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Abstract

Differential institutions imposed during colonial rule continue to affect the spatial structure and urban interactions in African cities. Based on a sample of 318 cities across 28 countries using satellite data on built cover over time, Anglophone origin cities sprawl compared to Francophone ones. Anglophone cities have less intense land use and more irregular layout in the older colonial portions of cities, and more leapfrog development at the extensive margin. Results are impervious to a border experiment, many robustness tests, measures of sprawl, and sub-samples. Why would colonial origins matter? The British operated under indirect rule and a dual mandate within cities, allowing colonial and native sections to develop without an overall plan and coordination. In contrast, integrated city planning and land allocation mechanisms were a feature of French colonial rule, which was inclined to direct rule. The results also have public policy relevance. From the Demographic and Health Survey, similar households, which are located in areas of the city with more leapfrog development, have poorer connections to piped water, electricity, and landlines, presumably because of higher costs of providing infrastructure with urban sprawl.

Keywords: colonialism, persistence, Africa, sprawl, urban form, urban planning, leapfrog
JEL Classifications: H7; N97; O1; O43; P48; R5

1 Introduction

This paper will show that the spatial structures of cities in Sub-Saharan Africa are strongly influenced by the type of colonial rule experienced. Francophone cities are more spatially compact, with less sprawl and less scattered land development. New developments are less fragmented and disconnected from the rest of the city. Our main findings are based on a sample of 318 cities in 15 former British and 13 former French colonies in Sub-Saharan Africa (excluding South Africa). Using data from 1990, 2000, and 2014, we find that the Burchfield et al. (2006) city-level measure of sprawl - openness - is higher in British cities on average by over 22%. Within cities, Francophone cities have much more intense development at the centre and intensity declines sharply with distance from it. In contrast, British cities have 75% less intense development at the centre and almost flat intensity throughout the city. Along with much higher intensity of land use nearer the centre in older colonial sections, Francophone cities have more of a 'Manhattan' gridrion structure to roads. At the extensive margin of urban development post 1990, we identify new patches of development which can be broken into in-fill and extensions of prior developments versus disconnected, or leapfrog [LF] developments. We find British cities have respectively 72% and 27% higher counts of LF patches and higher ratio of LF to total number of patches of new development. Relative to their Francophone counterparts, Anglophone cities tend to sprawl and leapfrog, as though they were an African Houston or Atlanta.

Why are there such differences? Central to our analysis is the idea that institutions affect urban spatial structures, road layouts, and the degree of compactness. Evidence in the literature suggests that, during the colonial era, the French imposed more centralisation and uniformity in urban governance, with standardised land use planning over the whole city which encouraged compactness and use of an integrated road grid system. The British had more decentralised development within cities, subject to less overall control and planning. The differences in process which reflect aspects of differences in colonial legal systems continue to affect city lay-outs today in two ways. First, Francophone cities were laid out differently and path-dependent historical infrastructure decisions impact urban form for decades. Public capital stocks are long lived and rights of way for roads which are key to laying out a city once established are usually followed, given the high costs of acquiring new rights of way in an already built-up city. Persistence due to prior infrastructure could go beyond the older sections of cities, since post colonial lay-outs may follow existing types of patterns as accretions of older developments. However there is a second influence: the persistence of colonial institutions and norms, with continuation of different legal systems and post-colonial training of urban policy makers.

Colonialism in Africa gives an experiment in which initial institutions are given by the happenstance of what colonial power a city fell under. Trying to distinguish persistence due to long lived physical form versus persistent institutions is difficult, but the context arguably offers an opportunity. In the older colonial areas of the city, persistence may be due to both persistence of physical stocks and of institutions. However the rapid growth of African cities driven by urbanisation allows us to look at what happens at a clear extensive margin, where there is less likely to be persistence of the physical. For 111 cities of the 318 of our cities which are included in the World Cities Data set[1], population grew by 550% from 1960 to 2000, with approximately the same growth rate of Anglophone and Francophone cities. For 249 of our cities for which we have a 1975 measure of the built cover area, built cover grew by 145% from 1975 to 2014.

Why does urban spatial form matter? The literature argues that how cities are shaped and sprawl affects how we live: whether we attain efficient density in the face of communication or social interaction externalities (Rossi-Hansberg, 2004; Helsley and Strange, 2007); how much we pollute (Glaeser and Kahn, 2010); how much time we spend commuting (Harari,

[1] http://www.econ.brown.edu/Faculty/henderson/worldcities.html

2016); and how we interact socially (Putnam, 2000), with sprawl argued to lower positive density externalities, increase pollution and commuting times, and enhance social isolation. On the direct public policy side, planners argue that compactness lowers the cost of providing public services and urban infrastructure outlays. Compact cities require less infrastructure per person in the form of roads and utilities and the opportunity to operate mass transit systems more effectively, with the planning literature offering assessments of the savings from compactness (e.g., Trubka et al. (2010) and Calderón et al. (2014)). Hortas-Rico and Solé-Ollé (2010) provide econometric evidence for Spain in support of the idea.

While this paper offers a positive assessment of compact cities, it is clear there are many ways to live and enjoy life in cities. Apart from Hortas-Rico and Solé-Ollé (2010), there is little econometric evidence on the virtues or not of compactness and evidence can be more nuanced. For example, using data on German neighbourhoods, Burley (2016) corroborates Putnam's hypothesized correlation between socialisation and neighbourhood density, but also presents panel data evidence to suggest that sorting may explain most of this: more social people move to denser neighbourhoods which facilitate socialisation. Of course that means greater density is of benefit to social people.

In looking at development in African cities today, we add a piece of evidence which suggests that urban form and compactness have implications for public service provision. We use Demographic and Health Survey data on utilities in a variety of African cities and find that families have worse connections to electricity, phone landlines, piped water, and city sewer systems, if they live in areas of a city which have more leapfrog development, presumably because of increased cost of infrastructure provision. For hundreds of millions of Africans as they urbanise, the institutions and history under which this happens will affect how they live their lives for better or worse. While we offer a positive view on compactness, for those with a more ambivalent or negative view, the main point remains: colonial origins have a strong lasting influence on the way people live in African cities, and mostly likely other parts of the world.

Our various results are robust to different samples and definitional choices which we will discuss below, to deal with issues of city age, city definition, different takes on the colonial division of Africa, and the like. Our OLS results face the issue of whether the differences arise solely because of colonial heritage or whether there are omitted variables that contribute to this difference. To try to answer this issue beyond having a very extensive set of controls, for the key outcome we conduct a border experiment identifying and matching cities within 100 kms of borders between different pairs of Anglophone and Francophone countries. We find as strong effects for this border sample.

In the paper after a discussion of institutions and the literature, we first establish that Anglophone and Francophone cities have quite different overall urban forms in terms of general measures of openness and sprawl. Then we divide the analysis into two parts. In the first we look specifically at older, more likely colonial sections of cities to establish strong differences there, reflecting at least in part the persistence of the colonial physical setups of cities. Then we turn to the vast extensive margins since 1990 of these rapidly growing cities, way past the colonial era. We introduce a new measure of leapfrog development to establish that Anglophone cities experienced much more leapfrog type development than Francophone cities over the last 25 years. Finally we will look at the impact of leapfrog development and hence sprawl on public utility provision.

2 Colonial legacies: Urban Institutional Choice

The literature on institutions and persistence (e.g., Banerjee and Iyer (2005) and Guiso et al. (2016)) argues that historical institutional accidents can have a strong impact on modern day outcomes.[2] Institutional choices and historical colonial rule have been documented to be significant for contemporary economic development and political stability (Acemoglu et al., 2000; La Porta et al., 2004). More specifically La Porta, Lopez-de-Silanes and Shleifer (2008) argue that having French civil law as opposed to British common law imposed has resulted in differences in regulatory outcomes, banking procedures, property rights enforcement and the like and these differences in turn negatively affected economic outcomes. They argue that French civil law operates to control economic life and remove disorder with less concern for dictatorship (p. 307). Mahoney (2001, p. 505) argues that given the ideological differences underlying the two legal systems, French civil law is more "comfortable with the centralized activist government." Here we examine directly the effect of the imposition of colonial institutions on something as concrete and granular as urban spatial structure. In arguing that these institutional differentials resulted in Francophone cities being more compact, we have potentially a dimension where French central control produced social good.[3]

Consistent with the economics literature, a substantial literature on the history of urban planning in Africa argues that the French compared to the British adopted more centralised and standardised urban institutions within cities. Much of this literature is based on contrasting the 'indirect rule' strategy of the British with French 'direct rule'. The British operated under a dual mandate system and dual structure of local government, under a strategy of indirect rule (Njoh, 2015). Home (2015) develops this theme in detail for Anglophone Africa and other parts of the British Empire: "Native authorities would continue to govern the native population, while townships, largely based on the cantonment model, accompanied the colonizers ... Land laws distinguished between on the one hand, the plantation estates and townships of the European colonizers, and, on the other hand, indigenous

[2] There is the specific work on Francophone and Anglophone colonial legacy within a small area of Cameroon (split into parts which are former British and French colonies) as affecting wealth and water outcomes Lee and Schultz (2012).

[3] In a different vein, Acemoglu, Cantoni, Johnson and Robinson (2011) argue that the imposition of French civil law in the 19th century on areas of Germany which had remnants of feudalism and elitist extractive institutions improved subsequent economic growth (Acemoglu et al., 2011). We have no comment on how colonial rule in general impacted African cities per se, just on the differential impact of two types of rule.

or customary land under the dual mandate approach....” (p.55, 57).

Driven to establish dominance over their colonies and with the stated aim of cultural association and assimilation, French institutions were set up with a goal of bringing all urban land under one control, supplanting all indigenous institutional structures and practices with French varieties, and bringing all public service provision under the local colonial government (Njoh, 2015). While the French may not have always truly adopted a direct rule strategy, any indirect rule was more supervisory of local chiefs than the advisory role under British rule (Crowder, 1964). Durand-Lasserve (2004) writes about the urban dimension to the direct control strategy: “Customary land management is not recognized.....In former French colonies, this situation is clearly linked with conception of freehold as defined in the Code Napoleon, and with the French Centralist political model. It is characterised by: (i) state monopoly on land, and state control over land markets and centralized land management system....”

We interpret these writings as indicating that, at the local level, the French imposed more centralised city planning and land use management, compared to the more hands-off British approach. That does leave open a separate issue of the operation of land markets and how effective the French were at replacing customary rights with private rights. Our focus is more on the the impact of centralised planning and urban lay-out. We also note that, like other European occupiers, the French promoted racial spatial segregation with Europeans often on higher ground. However, largely driven by military considerations and a desire to maintain social order and control over the landscape, the French wanted the different neighbourhoods spatially integrated and linked in a lineal pattern so that from one intersection an official could see 2 kms in four directions (Njoh, 2015, chap. 1). Silva (2015) also writes about how the French adopted centralised and standardised grid systems.

3 The literature on local governance, urban structure and sprawl

The local public finance and urban economics literature looks at aspects of the issue of compactness and leapfrogging. Theory papers analyse the role of an authority with overall control in metropolitan area governance, as opposed to there being either pure *laissez faire* or decentralised governance. There are also empirical papers which examine aspects of the situation.

3.1 Theory literature

An older literature argues that centralised governance by a benevolent city planner will lead to proper internalisation of externalities and provision of localised public goods overall for a city [4], but it does do not deal with sprawl or density. Brueckner (2001) and Brueckner (2005) note that uncoordinated developers will take advantage of the fact that congestion is unpriced, public infrastructure is subsidised resulting for example in ribbon developments sited along government built arterial roads, and the externality value of lost green space at city edges is unpriced. Brueckner argues that all these lead to sprawl.

Recent work examines specific externalities, typically to argue that cities under *laissez faire* have insufficient density. Rossi-Hansberg (2004) argues that, in the face of communication externalities which decay with distance, absent appropriate regulation, cities will lack efficient density of commercial activity near the city centre. Helsley and Strange (2007) develop a model with social interaction externalities for those traveling to work in a central business district. Either laissez faire development or developers with control over only parts of the

[4] Historically, Davis and Whinston (1964) argued in very general terms that zoning is needed at the metropolitan governance level to properly internalize externalities. Hochman et al. (1995) argue that, in the presence of local public goods which have different spatial areas of reach, or jurisdiction, metropolitan governance is needed for efficient allocations and financing. That paper relates to the huge literature on decentralization of governance within countries (see a summary in Oates (1999) and within cities (see Helsley (2004) and Epple and Nechyba (2004) for a summary). On lineal and interconnected road systems, economics has little to say about efficiency, although Yinger (1993) has a model of grid layouts.

city result in inferior outcomes compared to a benevolent city planner, who achieves higher intensity of residential land use. In sum, Rossi-Hansberg (2004) and Helsley and Strange (2007) present powerful arguments that uncoordinated and decentralised land development will result in cities that are less compact as an empirical prediction, with the normative overtone of being less efficient. That said, these papers don't model the political forces needed to induce an omniscient planner to behave benevolently. Nor are they planning papers dealing with the details of city spatial lay-outs and road systems.

Key parts of our paper focus on the issue of 'leapfrogging', examined in two recent theory papers. Turner (2007) examines whether neighbourhoods on the urban fringe will have leapfrog commercial developments. Henderson and Mitra (1996) consider a city with spatially decaying communication externalities across firms and strategic competition by developers setting up new developments on the city fringe. Such developments may be contiguous to old ones or leapfrog. Both papers argue that higher intensity of development in the core city is associated with lower likelihood of leapfrog development at the extensive margin.

3.2 Empirical literature

A key paper by Libecap and Lueck (2011) uses a border methodology to study the allocation of rural land in Ohio under a 'metes and bounds' system versus a rectangular survey system. The former is a decentralised system with plot alignments and shapes defined by the individuals claiming the land, while the latter involves centralised and regularised demarcation of surveyed plots. The authors generally find subsequent strong coordination benefits and reduced transaction costs due to regularity, which they show metes and bounds is less likely to achieve. Their exploration of land demarcation systems in rural areas presents two implications for urban areas. First, similar land institutions in urban areas may be distinguished by their degree of centralisation and standardisation. Second, a more centralised and standardised system in an urban area such as imposing a road grid pattern leads to greater contiguity of the urban spatial structure (Libecap and Lueck, 2011; Ellickson, 2012). The parallels to colonial land demarcation systems were extended more directly to cities by O'Grady (2014), focusing on an example comparing a centralised and standardised rectangular grid demarcation with a more *laissez faire* demarcation system. The idea is that the aggregation properties of rectangles without gaps or overlaps promotes contiguity of the spatial structure. O'Grady (2014) shows that, for New York City, neighborhoods with a greater fraction of rectangular grids imposed centrally and historically then experienced higher future land values and more compactness, or higher density of use.

