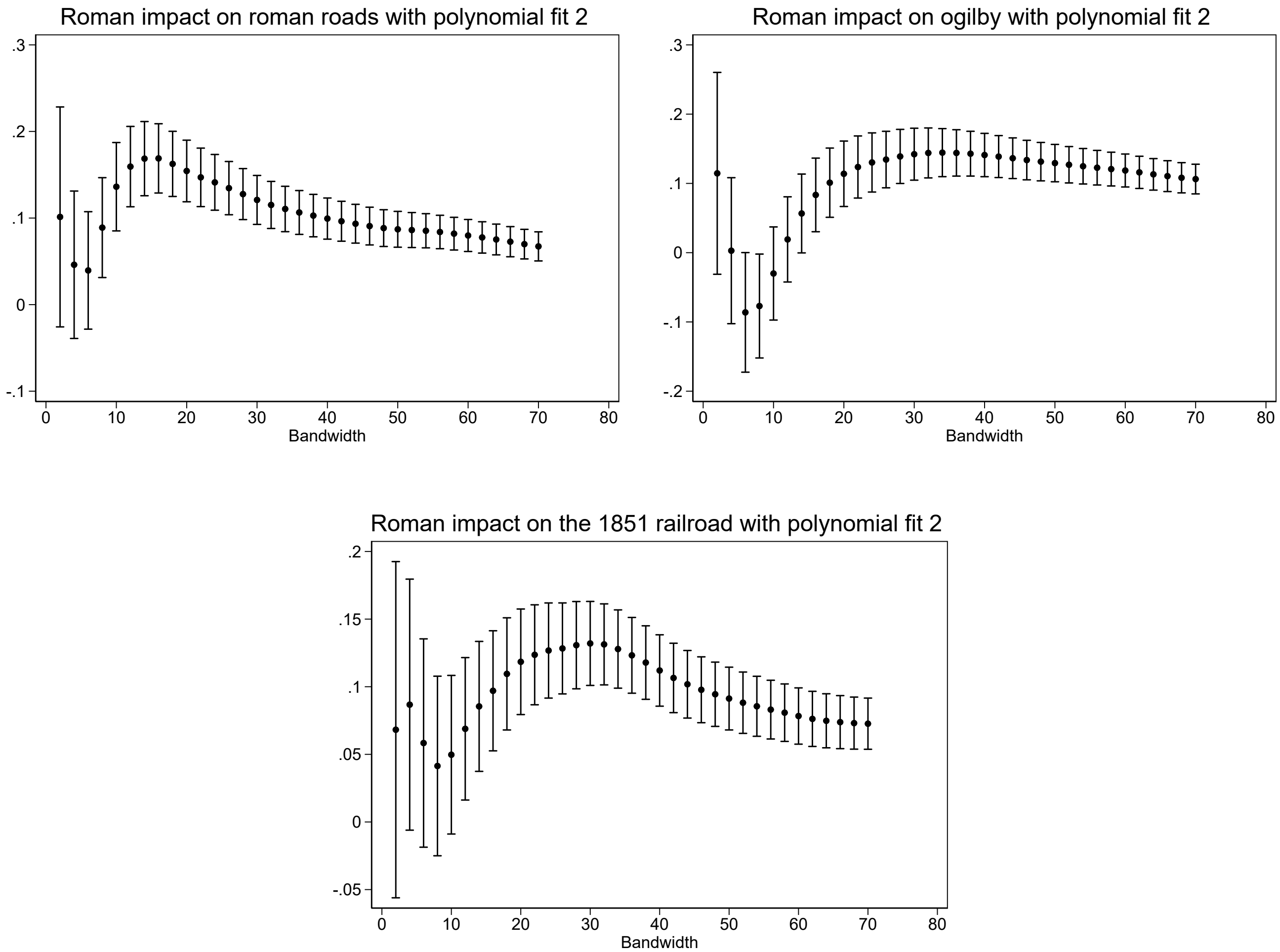


Figure B.9: Intermediate Human Capital Varying Bandwidth

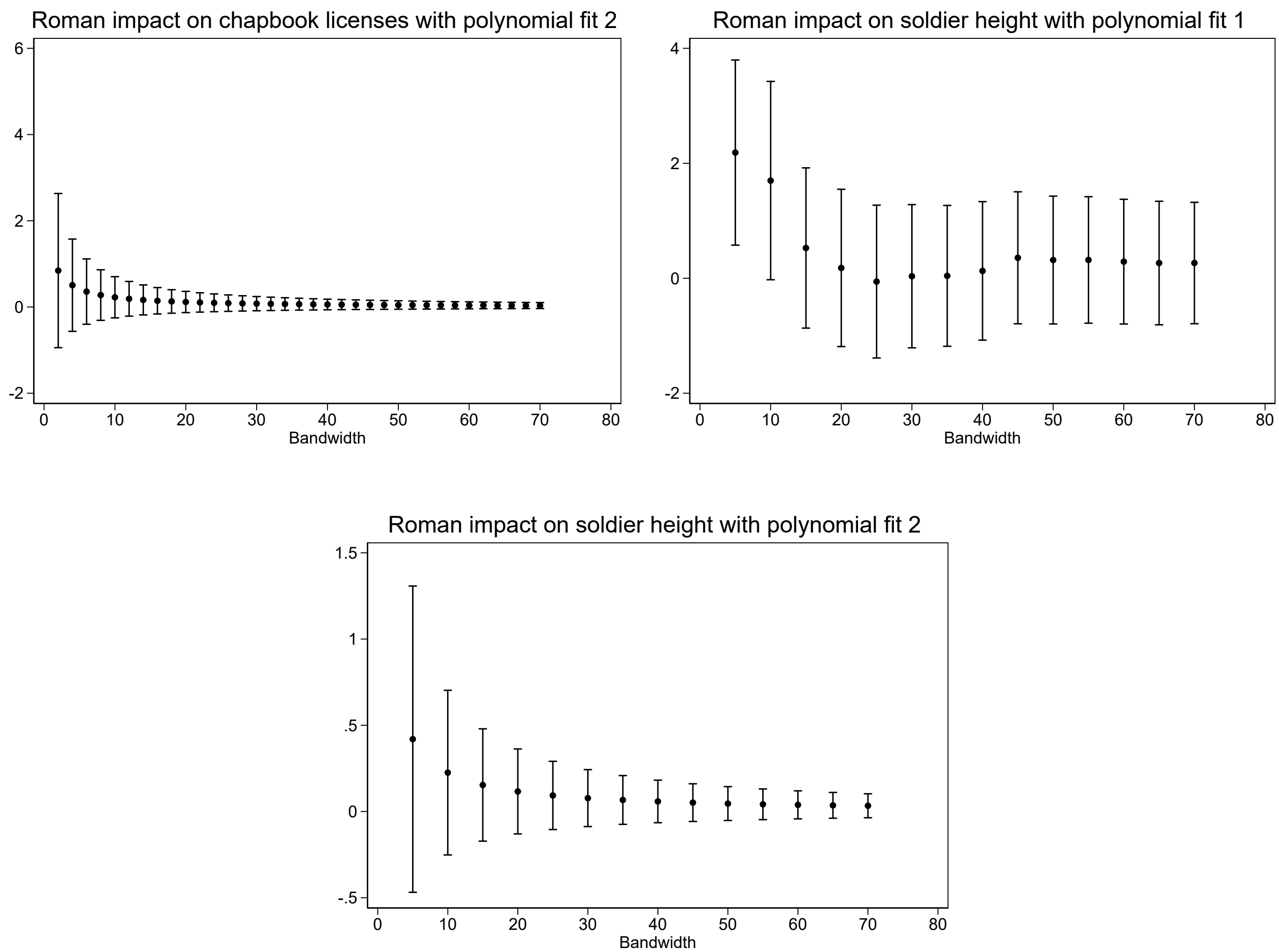


Figure B.10: Parish Population Around the Wall for 1800

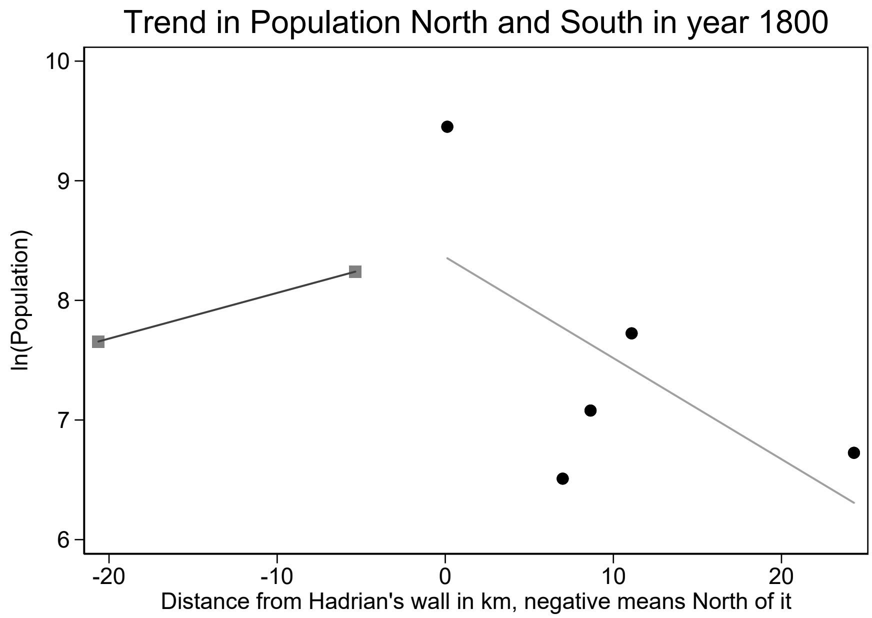


Figure B.11: Evolution of parish population for Polynomial 1

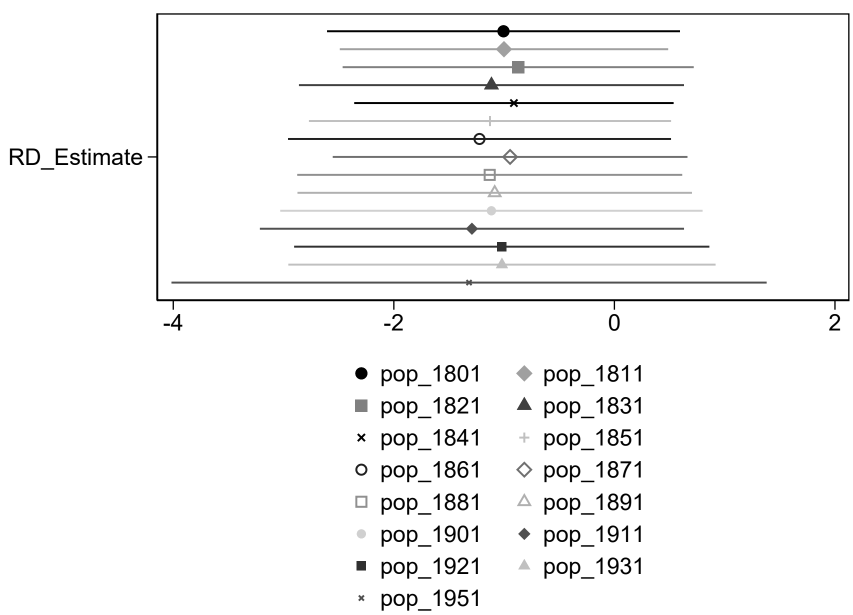
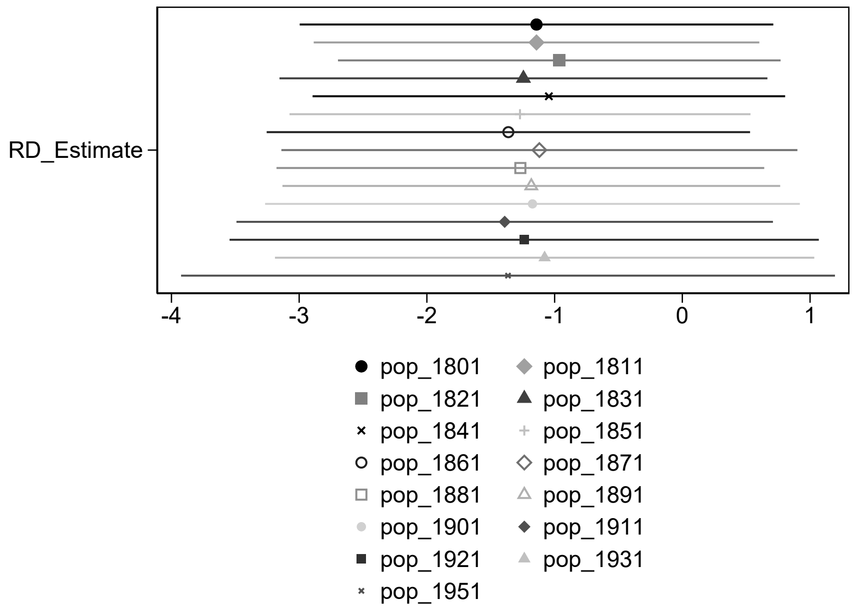