Other papers examine persistence in spatial outcomes driven by historical infrastructure investments, with Bleakley and Lin (2012) looking at the effect of location of portage areas in the Eastern USA and Brooks and Lutz (2014) looking at the effect of the location of historical tram stops on future local clustering of economic activity within Los Angeles.[5] The key paper on sprawl by Burchfield et al. (2006) analyses geographic and historical influences on the degree of land use sprawl in US cities. Shertzer et al. (2016) argue that 1923 Chicago zoning ordinances have a bigger effect on the spatial distribution of economic activity today than geography or transport networks in Chicago. Redfearn (2009) looks at how land use patterns in USA cities are driven by historical uses.

4 Context and Data

4.1 Colonial countries

Our classification of African countries by colonial origin is shown in Figure 1a along with the cities in our sample. The division is not always straightforward. World War I changed the colonial map, with former German colonies being split among the French (e.g., most of

[5] Michaels and Rauch (forthcoming) look at the differential influence of the fall of the Roman Empire in France versus England on urban population size and growth centuries later, based on the notion that French Roman settlements persisted after the fall, while British ones due to political upheavals disappeared almost immediately.

Cameroon) and British (e.g. Tanzania), with many complex splits vis a vis modern countries (e.g., Togo). If we think governance procedures and urban plans were developed near the end of the 19th century and early 20th before the end of World War I, those procedures could set the tone for decades to come. We would then face the problem of German influences confounding the picture. Omission of these countries in robustness checks has no impact on results. While some approaches to governance and land allocations are in place well before World War I, cities were typically in infancy, so the pre-World War I influence may be limited.

4.2 Data on land use and cities

We utilise three epochs of land cover data - 1990, 2000, and 2014 - which classify pixels of 38m spatial resolution into different uses where our general focus is on built cover (impervious surface) versus non-built cover (water, various vegetation and crop, barren water and so on). These data are constructed from the Global Human Settlement Layer (GHSL) – a new global information baseline describing the spatial evolution of the built environment, a project which is part of the Global Human Settlement Project by the European Commission and Joint Research Centre (Pesaresi et al., 2013). It is the most spatially global detailed dataset on built cover available today. While the data are based on open access Landsat satellite imagery[6] available since 1972 (Ban et al., 2015), the GHSL estimates the presence of built-up areas in different epochs (1975, 1990, 2000 and 2014)[7], using supervised and unsupervised classification processes based on a combination of data-driven and knowledge-based reasoning. [8] See Pesaresi et al. (2013) and Pesaresi et al. (2016) for details. For built up

[6]Landsat data is typically available at 30m spatial resolution. GHSL employs an information fusion operating procedure based on a tiling schema to combine the source Landsat imagery with other data. Discrete zoom levels of the adopted tiling schema imposes further restrictions on effective data resolution - the GHSL project adopts a nominal spatial resolution at the equator of 38.21m which best approximates the native 30m of the Landsat imagery. Please see Pesaresi et al. (2016) for more details.

[7]Pre-processed Landsat scenes were collected for the epochs (1975, 1990 and 2000) from the Global Land Survey (GLS) at the University of Maryland (Giri et al., 2005) and were combined with Landsat scenes for the 2014 epoch to create the spatio-temporal composite. The epochs that characterise the builtup GHSL data approximate the temporal dimension of the GLS data. Epochs signify a time-period range around a given year from which the best available Landsat scene is drawn. For instance, the 1990 epoch for a city i may be drawn from 1988, while it may be 1992 for city j.

[8]Spectral, textural and morphological features are extracted and a supervised classification method relying on machine learning is employed using a global training dataset derived from various sources at different scales – from publicly available

cover we have two types in any year, the stock of built cover from the prior period (defined to also be covered in the current and subsequent time periods) and new cover built since the last period, which we use to analyse the nature of new development.

In applying these data, we have a base sample of 333 cities, of which 106 are former Francophone cities and 227 former Anglophone cities, with the latter including 122 Nigerian cities. These cities are reported in Table A1 and shown in Figure 1a. These 333 cities are all cities in the relevant colonial origin countries which are over 30,000 in estimated population in 1990,[9] which have built cover data for years of 1975, 1990, 2000, and 2014 and are defined by places within a night lights boundary. We use *Citypopulation.de* to get city population numbers (based on Censuses), supplemented with data from *Africapolis* for Nigeria. The Appendix gives details. We set 30,000, because across countries and time there is a difference in population cut-off points for reporting on city populations; a 30,000 cut-off provides more consistency in reporting. We also wanted cities likely to have some degree of maturity to urban spatial development and planning (or lack thereof). We then apply criteria on the extent of persistent cloud cover to get cloud free city-year observations for 2000 and 2014. [10] Removing cities with cloud cover and hence only partial coverage for land cover, in 2000 we have 299 city observations and in 2010 we have 307, with a total of 318 out of 333 cities in one year or the other.

From the base sample, we explore various sub-samples, some noted here. One is West Africa which is distinct as seen in Figure 1a, in that it contains most of the Francophone countries. Another sub-sample excludes Nigeria which is a third of the sample, to make sure

and validated coarse-scale global urban data (MODIS Global Urban Extents, MERIS Globcover and Landscan among others) to more fine-scaled and volunteered geographic information (Open Street Maps and Geonames).

[9]These are based on population censuses around 1990 and with growth to 1990 generally based on city population growth rates between two relevant population censuses.

[10]We require the city-year to be 95% cloud free in 1990 for initial stock variables and 100% free in 2000 and 2014 for flow variables. We lose 49 city-year observations from imposing the 0 cloud cover restriction and 11 more from requiring no more than 5% cloud cover in 1990. If we imposed a 0 cut-off in 1990 for cloud cover, there be a loss of another 65 cities. We use the 1990 built cover within our cities at times as a control variable, when looking at flows to 2000 or 2014. Since 1990 defines 2000 pre-built area, in the 2000 analysis any 1990 cloud cover areas in a city are dropped from the calculations for that city.

it is not driving the results. A third is to look at newer cities whose origins appear to be colonial (from the French-British era) and founded after 1800, based on web scrapping of information. These cities are denoted in Table A1. We expect and do get stronger results for cities which are more subject just to colonial influences. Finally, there is a sample for Open Street Map analysis of all Francophone cities over 300,000 in 2012, with the size bound imposed to ensure more reliable OpenStreet map data which are new to Africa. These 20 cities are then propensity matched to 20 Anglophone cities which have similar populations, growth, coastal location or not and the like. We will use these to analyse differential urban structure and road lay-outs in the colonial portions of larger Francophone versus Anglophone cites. These cities are listed in the Appendix and mapped in Figure 1b.

4.3 Data on geography and the extent of the city

In applying these data, we must define the spatial extent of cities. Since outcome measures involve aspects of the built environment, we do not want to use a measure based on built cover per se to define the extent of the urban area. We will note later how that biases results, by tending to omit extensive margin developments which are more leapfrog in nature as opposed to infill and extension. We rely on night light readings for Africa (Donaldson and Storeygard, 2016; Henderson et al., 2017) and define the city to be the area within the outer envelope of all areas lit for at least two of the last 5 years from 2008-2012. African cities have generally low light levels, so we do not threshold the lights to be above some cut-off. For smaller cities thresholding excludes obvious built areas (looking at Google Earth) and even some entire cities. In very big cities blooming is an issue and the lights boundary can include large undeveloped areas and cover satellite towns. In robustness checks, some reported in footnotes and appendices, we experimented with imposing light thresholds, setting distance limits over which we look, and trimming the cities with high maximal and low minimum distances from the centre to the farthest edge. For bigger cities a lights cut-off of zero captures ribbons of satellite towns developing along transport arteries going out from a city, which these robustness experiments tend to exclude. We also use night lights to define the city centre, as the brightest lights pixel (about .8 x .8 kms square near the equator) in 1992/93. We note also that we defined smoothed built cover boundaries for cities as defined in the Appendix for 1975, 1990, 2000, and 2014. The 1990 measure gives an urban core, beyond which in the extensive margin we will find over 98.5% of our post-1990 leapfrog patches.

Finally a basic identification issue is whether Anglophone cities differ from Francophone because of colonial origins or because of differential underlying geographic conditions of cities which influence urban layout, regardless of colonial origins, noting that Burchfield et al. (2006), Saiz (2010) and Harari (2016) all show that geography influences urban form.[11]. For geography, we use measures found in different literatures, but primarily based on based on Burchfield et al (2006). First we are concerned about terrain where hilly terrain spreads out developments around inaccessible terrain. We have a basic measure of ruggedness as defined by Nunn and Puga (2012) and of the range of elevation within the city. Water is another constraining feature. We have distance to the coast from the city centre; and, if the city is coastal, the kms of coastline within its boundary, where extensive coast means more inlets and bays again influencing city shape (Harari, 2016) . In the land portion of the city we know the fraction of pixels that are inland water (lakes, rivers, wetlands). In some specifications, we then draw a 5 km buffer around the outer edge of the city land area. In that buffer we try to catalogue the percent of the buffer in different uses in the base period: forest, shrubs, crops, water and wetlands, and sparse and bare vegetation (compared to grasslands). This reflects an issue of the opportunity cost of city land (which could vary systematically between Francophone and Anglophone). For that reason we also utilize the rainfall average from 1950-2000. The hardest items to deal with are growth and economic opportunities for the city. We have initial population size (estimated 1990 population) and

[11]There are also social conditions and in a developed country context we might worry about differential attitudes towards use of the automobile and the development of sprawl. First we note that even in seven major Sub-Saharan African cities, automobiles presently account for under 15% of trips (Trans-Africa Consortium, 2010). Second, that fraction would have been even smaller in the colonial era.

lagged country level GDP per capita. For a city growth control, we are concerned about reverse causality so instead of focusing on growth in city lights at night (Henderson et al., 2012), we utilize growth of lights in the country, excluding the own city. Finally we have base 1990 land cover in the city.

5 Overall patterns in the data for cities as a whole

Using the GHSL Landsat based data, first, we correlate two common measures of sprawl with Anglophone colonial origins to see motivating patterns in the data. We examine the *openness index* from Burchfield et al. (2006) for the overall city and then examine intensity of built land use by distance from the centre. For openness, following Burchfield et al. (2006), for each built-up 38m x 38m pixel in a city in a year we calculate the fraction of unbuilt pixels in the immediate 1 sq km grid square. These fractions are then averaged across all built pixels in the city. The measure reflects the extent of open space around the typical built pixel in a city. We also looked at flows, or changes in this index to address the issue of convergence.

At a more detailed level within the city, we look at intensity of use, comparing the central part of the city with areas further out, in 1km ring intervals. To measure intensity, we divide the city into a 500m x 500m grid. Intensity is the count out of the approximately 173 pixels in each grid which are built cover. We then aggregate to rings and examine the stock ring levels of intensity in 2014 as a function of distance from the centre to get an intensity gradient, as well as looking at how intensity changes from 1990 to 2014.[12]

What correlations do we see in the raw data? First, we compare distributions of openness for Francophone versus Anglophone cities for 307 relatively cloud free cities,[13] based

[12]Aggregating to rings avoids dividing the data in a ring into three components: grid squares which are never built upon, grid squares which were built upon in both 1990 and 2014 and grid squares which were newly built upon after 1990. In the Appendix, we show results concerning these different margins.

[13]These are 307 cities where the Landsat images used are 95% cloud free in 1990 and 100% cloud free in 2014.

on graphs in Burchfield et al. (2006). Figures 2a and 2b show the pdf for the distribution of built up pixels in 1990 and 2014 by the percent of land not built in the surrounding one square kilometer (i.e., openness). In both years, the dotted line for Francophone relative to the solid line for Anglophone shows the Francophone pdf's shifted left. Francophone cities tend to have a greater fraction of built pixels in areas with very low openness and a smaller fraction of pixels in areas which are very open, suggesting that Francophone development is more compact and Anglophone more sprawled. There is a hint in the graphs that the differential is smaller in 2014, raising the possibility of some convergence.

Table 1 examines the Burchfield openness index in 2014 in regressions controlling for geography and other city characteristics. Apart from the Anglophone cities effect, column 1 has no controls other than the 2014 dummy; column 2 adds most controls; and column 3 adds the rest on use of land at city edge. The Anglophone effect in column 1 is an increase in openness of 23 % and with all controls added in column 3 it is 22 %. Clearly adding controls has little impact, which suggests fundamental differences in the geography or economies of Francophone and Anglophone cities are not driving the colonial correlation, even though some control variables have expected effects based upon the analysis in Burchfield et al. (2006). Bigger cities have less openness and cities with greater elevation differentials have more. Rainfall (opportunity cost of urban land) or related vegetation measures at the city edge tend to reduce openness. We also note that it could be that French centralised land use control may have responded to differential geography of cities differently than the more decentralised British approach. If we interact all covariates in column 3 with the Anglophone indicator and predict how a typical city with mean characterictics in the overall sample differs under the two regimes, under an Anglophone regime that typical city has 19% greater openness.

In columns 4-6 we estimate an intensity gradient. We expect land use intensity to decline with distance from the city centre, because the price of land declines with distance. Here adding controls actually augments the Anglophone differential. In column 6, Anglophone cities at the centre have 76% fewer built pixels. For the base Francophone cities, intensity declines at a rate of 6% per kilometer as we move away from the centre. In Anglophone cities that decline is significantly less, at net of about 1% a kilometer. Anglophone cities have lower intensity near the centre and an almost flat gradient, a good description of cities that sprawl relative to their Francophone counterparts.