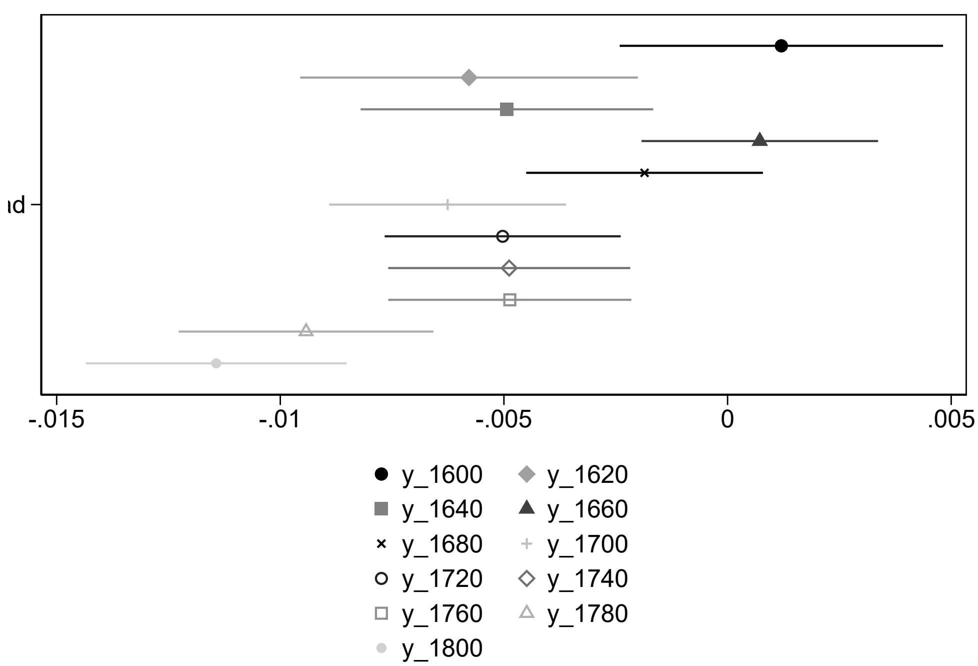


Figure B.12: Evolution of parish population for Polynomial 2



Note: Estimates show 95% confidence intervals.

Figure B.14: Evolution of influence of Roman roads on parish population



Note: Estimates show 95% confidence intervals on $ln(population)$. Every estimate represents past twenty year, e.g., 1620 represents the 1600-1620 period.