Table 2 addresses the issue of city level convergence for the overall index of openness (columns 1-2) and the ring measure of intensity (columns 3-4). Table 2 shows a long difference from 1990-2014, where the odd number columns have no control for the base period level (mean reversion), while even number columns do. All columns control for all geographic variables and city characteristics variables. For openness and intensity respectively, in columns 1 and 3 without the control for initial openness or ring built cover, it looks like there is a degree of convergence. Anglophone cities become less open, with more intensified land development. But in columns 2 and 4, the British indicator is insignificant. We also tried interacting the initial openness and intensity levels with Anglophone in columns 2 and 4 respectively, which yields small and insignificant coefficients. Convergence comes from the fact that Anglophone cities are less intensely developed to begin with and have more open space. Conditioning on openness or built cover, there is no Francophone-Anglophone difference overall and at the city centre. In column 4, the degree of intensification in Francophone cities tends to decline with distance from the centre, as the opportunity cost of land declines. But there is no gradient of intensification of Anglophone cities, again reinforcing the notion that these cities have fairly flat intensity gradients. [14] [15]

6 The Colonial portions of cities

6.1 Road layouts: Anglophone versus Francophone cities

To better understand aspects of colonial influence we start with an example, which compares Bamako to Accra. Both locations only emerge as cities in the late 19th century, Bamako under French rule and Accra under British. Their populations are similar in the early 20th century: Bamako at 16,000 in 1920 and Accra at 18,574 in 1911. [16] Accra retains that modest population difference with Accra at roughly 2.3 m and Bamako at 1.8 m today. While Accra is a coastal city, Bamako is on a major river with the initial city on just one side (like a coast line). Bamako had its first (apparently implemented) road plan in 1894 (Njoh, 2007, p. 92) replacing spontaneously prior developed roads with a street network on a classic gridiron with streets intersecting perpendicularly (Njoh, 2001, p. 23). Bamako's urban land was under state control by 1907 with the "Plan d'une cite administrative - un quartier de Bamako", with the state supreme in land allocations and assignment of set plots (Bertrand, 2004). Accra proceeded under the usual British dual mandate without a comprehensive plan until The Town and Country Planning Ordinance of 1945 (Ahmed and

[14] In Table A2 in the Appendix we break out grid squares within rings to look at the margins of intensification: intensification in grid squares with some 1990 built area, whether 1990 undeveloped grid squares developed or not, and, if so, at what intensity. Results are consistent with the aggregation to ring approach we are using. Column 1 of Table A2 estimates a linear probability model of whether a grid square is developed or not in 2014. Columns 2 and 3 look at the sample of undeveloped grid squares in 1990 and estimates an LPM of whether they develop by 2014, with no evidence of convergence on that margin. Column 4 looks at 2014 development intensity of 1990 grid squares which had built areas, with British being lower. Columns 5 and 6 look at intensification within these 1990 developed grid squares. Again it looks like there is convergence (column 5) until we control for initial intensity. Column 7 looks at 2014 intensity in newly developed grid squares. In short there is convergence, but not beyond what would be expected from mean reversion type convergence.

[15] In Tables 1 and 2, one concern is that our lights boundary for bigger cities with blooming of lights at the edge is quite generous and some cities have huge maximum distances from the centre to the farthest boundary. Table A3 in the Appendix examines this issue. There, restricting the area of cities does affect the magnitudes of the slopes of intensity gradients, given we can have huge extensive margins of cities with very low development. In Table A3 we experiment with the level intensity formulation from Table 1 and the convergence, or intensification one from Table 2. We tried many cuts, all to the same affect. Table A3 shows one where we still use a zero lights boundary but cut the rings off after 30 kms from the centre and one where we use a lights boundary of 5 and trim the top and bottom 5 % of cities in terms of maximum distance from the centre to the outer lights boundary of 5. Patterns are very similar to Table 1 and 2. Thus with the trimming, intensity does declines more sharply with distance from the city centre. However the degree of decline remains significantly less in Anglophone cities.

[16] For Bamako: "France: Africa: French West Africa and the Sahara". Statesman's Year-Book. London: Macmillan and Co. 1921. pp. 895–903 – via Internet Archive. Colony of French Sudan. For Accra "Population Studies: Key Issues and Continuing Trends in Ghana" S.N.A. Codjoe, D.M. Radasa, and S.E. Kwankje, Sub-Saharan Publishers, Accra, 2014, p.115

Dinye, 2011) when, according to Grant and Yankson (2002), "zoning and building codes were strictly enforced to maintain an orderly European character and ambience", especially in the European Central Business District (Ahmed and Dinye, 2011) (Grant and Paul, 2003).

Figures 3a and 3b show the road layout in the older sections of these cities, roughly up to 4-5kms out from the city centre. For Bamako we show the 1963 road layout from tracings of road maps and the road layout today from OpenStreetMaps. For Accra we show the roads for 1966 [17] as well as today. Inspection suggests several takeaways. First in both cities, roads that were in place 50 years ago generally remain in place today– phyical persistemce. Second Bamako presents as having large sections of intense dense, gridlike road structures where sections are interconnected by mostly long lineal roads. And 1963 fringe roads that appear to meander to the north east have in some cases been replaced by gridlike structures. New sections of the city generally are on a rectangular grid structure. In contrast is Accra. Accra shows much less grid like structure with fewer lineal connecting roads between developments even in the colonial parts of the city. And new developments on the fringes of the colonial parts of the city appear to have much less rectangularity and lineal connections than Bamako. Note that for the same map scale, we see much more of the city, its road system and lay-out for Bomako, than for sprawling Accra.

To test whether these differences hold more generally, we took all 20 Francophone cities in Sub-Saharan Africa over 300,000 in 2012, to analyse road layouts from OpenStreetMaps. Since OpenStreetMap data is relatively new for Sub-Saharan Africa, we restricted to larger cities and to mapping within 3-5 kms of the centre to try to ensure better reporting. We then chose 20 corresponding Anglophone cities over 300,000 out of the 68 in that size range, using a one to one Mahalanobis distance based matching approach without replacement. The covariates include initial city population in 1990, average rainfall from 1950 to 2000,

[17] The source of both old maps is Oxford Library. It is digitalized by Ramani Geosystems, a GIS firm based on Nairobi

coastal dummy, absolute elevation, and city annual estimated population growth from 1990 to 2012. With matching, means of the matching variables show miminal (and completely insignificant) differences between Francophone and chosen Anglophone cities. Also in the end there are 11 Nigerian out of 20 Anglophone cities, effectively matching Francophone ones concentrated in West Africa. Other samples drawn to reduce the Nigerian count show similar if not stronger results. [18].

For this matched sample we ask if the Francophone colonial sections of cities and immediate extensions have different structures than Anglophone ones, with a more regular and connected road system, which would guide the complementary layout of private investments. Here we give quantitative evidence of the more standardised grid system of Francophone cities. Figure 4 illustrates the process followed and derivation of measures. In part A we have the raw OSM road network data for part of a city and B shows the derived road blocks. Road blocks are categorised by their degree of rectangularity using the minimum bounding rectangular method of Žunić et al. (2012) and Rosin (1999). The minimum bounding rectangle is a rectangle which minimally encloses the actual block polygon. Rectangularity of a block is the ratio of the area of the block to the area of its minimum bounding rectangle - a perfectly rectangular road block would be 1, and the ratio tends to fall as it takes on more complex shapes. Part C of Figure 2 ranks all the blocks in the shot - the dark blocks with rectangularity measures equal to or greater than 0.9 are ones we call rectangular blocks. We chose a cut-off of 0.9 to allow for measurement error and topography in approximating perfect rectangles.

Part D of Figure 4 shows how we define *gridiron blocks*, which is the basis for our main measure and captures contiguity in rectangularity of layout of sections of a city. To be a

[18] For example, for another project, we had a sample of 55 cities generally over 240,000 for which we obtained SPOT data which was weighted against having too many Nigerian cities and towards greater country (Francophone) coverage. Or we matched with Anglophone cities without an explicit requirement that they be over 300,000 which again weighs against Nigeria

gridiron block, a block must have a rectangularity index greater or equal to 0.9, be devoid of dangles, and be connected to all neighbouring blocks by 4-way intersections. Dangles are roads off the regular road network which lead to no connection (i.e., dead-end), or blocks with a *cul-de-sac*, dead-end, or T-intersection; and they are illustrated in Part E of Figure 4. Part D of Figure 2 shows in yellow the subset of rectangular blocks which qualify as gridiron. For analysis we calculate the share of gridiron blocks to all blocks in the area in question.

We believe OSM data pretty comprehensively maps roads in these 40 African cities up to about 5 kms from city centres, covering both the colonial parts of the city which generally lie within 3 or fewer kms of the centre and post-colonial immediate extensions. Further out, mapping is expected to be of poorer quality because of the incomplete nature of volunteered OpenStreetMap information. In Figure 5, for each of these cities we show the fraction of gridiron blocks out to 5 kms with Anglophone cities represented by the darker shades. Although the pattern is somewhat mixed, Francophone cities generally have higher shares of gridiron blocks. The visual impression is confirmed by a regression coefficient giving the average Anglophone differential. Anglophone cities average 20 percent points fewer gridiron blocks, from a mean of 17. The sample mean is almost the same at 3 and 5 kms, so there is no overall diminishing of regularity with the 150 percent increase in area covered.

We note two other things. First results on the share of rectangular blocks are similar to those for gridiron, but we prefer the tougher criterion which captures contiguity. Second we also looked at the share of dangles. Anglophone cities have 3.5% higher shares of blocks (for a mean of 10.7) with at least one dangle to all blocks of the area in question, but the coefficient is only significant at the 11% level. Overall the results suggest a strong colonial influence of centralised control and grid planning, as suggested by Njoh (2015) and Durand-Lasserve (2004), which persists until today [19].

[19] One issue is whether Anglophone cities were regularly laid out but just not on a rectangular grid, using more diagonal roads with roundabout intersections. We checked the count of roundabouts within 5 kms of the centre. On average there is

6.2 Intensity of land use in the colonial portions of cities and immediate extensions.

Corresponding to gridlike structures of roads is much greater intensity of land use in the colonial portions and their extensions, for Francophone cities compared to Anglophone, indicating much greater compactness. In Table 3, for the full sample of cities, we show ring by ring intensity regressions for 1990, the year nearest the colonial era, as we move out from the city centre in 1 km increments, looking more in depth at what was reported in Tables 1 and 2. The dependent variable is the log of the total number of built pixels in each ring. Shown are the coefficients for British and for a control for the number of available pixels (built ot not) in each ring by city, which also allows for differential differential ring counts based on geography (e.g., cities on a coastline or river vs. more circular non-coastal cities). All columns control for all geographic charateristics and 1990 city population and country GDP per capita.

For rings 0-1, 1-2, 2-3 and 3-4 kms Anglophione cities have 37-78% fewer built pixels. They are much less intensely developed. After 4kms, the sample starts to drop quickly as we lose smaller cities with no area beyond the given radius. Second the story gets more complex. Francophone cities as we saw in Table 1 have sharply negative density gradients, while Anglophone cities sprawl. So for the same population, at some distance from the centre, Francophone cities end while Anglophone cities continue with built area. That said while there are no significant differences, for the British indicator beyond 4 kms, until 11 kms out all but one coefficient are both negative and in the 30% range. Only at the tail reported at 11-12 kms does the British coefficient become positive, albeit insignificant. Regardless, colonial portions out to 4 kms of Anglophone cities have much less intense land use than Francophone ones.

absolutely no difference between Francophone and Anglophone cities.

Is there convergence in these colonial portions? In Table 4 we look at rings 0-1, 1-2, 2-3, and 3-4 with a long difference of the log intensities between 1990 and 2014. The controls include all those in Table 1 and the city ring pixel count (built or not). In columns 1-4, for each ring in succession, the reported coefficient is for the British indicator. Then in columns 5-8 for the same respective rings there is an added control of the ln count of built pixels in each city-ring in 1990. Columns 1-4 indicate a reasonable degree of convergence. Columns 5-8 suggest that convergence is again from mean reversion: areas with less built pixels will fill-in. In general there is no significant extra British effect either overall or in the degree of mean reversion. So convergence is for all types of cities where, intially lower density places fill-in more.

7 Compactness in the (vast) post-colonial extensive margins of cities

Differentials at the extensive margin of cities are more difficult to capture with the framework utilised above. Francophone cities have high intensity at the centre which declines sharply while Anglophone cities have fairly flat intensity gradients. Thus as noted above, for the same population, their spatial reaches differ. To deal with that problem, in the remaining parts of the paper, we focus on the extensive margin of cities post-1990 and on a concept well established in the literature, leapfrogging, with our own specific measure. Leapfrogging is a flow measure of leapfrog patches occurring under development from 1990 to 2000 and then under development from 2000 to 2014.

How do we define leapfrog development? Using the 1990 to 2000 period as an example, in 1990 we have a set of built pixels, which are typically in clusters. We define the boundary or outer envelope of each cluster of contiguously developed pixels, which we call patches (where some patches are isolated singleton developed pixels). In the illustrative Figure 6, the 1990 developed areas are the light shaded (orange-pink) ones. The focus is on newly developed pixels. These also appear as patches of contiguous newly built pixels, which also have boundaries. Around each bounded patch (or singleton) of newly built pixels we draw a 300m buffer, effectively including all pixels or parts of which lie within 300m of the nearest border of the new patch. Then we focus on the areas *within (just) these buffers* around new patches to define three types of new development. If that buffer area is generally contained within an existing development it is called infill (red area in the figure). If it only marginally intersects the existing cover (or is within 300m of it), it is called extension (blue in figure). If does not intersect (within 300m) any existing 1990 development it is called leapfrog (green patch). Our buffer choice of 300m is guided by the literature on 'walkable neighbourhoods' - most notably, Barton et al. (2003) claim a theoretical circular catchment of radius 300m (corresponding to walking time of 5 minutes) as a planning goal for urban amenities and interactions. Thus, leapfrogging occurs when a new urban patch development arises beyond the walkable distance of an existing urban patch. Of course, walkable distance is in the eye of the beholder and we experimented with different size buffers as reported under robustness checks.

Given these concepts, we have a measure of the connectedness of urban expansion, or the landscape expansion index (LEI) (Liu et al., 2010) where

$$LEI = \frac{A_b}{A_b + A_o} * 100 \tag{1}$$

where A_b is area of intersection between the buffer zone of a new patch with existing built cover, to give the area of already built pixels within the buffer zone of a newly built area. A_o is the area of intersection between (just) the buffer zone itself for new patches with open space, to give the area of open space in the buffer zone. Thus the denominator is total area in the buffer zone and the numerator the built area within that. Infill might be defined as an $LEI > 50$, so at least 50% of the buffer is already built space. Our focus will be on leapfrog patches where the LEI is 0, so there is absolutely no already built space in the buffer surrounding new development. However first in Figure 7, we show the pdf of the LEI measure for patches of new development in all Francophone versus Anglophone cities. The Anglophone measure is much more concentrated at the low end of LEI's between 0 and 5%, representing a greater concentration of leapfrog or almost leapfrog developments.

We now turn to statistical analysis and look at the absolute and relative count of leapfrog patches in a city and the area they encompass. Most critical to our claim that we are looking at the extensive margin is the fact that over 98% of all leapfrog patches in the sample lie outside the smoothed land cover boundary of the city in 1990. These are developments in areas new to the city since 1990. LP patches average about 12% of all patches but have high variation across cities (the standard deviation on the variable is 11).