Figure B.13: Evolution of Baptisms Around the Wall

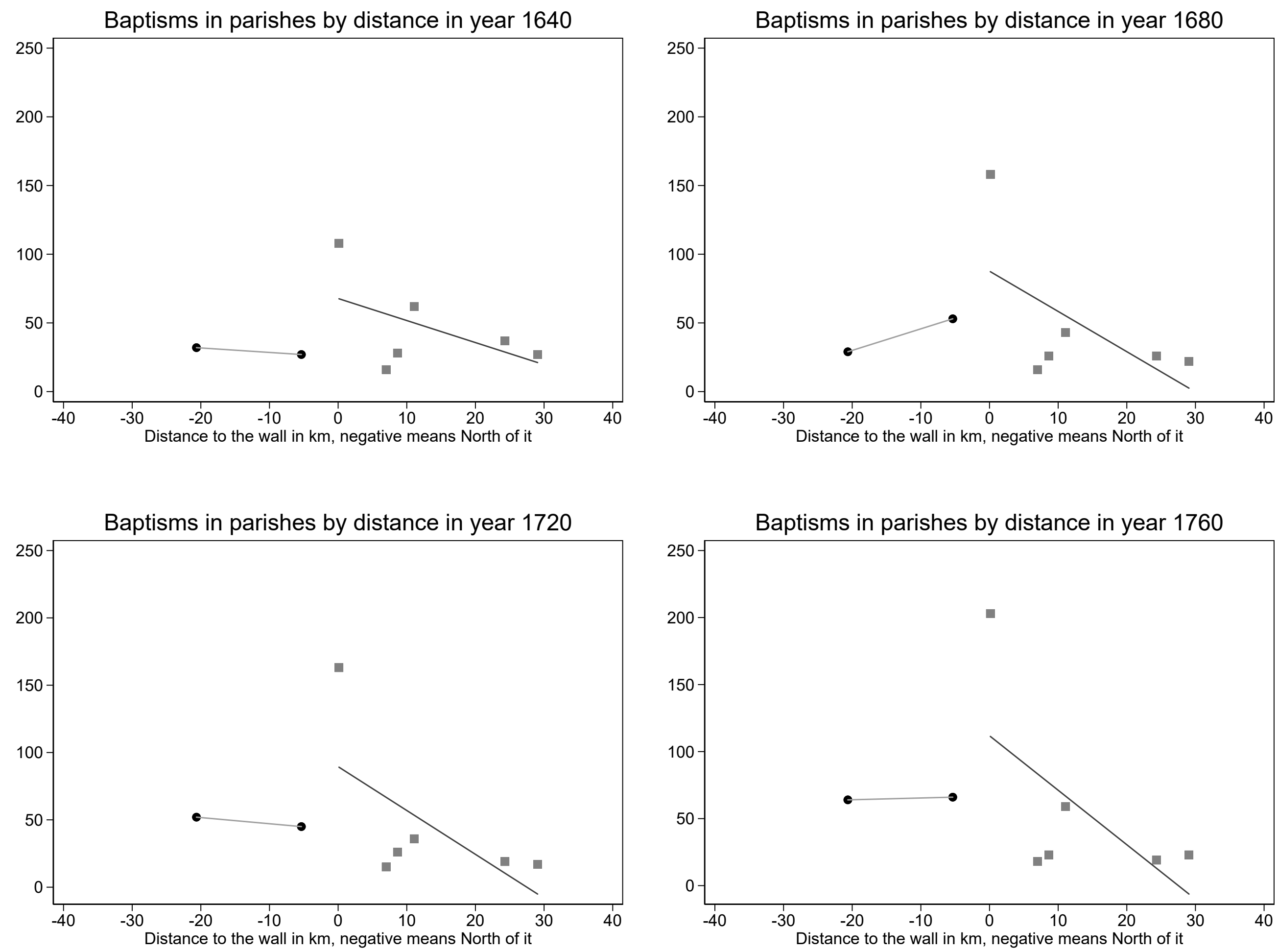