7.1 Primary results

Given we are pooling flow data and turning to our primary results, here we do note the estimating equation:

$$Y_{ijt} = X_{ij}\beta + Z_{ijt}\theta + \delta Anglophone + d_t + \epsilon_{ijt} \tag{2}$$

where i is city, j is country and t is time. We have different counts and areas of leapfrog patches in 2000 (from 1990) and 2014 (from 2000) as the dependent variable. Note leapfrogging is a flow measure for 1990 to 2000 and 2000 to 2014. X_{ij} are city i factors which are either time invariant or for which we want a base period measure. Z_{ijt} are time varying factors. These controls are shown in Tables 1 and 2. d_t is a time dummy, where at a minimum it captures the fact that the second time interval (00-14) for LF patches is 4 years longer than the first (90-00). The coefficient of interest is δ , the Anglophone differential. Focusing on flows and the extensive margin may help difference out the influence of key unobserved geographic factors. A finding of greater leapfrogging in Anglophone cities would suggest colonial patterns of disconnected and independent developments in Anglophone compared to Francophone cities persist under today's inherited institutions at a margin well beyond the physical colonial city.

Columns 1 and 2 in Table 5 show basic results for the logarithm of the count of leapfrog patches in a city. Column 1 (and odd numbered columns) has just base specification controls, while column 2 has all controls. The main result of the paper is in column 2 with full controls: Anglophone countries have 72% more leapfrog patches. Here the added controls have a modest effect in dampening results; coefficients are about 20% smaller in column 2 than in column 1. In the specification, there is a small count of about 5% of observations which are zeros which we set to the minimum of 1 (so the log is zero). Results in the Appendix Table A4 show OLS results excluding these zeros, Tobit results, and Poisson count results. The Anglophone effect remains basically unchanged.[20] We also note the issue again that Francophone regime cities have respond to differential geography of cities differently than the Anglophone ones. If we interect all covariates in column 2 with the Anglophone indicator and predict how a typical city with mean characterictics in the overall sample differs under the two regimes, under an Anglophne regime that typical city would have 68% more leapfrogging.

In columns 3 and 4, we show results for the log (count LP patches/ count total patches). The coefficient on the ratio in column 4 is 0.27.[21] This implies the marginal effect on all patches for Anglophone (over Francophone) cities is about 0.45 (0.72- 0.27). British colonial cities develop more by building in greenfield areas, rather than intensifying already built cover

[20]The effect is about 30% smaller for the Poisson but, by comparison to other columns that is clearly due to Poisson functional specification.

[21]For the typical city under a specification where all covariates are interacted with the Anglophone indicator, the differential is 22%.

in general, or have more patchy development. But, given that, they are even more prone to these patches being leapfrog ones. In columns 5 and 6 we show results for log (average area of LP patches), which checks whether Anglophone patches are somehow bigger, so they might be easier to service. There is no average size difference in leapfrog patches between the two types of cities. In summary Anglophone cities have more patchy development at the extensive margin, especially leapfrog development, where these leapfrog patches are no bigger or smaller than their Francophone counterparts.

7.2 Identification

Are the effects in Table 5 causal? In part we are arguing causality through the weight of different pieces of evidence and the use of a large set of controls and flow data, but biases obviously may remain. Although the insertion of many controls has little impact on the Anglophone 'treatment', the characteristics between the Anglophone and Francophone sets of cities are not balanced in all cases, suggesting there could be unobservables affecting outcomes which are also unbalanced. To deal with this we turn to a border experiment, to try to compare Anglophone versus Francophone cities facing identical circumstances.

Figure 8 shows West Africa where 5 Anglophone countries share borders with a number of Francophone countries. At these borders there are no significant waterways. We show cities within a 100 km buffer of the borders involved. Results are almost the same if use a 125 km or 150 km buffer. We chose the smaller buffer, but dropping below 100 kms loses too many cities. To refine the border experiment, we break border segments into 15 finer portions, grouping cities into natural clusters of cities that are very near to each other, to try to control for unobserved geographic or other influences. These clusters are given in Figure 8. Two of the 15 contain only one type of colonial city and as such are neutralized by their cluster FE's. An issue for country borders is that part of Francophone Cameroon (orange border) was under British control after World War I through to the mid-1960's. We do the analysis both excluding this area (which is 1 cluster) and treating the border between Anglophone and Francophone Cameroon as the true border. We think it is better to exclude the area. Clearly the Anglophone Cameroon cities have conflicting effects: British heritage versus French rule for 50 years.

With these 15 clusters, have we attained balance? Table A5 shows our key covariates from Column 2 of Table 1 regressed on a constant and the Anglophone indicator. To key covariates we add the ratio of 1992 lights to 1990 population as a crude measure of city GDP per capita and city lights growth from 1992 to 2014 as a city growth measure. In Table A5 we show that for the full sample there is a lack of balance for many covariates. With the border sample considered here only 2 of 11 covariates differ in mean for Anglophone cities and once we add the 15 cluster FE's, only one of 11 differs.

In Table 6, we run the same leapfrog regressions as in Table 5 with a full set of controls. We show the results for a base case without FE's in columns 1 and 3 and then in columns 2 and 4 we add the cluster FE's. Results compare 37 Anglophone cities with 30 Francophone cities for the full sample and 35 Anglophone and 23 Francophone cities when we drop the Anglophone-Francophone Cameroon segment. In each of the three rows we show the outcomes: log (count of LF), and log (ratio of LF to total count) and log (average area of leapfrog patches). First the exclusion or inclusion of the controversial area of Cameroon makes a modest difference, with stronger effects in columns 3 and 4 when we drop the controversial Cameroon area. We focus on those. In Table 6, the Anglophone degree of leapfrogging is significantly higher in both specifications with somewhat larger point estimates than in Table 5: 0.86 for the city-cluster FE's in Table 6 versus 0.70 in Table 5. For the ratio of leapfrog to all patches, results are statistically weaker, but magnitudes higher than in Table 5 (0.45 versus 0.27). As is the case in general, areas of patches do not differ by colonial origin. Overall Table 6 is strong evidence that it is colonialism and not other factors driving our results.

7.3 Robustness

The next issue is robustness of Table 5 leapfrog results to other considerations. For that we turn to Table 7. In Table 7 in column 1 we show the base case. As in Table 5, in each of the three rows we show the outcomes: log (count of LF), and log (ratio of LF to total count), and log (average area of leapfrog patches). In columns 2 and 3, first we experiment with types of leapfrog measures. Column 2 removes from the counts and areas any developments that are just one (isolated) pixel (38 m x 38m), as an attempt to deal with obvious impacts of mis-measurement of built cover. Column 3 uses a buffer around newly built areas of 60 m rather than 300m in defining LEI and LF developments. In both cases, the impact on point estimates is minimal. The rest of the columns deal with sampling issues.

Column 4 worries about blooming of night lights in bigger cities, which then add non-urban areas within the lights boundary, where Anglophone versus Francophone differentials might exist for other reasons. Column 4 uses city light boundaries cut at 5 and a dataset where we trim the top and bottom 5% of cities in terms of maximum distance from the centre to any part of the lights boundary. Again that has little effect on results in all 3 rows. We note however (but not shown in the table), that if we defined the area of the city as a smoothed 2014 built area cover, that would bias our results. For the leapfrog count outcome, the coefficient is minimally affected, but the ratio of LF to all patches then has a coefficient of zero. By cutting on smoothed cover, we mechanically tend to exclude areas with more leapfrogging relative to other patches.

Columns 5 and 6 turn to different country samples which are potentially more problematic. Column 5 removes countries which were initially German colonies before being assigned to Britain or France after World War I. Dropping those countries (Namibia, Tanzania, Togo, and Cameroon) has little effect on results. Similarly dropping Nigeria which is a big portion of the sample has little impact on the Anglophone coefficients for any of the 3 outcomes. Column 7 looks at colonial origin cities, which were built after 1800 and appear to be colonial constructs. Point estimates here are much larger, hinting at much stronger differences for cities built from scratch under the different colonial regimes, although the sample is small. But the intuition is appealing. Column 8 focuses on the sample of 40 cities for which we assembled OpenStreetMap data. Here the point estimates on absolute and relative LF counts are somewhat larger than in column 1, but the results for this sample are not out of line with the rest of the data. That is reassuring for the applicability of the gridiron results.

In sum, throughout, the basic bottom line is that the extensive list of robustness checks and the border experiment suggest the quantitative LF results hold under different measures and samples and experimental contexts. Secondly in the one case where they differ enormously, it makes sense: much stronger results for colonial origin cities.

8 The so-what question: Public policy relevance

The planning literature argues that having compact and more regularly laid out cities lowers the cost of infrastructure provision. In Africa we would further argue that higher costs will lower the likelihood of receiving public infrastructure provision. To assess the reduced form impact, we use DHS data on whether a family has a piped water connection (with the alternatives being a shallow or deeper well or having no water connection), an electricity connection, a telephone land line connection, or a (flush) toilet connected to a public sewer system. The last two are less frequent to begin with. DHS uses cluster sampling of 20-30 households in a neighbourhood and we restrict attention to clusters defined by DHS to be in urban areas. We cover 21,016 households in 745 clusters in 115 cities in 9 countries. Of the 115 cities, only 16 are Francophone. The focus here is not on Francophone versus

Anglophone per se; but, rather, the impact of leapfrogging within any city on public utility provision. Virtually every survey we use asks about all four public utility connections of the household.

The challenge in implementation concerns location. Within an urban area, cluster locations are randomized within 2 kms by randomly picking a directional ray (angle) from the true cluster centre and then choosing a location randomly along that ray within 2 kms of the cluster centre. Under this algorithm, while locations near the true location are more likely to be chosen, the randomized location is equally likely to be in any ring out from the true location up to the 2kms. We draw a 2 km circle around the specified location and look at the existence and frequency of leapfrog patches conditional on how developed that circle is, how far it is from the city centre, and other controls. One could view this as a measure of how likely a cluster is to be in a leapfrog patch, but we interpret it as a measure of the overall degree of leapfrog development in the surrounding area. To exploit economies of scale in construction, cities roll out public utilities in large spatial zones. The higher the degree of leapfrog development in an area, the less likely it is to be serviced, because roll-out is more costly. Regardless, because of the randomization of location, the variables of interest are measured with error. We could not think of an instrument which both met the exclusion restriction [22] and has power (e.g., being a Francophone country). Given the measurement error involved we did not anticipate getting strong results. However we were surprised.

The results are in Table 8 covering about 21,000 household for each attribute. In a linear probability formulation, each attribute has two columns. The first (odd numbered) column has basic supply controls, with our variables of focus: whether there are nearby leapfrog developments and, if so, how many. The second column (even numbered) controls for household demand characteristics, which only serve to strengthen the results. The count

[22] e.g. Using the propensity of surrounding areas to have LF development for whether cluster is recorded in a leapfrog patch does not.

of leapfrog patches significantly reduces the likelihood of an electricity connection and a landline connection and with weaker significance reduces the likelihood of a piped water connection. The sign on flush toilets is negative, but the results are insignificant. Effects are not huge, given attenuation bias. On the count of leapfrog patches, for electricity it is -0.009 from a mean likelihood of 0.76 (although there is a base leapfrog indicator effect of -0.04); for landlines a -0.004 from a mean of 0.05; and for water -0.004 from a mean of 0.5. Using a radius of 3 kms to describe the degree of leapfrog development in the surrounding area yields significant results for all 4 outcomes, but magnitudes of coefficients are lower for the first three outcomes. Overall, effects are consistent, suggesting that indeed there is a connection between sprawl and public utility provision.

9 Conclusions

The literature on colonialism in Africa suggests that, compared to the British, the French imposed more comprehensive city wide land use planning, including the lay-out of roads. The theoretical literature in economics suggests that an omniscient and benevolent city planner would create a more compact city which encourages fluidity of movement than *laissez faire* development and that leapfrogging is related to intensity of centre city development. The empirical literature suggests that areas which through centralized control are more regularly laid out on a grid system will have higher levels of future development and/or land values. The African context of colonialism provides an experiment to show that choice of institutions which involve more centralized control within each city, as in Francophone compared to Anglophone cities, lead to more compact cities.

Specifically the paper shows that Francophone African cities have more grid-like structures in their core areas. Anglophone cities have a city wide index of openness which is 22% higher. Their intensity of land use is 76% lower at the centre and, in contrast to Francophone cities, the intensity of land use gradient is almost flat. Anglophone cities are more sprawled. Correspondingly, with new development, Anglophone cities have about 70% more leapfrog patches, a number that is robust to a border experiment and many experiments with definitions and relevant cuts on the data in terms of samples. There is a consequence to having greater leapfrog development. Such areas are less likely to receive connections to public utilities, such as electricity, phone landlines, piped water, and city sewers.