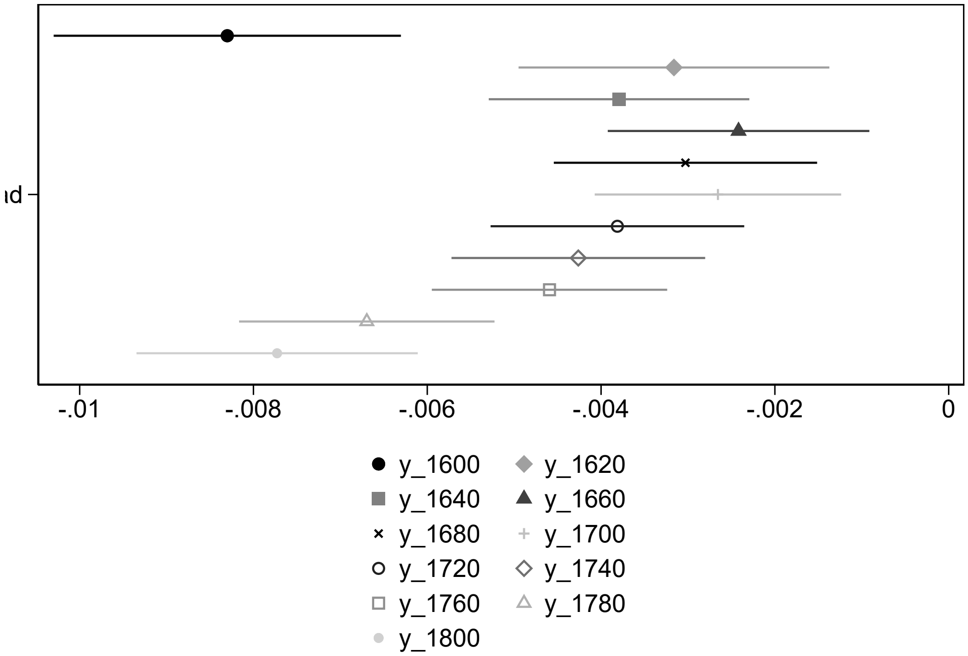
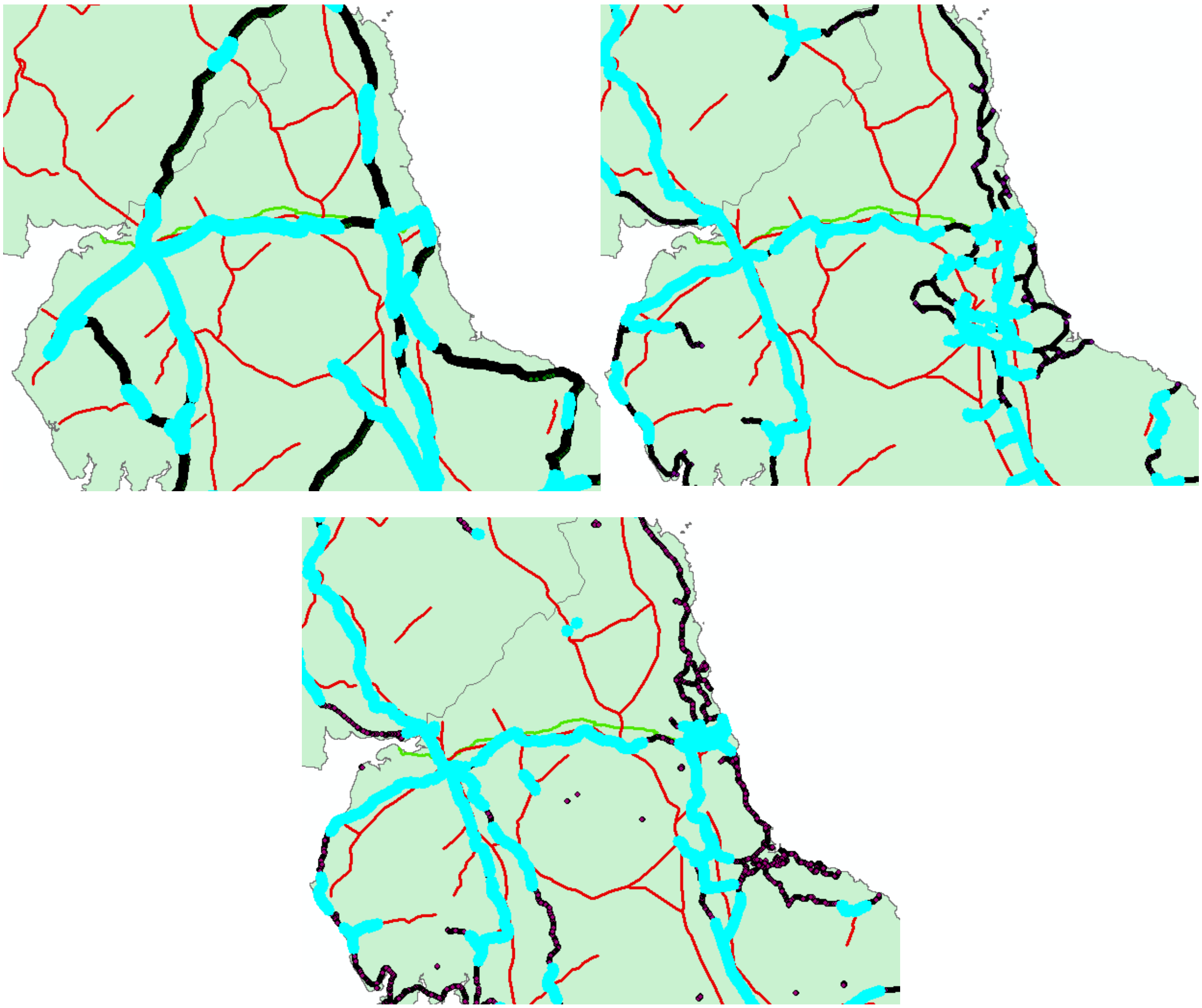