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Table 1: Openness and sprawl

	Ln openness index 2014			Ln ring built pixel		
	Base	City controls	Full controls	Base	City controls	Full controls
	(1)	(2)	(3)	(4)	(5)	(6)
Anglophone country	0.229***	0.192***	0.221***	-0.457**	-0.687***	-0.755***
	(0.0455)	(0.0510)	(0.0523)	(0.195)	(0.205)	(0.229)
Ring distance				-0.0282***	-0.0551***	-0.0578***
				(0.00438)	(0.00684)	(0.00613)
Ring distance × Anglophone				0.0132**	0.0438***	0.0481***
				(0.00556)	(0.0107)	(0.0118)
Ln ring total pixel				0.895***	0.701***	0.699***
				(0.0866)	(0.0426)	(0.0431)
Ln income per capita 1990		0.0423	0.0632		-0.169	-0.213
		(0.0435)	(0.0444)		(0.154)	(0.166)
Ln projected city population 1990		-0.175***	-0.158***		0.510***	0.496***
		(0.0210)	(0.0216)		(0.0762)	(0.0827)
Ln country light growth 92 to 12 excluding own city		-0.0328	0.00101		0.0142	-0.0311
		(0.0531)	(0.0518)		(0.162)	(0.169)
Ln ruggedness		-0.00320	-0.00865		0.0228	0.00501
		(0.0213)	(0.0213)		(0.0773)	(0.0753)
Ln rainfall		-0.123***	-0.134***		0.564***	0.299
		(0.0383)	(0.0506)		(0.202)	(0.188)
Ln elevation range		0.131***	0.108***		-0.0630	-0.00827
		(0.0323)	(0.0331)		(0.144)	(0.128)
Coast dummy		0.131	0.987		0.107	-1.178
		(1.229)	(1.290)		(3.130)	(3.301)
Ln coast length × coast dummy		-0.0454	-0.0900		0.177	0.211
		(0.101)	(0.106)		(0.353)	(0.306)
Ln distance to coast × coast dummy		0.0363	-0.0190		-0.181	-0.0660
		(0.0708)	(0.0692)		(0.151)	(0.170)
Fraction of river area		0.0622	0.0346		0.832	0.646
		(0.609)	(0.608)		(2.867)	(2.629)
Fraction of lake area		-0.651	-0.154		-0.156	-0.725
		(1.007)	(0.966)		(3.052)	(3.187)
Fraction of forest			0.241**			0.00880
			(0.107)			(0.383)
Fraction of shrubs			0.229**			-0.0547
			(0.0966)			(0.330)
Fraction of crops			0.0461			0.252
			(0.0873)			(0.316)
Fraction of wetlands and water			-0.609			2.792**
			(0.415)			(1.354)
Fraction of sparse vege and bare land			0.215			-1.133*
			(0.150)			(0.654)
Observations	307	307	307	4,875	4,875	4,875
R-squared	0.080	0.304	0.343	0.193	0.326	0.333

Notes: Robust standard errors in parentheses for openness index; Standard errors are clustered at city level in column 4-6.
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Intensification and convergence

	Ln openness index growth 90-14		Long difference of ln ring built pixel	
	Full controls	Add openness index 1990	Full controls	Add built cover 1990
	(1)	(2)	(3)	(4)
Anglophone country	-0.0472**	-0.0328	0.262***	0.0589
	(0.0237)	(0.0278)	(0.0847)	(0.0878)
Ln openness index 1990		-0.0537		
		(0.0400)		
Ring distance			0.00768***	-0.00849***
			(0.00180)	(0.00219)
Ring distance × Anglophone			-0.00217	0.00990***
			(0.00221)	(0.00293)
Ln ring total pixel			0.181***	0.268***
			(0.0271)	(0.0252)
Ln ring built cover in 1990				-0.261***
				(0.0175)
Geographic controls	Yes	Yes	Yes	Yes
Observations	307	307	4,499	4,499
R-squared	0.066	0.076	0.102	0.427

Notes: Geographic controls include log ruggedness, log rainfall, log elevation range, coast dummy, interaction of log coast length with Anglophone dummy, interaction of log distance to coast with Anglophone dummy, fraction of river area, fraction of lake area, fraction of forest, fraction of shrubs, fraction of crops, fraction of wetlands and water, fraction of sparse vegetables and bare land. Other control variables include log income per capita 1990, log projected city population 1990, log country light growth 1992 to 2012 excluding the city itself. Robust standard errors in parentheses for openness index; Standard errors are clustered at city level in column 3 and 4. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Intensity by rings in 1990

	<1km	1-2km	2-3km	3-4km	4-5km	5-6km
Anglophone country	-0.373**	-0.618***	-0.784***	-0.760***	-0.304	0.0351
	(0.154)	(0.167)	(0.192)	(0.223)	(0.240)	(0.264)
Ln ring total pixel	1.075***	0.521	-0.0871	0.205	0.499***	0.412***
	(0.351)	(0.461)	(0.208)	(0.156)	(0.168)	(0.142)
Geographic controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	312	316	307	283	254	218
R-squared	0.252	0.325	0.417	0.502	0.531	0.469
	6-7km	7-8km	8-9km	9-10km	10-11km	11-12km
Anglophone country	-0.391	-0.282	-0.294	-0.301	-0.262	0.272
	(0.316)	(0.320)	(0.349)	(0.367)	(0.322)	(0.375)
Ln ring total pixel	0.689***	0.586***	0.620***	0.445**	0.628***	0.460**
	(0.261)	(0.218)	(0.207)	(0.205)	(0.169)	(0.202)
Geographic controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	199	169	160	146	133	122
R-squared	0.491	0.575	0.499	0.482	0.518	0.513

Notes: Geographic controls include log ruggedness, log rainfall, log elevation range, coast dummy, interaction of log coast length with Anglophone dummy, interaction of log distance to coast with Anglophone dummy, fraction of river area, fraction of lake area, fraction of forest, fraction of shrubs, fraction of crops, fraction of wetlands and water, fraction of sparse vegetables and bare land. Other city characteristics control variables include log income per capita 1990, log projected city population 1990. Columns 5-8 add the control of log country light growth 1992 to 2012 excluding the city itself. Robust standard errors in parentheses for openness index; Standard errors are clustered at city level.
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Intensification by rings

	Full controls				Add built cover 1990			
	<1km	1-2km	2-3km	3-4km	¡1km	1-2km	2-3km	3-4km
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Anglophone country	0.249**	0.370***	0.442***	0.372***	1.134	1.474*	1.473	0.716
	(0.110)	(0.0790)	(0.112)	(0.129)	(1.611)	(0.870)	(0.920)	(0.729)
Ln ring total pixel	-0.569*	0.0340	0.268***	0.208***	0.196	0.471***	0.450***	0.341***
	(0.321)	(0.125)	(0.0941)	(0.0779)	(0.154)	(0.132)	(0.0948)	(0.0711)
Ln ring built cover in 1990					-0.360***	-0.198***	-0.236***	-0.252***
					(0.111)	(0.0523)	(0.0653)	(0.0519)
Ln ring built cover in 1990 × Anglophone					-0.0765	-0.0924	-0.0979	-0.0467
					(0.112)	(0.0586)	(0.0624)	(0.0515)
Geographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	312	316	307	283	312	316	307	283
R-squared	0.157	0.212	0.256	0.229	0.655	0.536	0.565	0.454

Notes: Geographic controls include log ruggedness, log rainfall, log elevation range, coast dummy, interaction of log coast length with Anglophone dummy, interaction of log distance to coast with Anglophone dummy, fraction of river area, fraction of lake area, fraction of forest, fraction of shrubs, fraction of crops, fraction of wetlands and water, fraction of sparse vegetables and bare land. Other city characteristics control variables include log income per capita 1990, log projected city population 1990, log country light growth 1992 to 2012 excluding the city itself. Robust standard errors in parentheses for openness index; Standard errors are clustered at city level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Leapfrogging

	Ln count of LF		Ln LF minus ln total patches		Ln avg. LF area	
	Base	Full controls	Base	Full controls	Base	Full controls
	(1)	(2)	(3)	(4)	(5)	(6)
Anglophone country	0.907***	0.720***	0.339***	0.274**	0.0345	0.0166
	(0.155)	(0.147)	(0.109)	(0.110)	(0.0512)	(0.0616)
Ln initial built cover 1990	0.656***	0.332***	-0.0812***	-0.290***	0.0645***	0.0318
	(0.0337)	(0.0432)	(0.0252)	(0.0260)	(0.00909)	(0.0193)
Year dummy 2014	0.517***	0.471***	0.119	0.112*	0.145***	0.145***
	(0.170)	(0.100)	(0.0947)	(0.0630)	(0.0476)	(0.0391)
Ln income per capita t-1		0.219		-0.0215		-0.00329
		(0.149)		(0.0895)		(0.0447)
Ln projected city population 1990		0.649***		0.410***		0.0278
		(0.0807)		(0.0429)		(0.0426)
Ln country light growth excluding own city		0.620***		0.402***		0.148**
		(0.170)		(0.0901)		(0.0608)
Ln ruggedness		-0.0154		-0.103***		-0.0137
		(0.0568)		(0.0339)		(0.0205)
Ln rainfall		-0.350***		-0.189**		-0.0576
		(0.105)		(0.0710)		(0.0542)
Ln elevation range		0.472***		0.251***		0.127***
		(0.0674)		(0.0460)		(0.0277)
Coast dummy		-7.018**		-8.029***		-2.813***
		(2.743)		(1.848)		(0.857)
Ln coast length × coast dummy		0.462*		0.499***		0.191**
		(0.263)		(0.159)		(0.0832)
Ln distance to coast × coast dummy		0.222		0.316**		0.0917
		(0.146)		(0.129)		(0.0603)
Fraction of river area		1.000		-0.167		-0.862
		(1.818)		(1.041)		(0.570)
Fraction of lake area		-2.905**		-2.929**		-1.290*
		(1.394)		(1.330)		(0.743)
Fraction of forest		0.00145		-0.202		-0.116
		(0.256)		(0.159)		(0.113)
Fraction of shrubs		0.566**		0.168		-0.118
		(0.233)		(0.124)		(0.0755)
Fraction of crops		-0.0164		-0.122		-0.0148
		(0.219)		(0.149)		(0.117)
Fraction of wetlands and water		0.908		1.138*		0.171
		(0.908)		(0.590)		(0.355)
Fraction of sparse vege and bare land		-1.637***		-1.305***		-0.445**
		(0.386)		(0.308)		(0.173)
Observations	606	606	606	606	578	578
R-squared	0.448	0.594	0.058	0.239	0.078	0.151

Notes: Standard errors are clustered at country year level
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Border regression discontinuity 100km

	With Anglophone Cameroon		Without Anglophone Cameroon	
	Full controls	City cluster FE	Full controls	City cluster FE
	(1)	(2)	(3)	(4)
Anglophone country: Ln count of LF	0.887***	0.674**	1.092***	0.856**
	(0.299)	(0.321)	(0.325)	(0.356)
Anglophone country: Ln LF minus ln total patches	0.442*	0.282	0.575**	0.449
	(0.238)	(0.249)	(0.265)	(0.288)
Anglophone country: Ln avg. of LF area	-0.259	-0.123	-0.235	-0.157
	(0.200)	(0.171)	(0.222)	(0.201)
N (counts)	131	121	113	107

Notes: Standard errors are clustered at city year level
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Leapfrogging: Robustness

	Base case	No single pixel LF patches	60 m buffer rather than 300	Trim	No German	No Nigeria	Colonial cities strict	40 Cities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Anglophone country: Ln count of LF	0.720***	0.673***	0.694***	0.661***	0.640***	0.746***	2.666***	1.153***
	(0.147)	(0.169)	(0.107)	(0.163)	(0.127)	(0.193)	(0.650)	(0.273)
Anglophone country: Ln LF minus ln total patches	0.274**	0.196	0.248***	0.316**	0.184**	0.260*	0.992*	0.342
	(0.110)	(0.133)	(0.0620)	(0.127)	(0.0753)	(0.149)	(0.568)	(0.284)
Anglophone country: Ln avg. of LF area	0.0166	0.0138	-0.00184	0.0514	-0.00920	-0.0350	0.235	0.179
	(0.0616)	(0.0522)	(0.0482)	(0.0570)	(0.0572)	(0.0630)	(0.349)	(0.161)
N (counts)	606	606	606	545	544	377	69	58

Notes: Standard errors are clustered at country year level
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Public utility connection

	Has electricity		Has phone land line		Has piped water		Has flush toilet	
	Base	Full controls	Base	Full controls	Base	Full controls	Base	Full controls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Count of LF	-0.00879***	-0.00936***	-0.00353***	-0.00376***	-0.00405*	-0.00416*	-0.00110	-0.00148
	(0.00243)	(0.00221)	(0.00114)	(0.00111)	(0.00235)	(0.00235)	(0.00200)	(0.00185)
Dummy has LF	-0.0452*	-0.0396*	0.00765	0.00970	0.000174	0.00111	-0.00735	-0.00579
	(0.0254)	(0.0240)	(0.00967)	(0.00944)	(0.0255)	(0.0261)	(0.0213)	(0.0203)
Share of built cover	-0.0441	-0.0516	0.0174	0.0131	0.0142	0.00682	0.130***	0.120***
	(0.0487)	(0.0451)	(0.0169)	(0.0165)	(0.0634)	(0.0637)	(0.0431)	(0.0406)
Ln buffer center distance	-0.0672***	-0.0578***	-0.0118**	-0.00960**	-0.0469***	-0.0476***	-0.0129	-0.00882
	(0.0126)	(0.0118)	(0.00479)	(0.00478)	(0.0163)	(0.0167)	(0.0107)	(0.0103)
Ln buffer ruggedness	0.0553**	0.0540**	0.00166	0.00186	0.0716**	0.0709**	0.00573	0.00529
	(0.0255)	(0.0240)	(0.00464)	(0.00461)	(0.0336)	(0.0338)	(0.0126)	(0.0126)
Buffer has river of lake	-0.00846	-0.000738	-0.0433***	-0.0392***	0.0859	0.0865	0.0149	0.0234
	(0.0414)	(0.0379)	(0.0147)	(0.0151)	(0.0593)	(0.0594)	(0.0393)	(0.0368)
Household size		0.00785***		0.00437***		0.00150		0.00317***
		(0.000972)		(0.000734)		(0.000968)		(0.000749)
Sex of household head: Male		-0.00475		-0.00434		-0.00376		-0.0174***
		(0.00718)		(0.00359)		(0.00699)		(0.00614)
Highest educational level of head: Primary		0.0385***		-0.00346		0.00882		-0.0323***
		(0.0110)		(0.00444)		(0.0108)		(0.00672)
Highest educational level of head: Secondary		0.145***		0.0135***		0.0247**		0.0166***
		(0.0102)		(0.00441)		(0.0101)		(0.00570)
Highest educational level of head: Higher		0.257***		0.0701***		0.0357***		0.141***
		(0.0126)		(0.00693)		(0.0137)		(0.0115)
Highest educational level of head: Don't know		0.189*		0.101		-0.0387		0.0214
		(0.0989)		(0.124)		(0.0737)		(0.110)
Mean	0.764	0.764	0.0526	0.0526	0.499	0.499	0.140	0.140
Observations	20,985	20,306	20,658	19,979	21,016	20,336	20,976	20,297
R-squared	0.300	0.348	0.106	0.125	0.529	0.521	0.330	0.356
City FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are clustered at DHS survey cluster level
*** p<0.01, ** p<0.05, * p<0.1

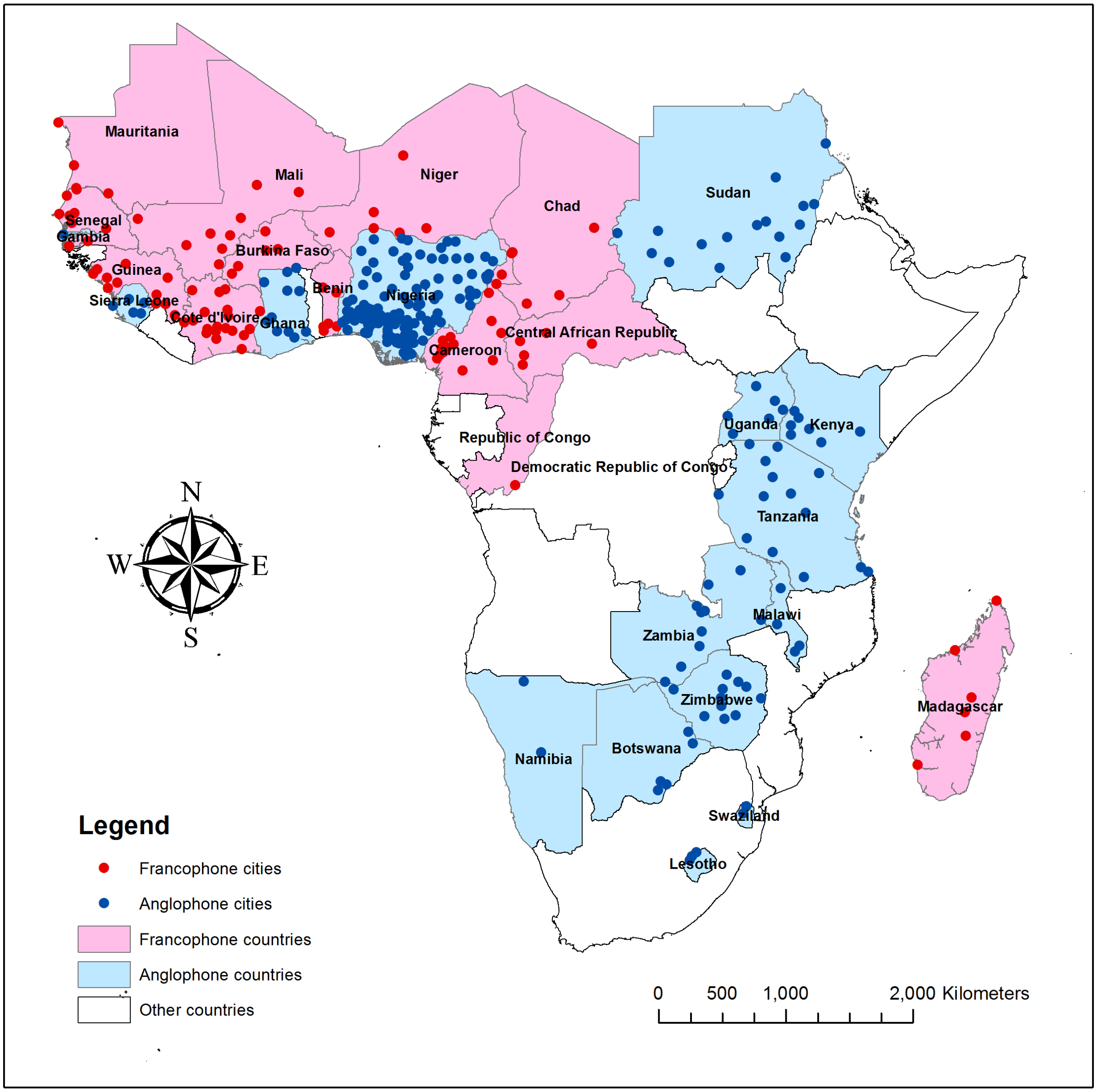

Figure 1a: Spatial distribution of full sample cities

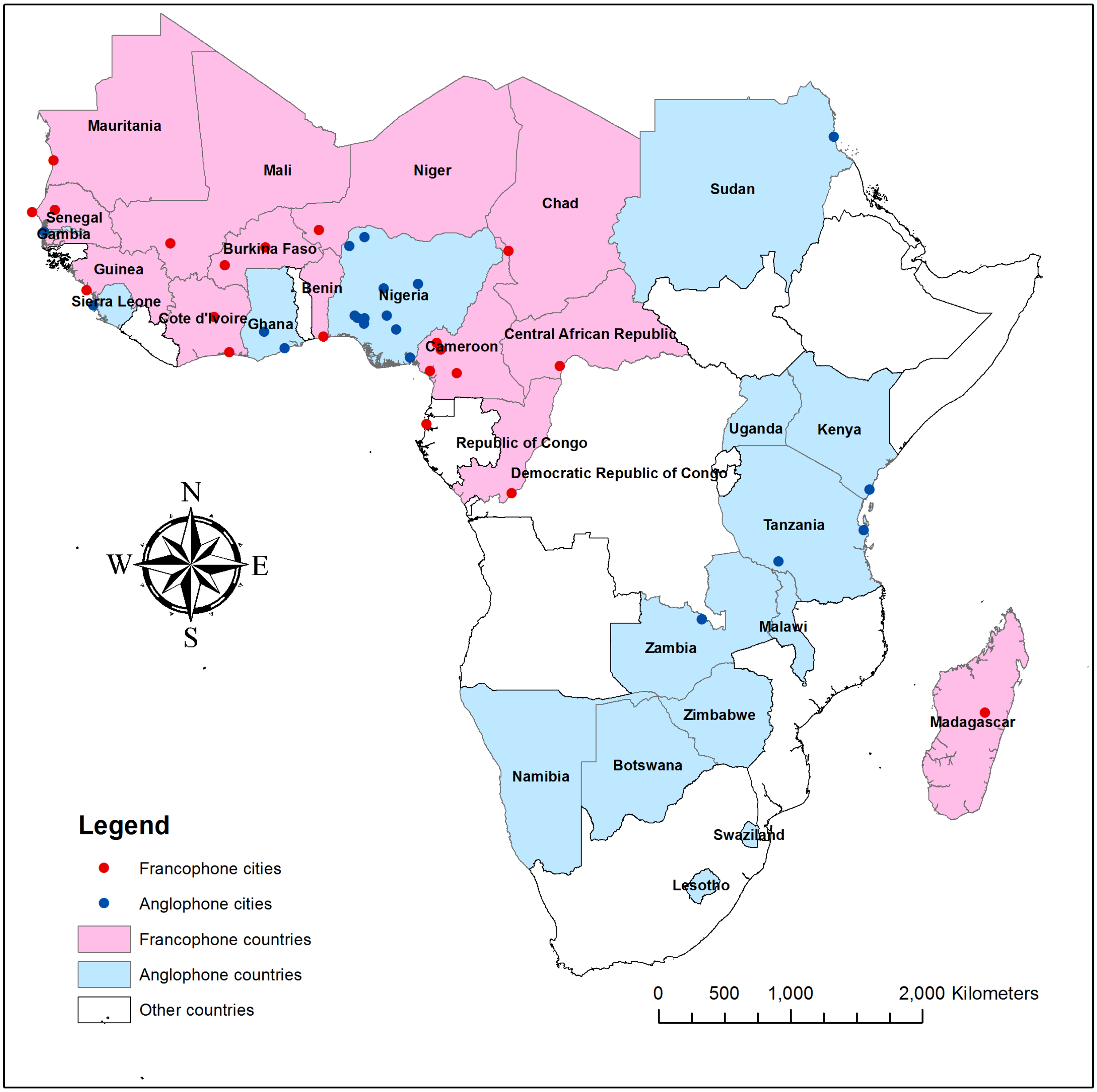

Figure 1b: Spatial distribution of 40 sample cities

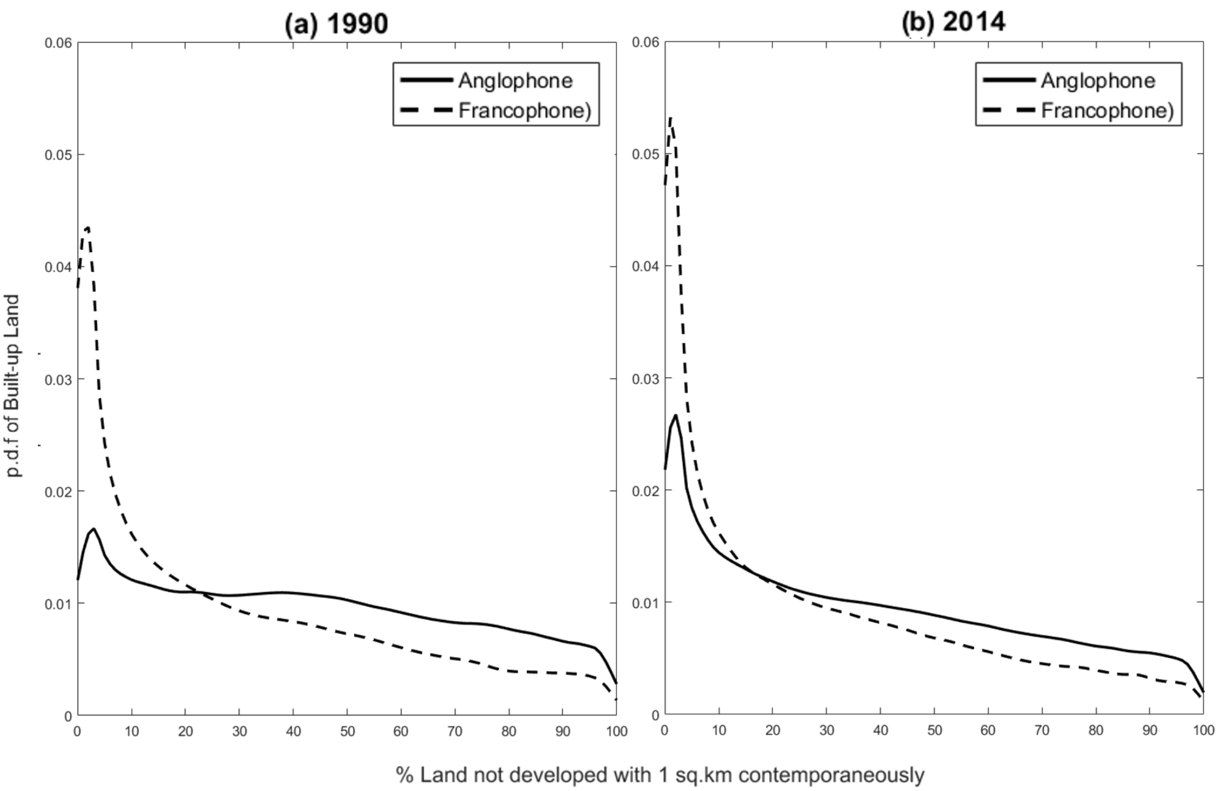

Figure 2: Probability function of Anglophone and Francophone built-up land across areas with different degrees of sprawl for (a) 1990 and (b) 2014