Figure B.15: Evolution of influence of Roman infrastructure on parish population



Note: Estimates show 95% confidence intervals on $ln(population)$. Every estimate represents past twenty year, e.g., 1620 represents the 1600-1620 period.

Figure B.16: Roman Roads with Other Sources of Connectivity



Note: In red Roman roads, in black other sources of connectivity, in green Hadrian's wall and in blue points of roads that are near Roman ones. The first quadrant shows Ogilby's roads, the second the 1851 railroad and the third the modern one.

C. Access to Data

As mentioned in Section 4, some data is available online (others were created from scratch). For all datasets that are, I provide here a link to access them. As it chronologically appears in the thesis:

- Nightime Luminosity:

  https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

- Monasteries, Friaries and Abbeys (extracted one by one with their location coordinates):

  https://www.pastscape.org.uk/background.aspx

- Prerogative Court of Canterbury Wills, 1384-1858:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=4816

- Modern Railroad for all of Great Britain was merged from the separate data files of Wales, England and Scotland at:

  https://download.geofabrik.de/europe/great-britain.html

- Roman Roads:

  https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/TI0KAU

- Ogilby's roads were created by myself geo-referencing the map of "The Cambridge Group for the History of Population and Social Structure":

  https://www.geog.cam.ac.uk/research/projects/occupations/onlineatlas/principalroads1675.html

- 1851 Railroad:

  https://reshare.ukdataservice.ac.uk/852991/

- School Scores in 2018:

  https://www.compare-school-performance.service.gov.uk/?_ga=2.137106803.2117353172.1594265290-1628249307.1586808728

- GIS of schools in England:

  http://hub.arcgis.com/datasets/37297a6b746d483ea4f594a356d6415d_0/geoservice

- The map from Spufford's book I used to create the GIS file can also be found in Dittmar (2011):

  https://www.semanticscholar.org/paper/The-Welfare-Impact-of-a-New-Good%3A-The-Printed-Book-Dittmar/939bb19e943dfc478359f74b5c7bc87c2034230a

- Soldier Height by Floud (1986) can be found at:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=2131

- Modern Parish Population:

  https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/population-

  -estimates/adhocs/009305populationestimatesforparishesinenglandandwalesmid2002tomid2017

- GIS for Modern Parishes in 2011:

  http://hub.arcgis.com/datasets/137b5ea2c69e44dfbc87cf15a4022f8a_0

- Census Data by Parish from 1801 to 1951:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=4560

- Parish Baptisms, Burials and Marriages:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=4491

- GIS of the Ancient Parishes of England and Wales, 1500-1850:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=4828

- Altitude:

  ftp://edcsgs9.cr.usgs.gov/pub/data/srtm/version1/

- Silt:

  https://soilgrids.org/

- Soil Quality in 1801:

  https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=5156