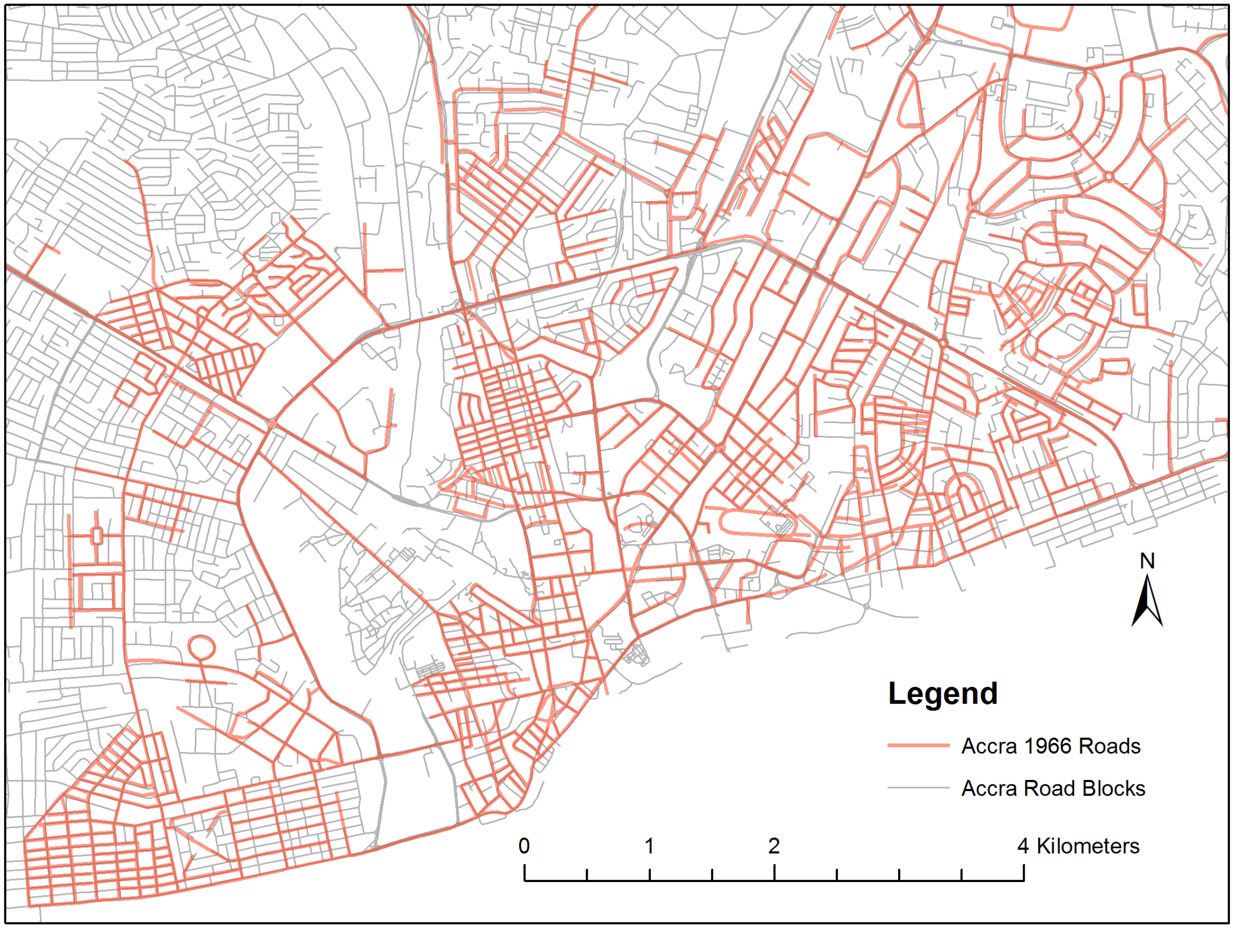

Figure 3a: Persistence of road blocks in Accra

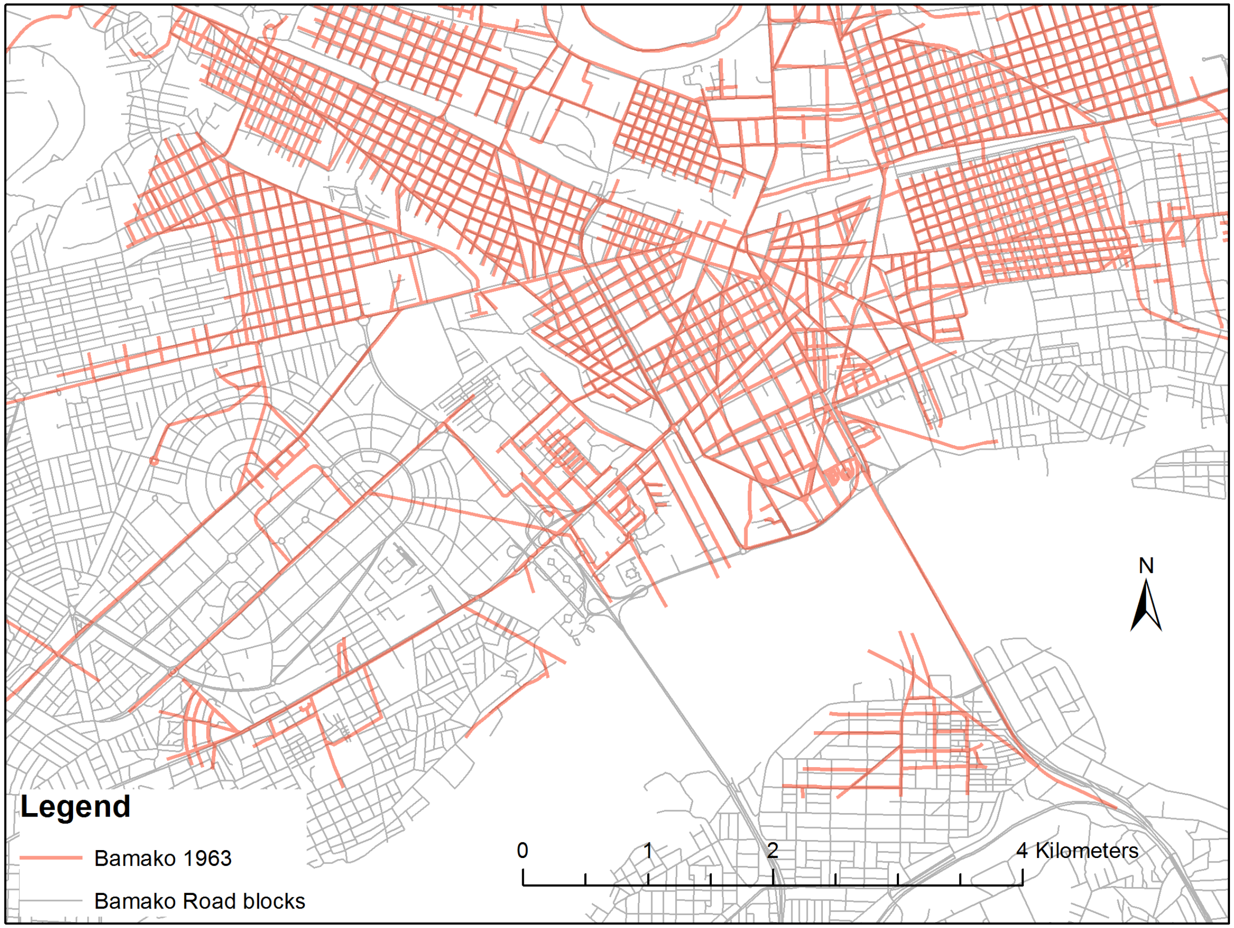

Figure 3b: Persistence of road blocks in Bamako

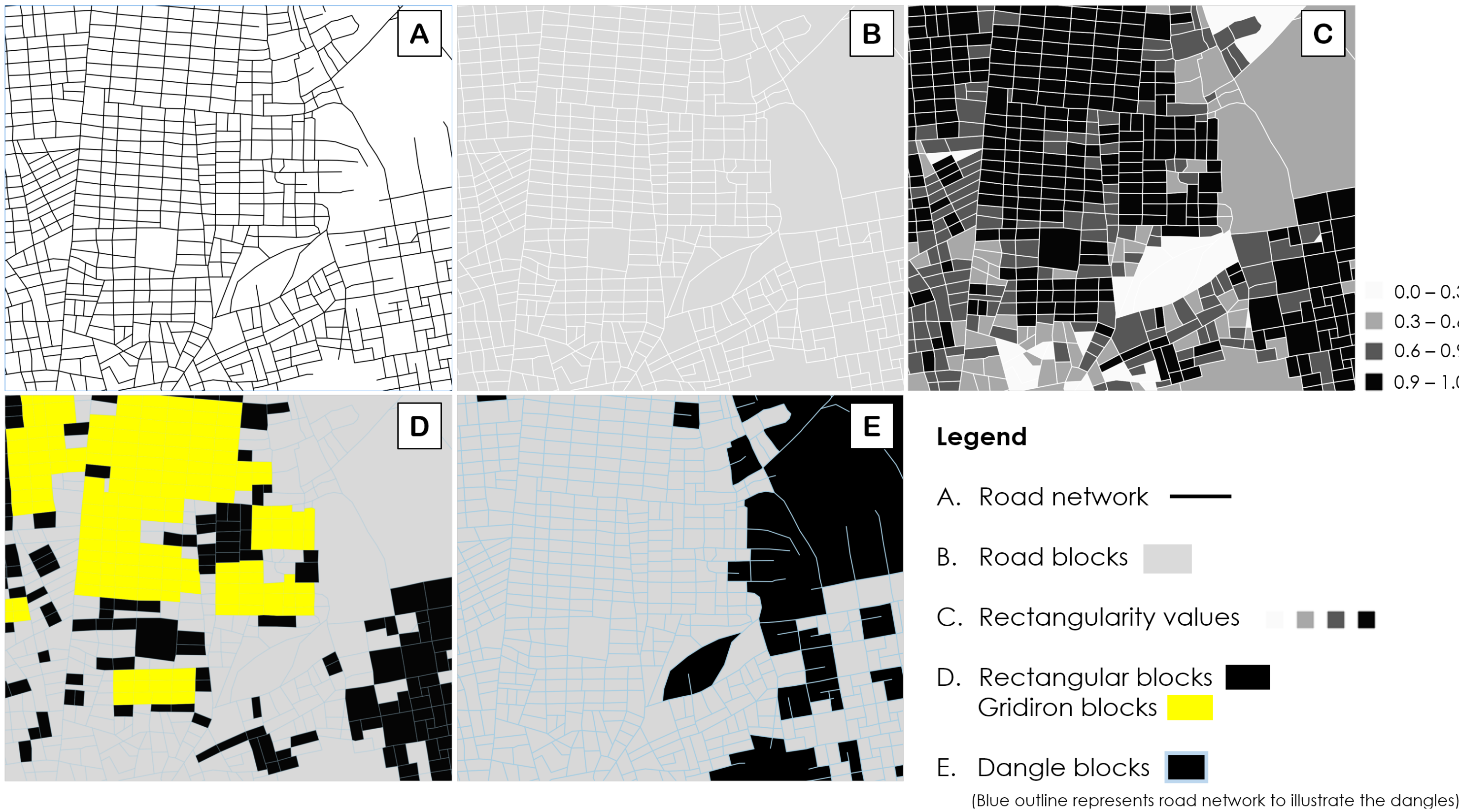

Figure 4: Road blocks and rectangularity

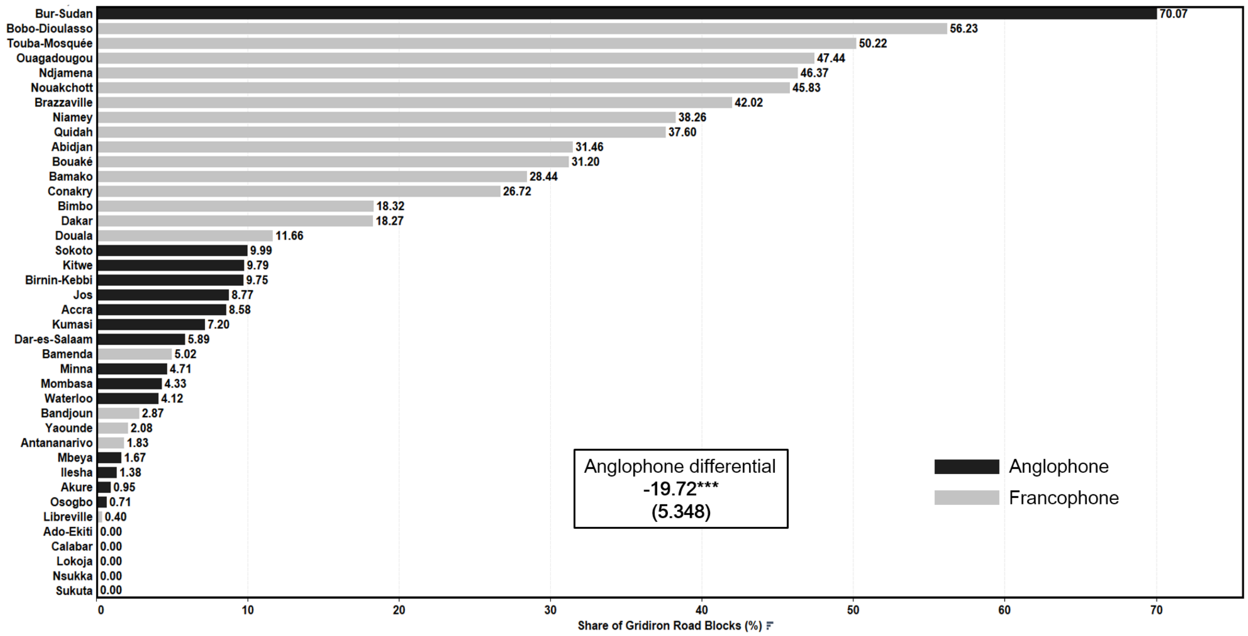

Figure 5: Share of gridiron road blocks within contemporary 5km

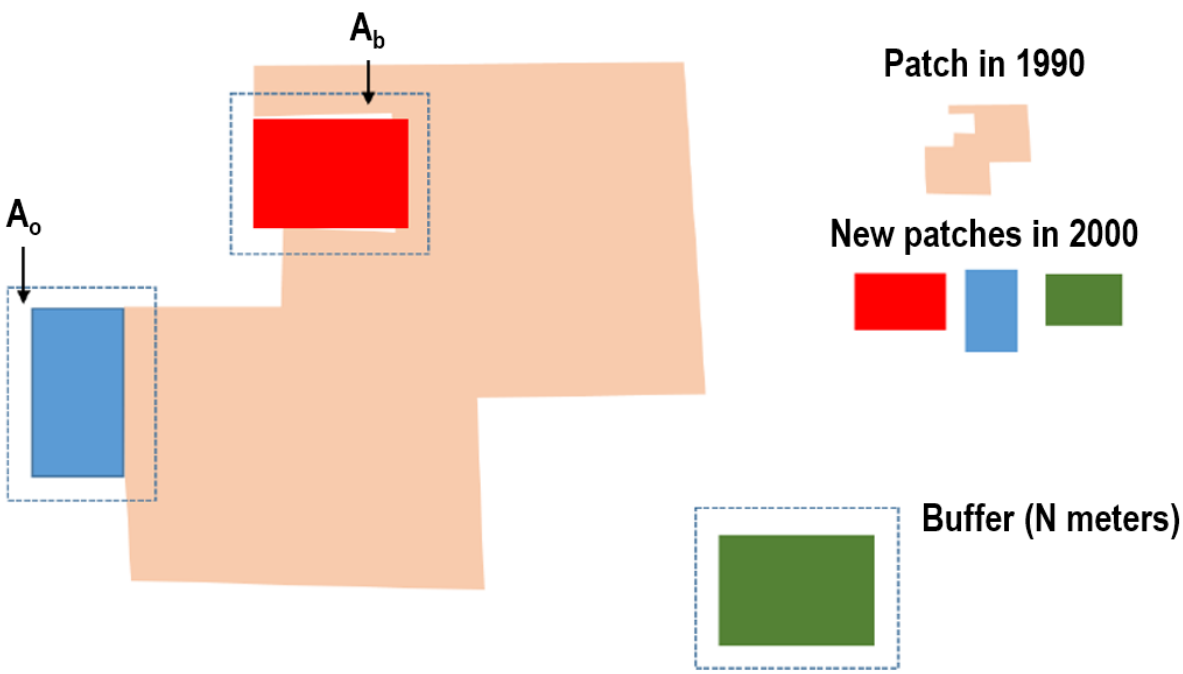

Figure 6: Illustration of using the landscape expansion index for defining leapfrog patches

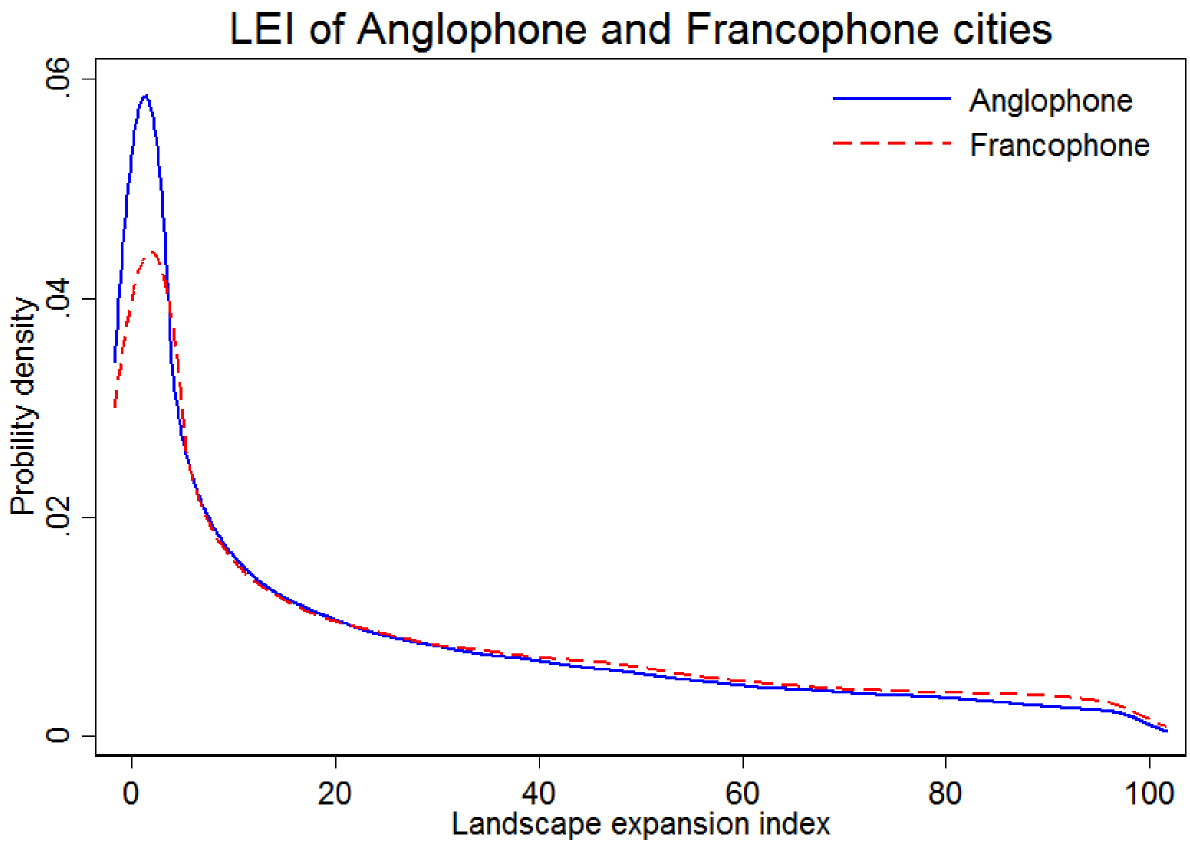

Figure 7: Probability function of LEI of patches by Anglophone and Francophone cities

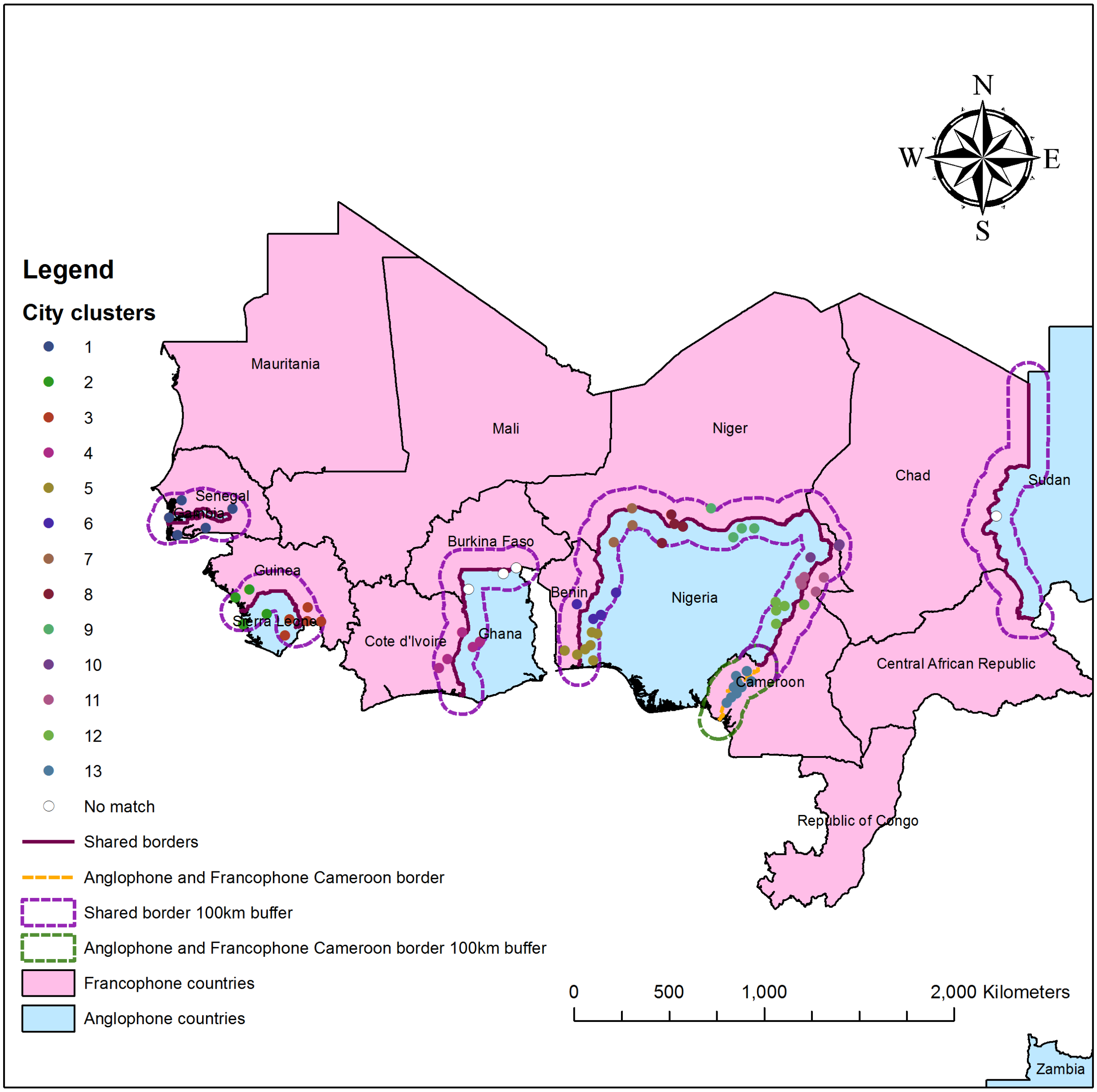

Figure 8: Shared borders

A On-line Appendix

A.1 City built cover boundary

We adopted a smoothing algorithm to define the city built cover boundary. First, we measured the area of total built cover for each 500m $\times$ 500m grid. Then the smoothing algorithm gives each grid the average built cover value of its neighbor grids and itself. The neighborhood is all queen and rook neighbors on the grid. Note if there is any grid in a neighborhood that has no built-up cover, the averaged built-up is set to be zero. This condition helps to eliminate scattered built-up and obtain continuous built cover area. Finally, we select the grids with neighbourhoods which average over 10% built cover, and use them to form the final built cover boundary of cities.

Table A1: Sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Bohicon	Benin	0	89,553	166,611		
Djougou	Benin	0	47,383	81,341		
Lokossa	Benin	0	30,328	70,048		
Parakou	Benin	0	96,206	216,706		
Pobè	Benin	0	35,163	67,425		
Quidah	Benin	0	921,859	1,922,874		
Toviklin	Benin	0	35,688	66,505		
Francistown	Botswana	1	65,935	109,269	Yes	
Gaborone	Botswana	1	215,068	487,079	Yes	
Kanye	Botswana	1	30,552	47,698		
Molepolole	Botswana	1	35,517	67,791		
Selebi-Phikwe	Botswana	1	45,446	61,570		
Banfora	Burkina Faso	0	41,261	97,859		
Bobo-Dioulasso	Burkina Faso	0	262,478	645,198		
Koudougou	Burkina Faso	0	60,177	99,187		
Ouagadougou	Burkina Faso	0	578,653	2,213,074		
Ouahigouya	Burkina Faso	0	44,462	89,579		
Bafang	Cameroon	0	37,503	33,806		
Bamenda	Cameroon	0	129,657	413,538		
Bandjoun	Cameroon	0	129,500	359,215		
Bertoua	Cameroon	0	48,871	116,686		
Douala	Cameroon	0	935,407	2,691,721		
Dschang	Cameroon	0	39,347	80,013		
Edéa	Cameroon	0	52,976	74,076		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Foumban	Cameroon	0	60,988	96,722		
Garoua	Cameroon	0	154,400	287,668		
Guider	Cameroon	0	35,432	62,750		
Kousséri	Cameroon	0	58,443	108,520		
Kumbo	Cameroon	0	38,606	112,836		
Loum	Cameroon	0	40,726	60,213		
Maroua	Cameroon	0	133,940	243,578		
Mbouda	Cameroon	0	37,434	50,758		
Meiganga	Cameroon	0	32,793	40,857		
Ngaoundéré	Cameroon	0	87,298	198,223		
Nkongsamba	Cameroon	0	88,275	112,347		
Yaounde	Cameroon	0	771,858	2,744,391		
Bambari	Central African Republic	0	38,985	43,081		
Berbérati	Central African Republic	0	45,426	110,757		
Bimbo	Central African Republic	0	492,970	995,932		
Bossangoa	Central African Republic	0	32,124	39,833		
Bouar	Central African Republic	0	39,766	40,765		
Carnot	Central African Republic	0	32,915	56,765		
Abéché	Chad	0	48,962	109,300		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Moundou	Chad	0	93,710	145,775		
Ndjamena	Chad	0	475,961	1,061,368		
Sarh	Chad	0	71,999	101,946		
Abengourou	Cote d'Ivoire	0	61,400			
Abidjan	Cote d'Ivoire	0	2,312,639	4,395,000		
Akoupé	Cote d'Ivoire	0	38,495			
Bondoukou	Cote d'Ivoire	0	35,283			
Bouaflé	Cote d'Ivoire	0	37,918			
Bouaké	Cote d'Ivoire	0	352,785	536,719		
Daloa	Cote d'Ivoire	0	130,708			
Danané	Cote d'Ivoire	0	34,582			
Dimbokro	Cote d'Ivoire	0	39,581			
Ferkéssédougou	Cote d'Ivoire	0	40,675			
Gagnoa	Cote d'Ivoire	0	112,890			
Issia	Cote d'Ivoire	0	30,922			
Katiola	Cote d'Ivoire	0	34,581			
Korhogo	Cote d'Ivoire	0	115,302			
Man	Cote d'Ivoire	0	94,435			
Odienné	Cote d'Ivoire	0	31,202			
Sinfra	Cote d'Ivoire	0	37,773			
Séguéla	Cote d'Ivoire	0	31,517			
Yamoussoukro	Cote d'Ivoire	0	139,062			
Libreville	Gabon	0	394,152	694,622		
Sukuta	Gambia	1	357,893	460,450	Yes	Yes
Accra	Ghana	1	2,004,164	3,689,581	Yes	Yes

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Bawku	Ghana	1	39,747	63,318		
Bolgatanga	Ghana	1	37,953	69,431		
Dzodze	Ghana	1	52,458			
Ho	Ghana	1	45,396	116,172		
Koforidua	Ghana	1	68,148	129,122	Yes	
Kumasi	Ghana	1	836,568	2,382,131		Yes
Nkawkaw	Ghana	1	35,816	48,870		
Sunyani	Ghana	1	46,279	76,966		
Tamale	Ghana	1	177,409	409,675		
Techiman	Ghana	1	34,094	69,700		
Wa	Ghana	1	45,405	71,967		
Yendi	Ghana	1	34,652	54,365		
Boké	Guinea	0	35,332	58,679		
Conakry	Guinea	0	942,708	1,824,765		
Fria	Guinea	0	41,303	53,703		
Guéckédou	Guinea	0	85,391	64,617		
Kamsar	Guinea	0	55,242	82,002		
Kankan	Guinea	0	80,409	180,127		
Kindia	Guinea	0	85,776	129,993		
Kissidougou	Guinea	0	59,539	86,954		
Labé	Guinea	0	40,570	84,218		
Macenta	Guinea	0	44,266	56,709		
Mamou	Guinea	0	45,178	63,059		
Nzérékoré	Guinea	0	88,082	181,799		
Eldoret	Kenya	1	116,456	285,187		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Garissa	Kenya	1	32,881	161,277		
Kisii	Kenya	1	47,004	74,984		
Kisumu	Kenya	1	194,711	326,009		
Kitale	Kenya	1	56,884	80,007		
Mombasa	Kenya	1	491,834	1,167,440	Yes	Yes
Nairobi	Kenya	1	1,516,055	5,044,352	Yes	
Nakuru	Kenya	1	170,002	336,431	Yes	
Maputsoe	Lesotho	1	59,779	103,567		
Maseru	Lesotho	1	117,442	178,016	Yes	
Teyateyaneng	Lesotho	1	42,583	61,599		
Antananarivo	Madagascar	0	675,058	1,300,000		
Antsirabe	Madagascar	0	117,026			
Antsiranana	Madagascar	0	54,808			
Fianarantsoa	Madagascar	0	101,428			
Mahajanga	Madagascar	0	99,126			
Toliara	Madagascar	0	75,032			
Blantyre	Malawi	1	372,552	738,274	Yes	
Lilongwe	Malawi	1	268,767	799,762		
Mzuzu	Malawi	1	59,752	159,233		
Zomba	Malawi	1	48,517	99,277		
Bamako	Mali	0	758,125	2,452,195		
Gao	Mali	0	54,413	99,059		
Kayes	Mali	0	55,029	149,909		
Koutiala	Mali	0	55,163	167,010		
Mopti	Mali	0	76,285	134,933		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
San	Mali	0	34,466	73,915		
Sikasso	Mali	0	87,024	261,123		
Ségou	Mali	0	92,519	188,365		
Tombouctou	Mali	0	31,338	64,488		
Kaédi	Mauritania	0	31,104	47,803		
Nouadhibou	Mauritania	0	61,209	113,789		
Nouakchott	Mauritania	0	418,294	938,154		
Rosso	Mauritania	0	30,530	50,861		
Oshakati	Namibia	1	34,552	83,432		
Windhoek	Namibia	1	140,410	358,996	Yes	
Arlit	Niger	0	36,261	78,651		
Birni-N'Konni	Niger	0	31,023	63,169		
Maradi	Niger	0	115,144	292,762		
Niamey	Niger	0	427,540	978,029		
Tahoua	Niger	0	52,951	117,826		
Zinder	Niger	0	126,517	235,605		
Aba	Nigeria	1	444,346	1,091,560	Yes	
Abakaliki	Nigeria	1	158,289	439,893		
Abraka	Nigeria	1	119,940	259,762		
Abuja	Nigeria	1	384,364	3,028,557	Yes	
Ado-Ekiti	Nigeria	1	291,866	647,182		Yes
Afikpo	Nigeria	1	74,524	141,516		
Agbor	Nigeria	1	67,857	129,551		
Aiyetoro	Nigeria	1	43,862	49,195		
Ajaokuta	Nigeria	1	57,702	82,522		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Akure	Nigeria	1	356,210	675,366	Yes	Yes
Akwanga	Nigeria	1	41,705	91,050		
Ankpa	Nigeria	1	39,291	70,006		
Argungu	Nigeria	1	40,367	87,700		
Auchi	Nigeria	1	72,986	147,505		
Azare	Nigeria	1	65,234	124,820		
Bama	Nigeria	1	64,076	107,727		
Bauchi	Nigeria	1	232,939	435,001		
Bida	Nigeria	1	85,084	233,626		
Birnin-Kebbi	Nigeria	1	142,795	347,188		Yes
Biu	Nigeria	1	49,067	105,096		
Calabar	Nigeria	1	159,490	436,394	Yes	Yes
Damaturu	Nigeria	1	36,386	85,027		
Doma	Nigeria	1	42,091	83,383		
Dutse	Nigeria	1	152,198	193,025		
Egbe	Nigeria	1	34,188	89,210		
Egume	Nigeria	1	71,733	133,130		
Ejigbo	Nigeria	1	31,525	92,402		
Ekehen	Nigeria	1	30,566	57,101		
Emure-Ekiti	Nigeria	1	67,364	78,826		
Enugu	Nigeria	1	503,384	912,182	Yes	
Funtua	Nigeria	1	89,954	183,064	Yes	
Ganye	Nigeria	1	58,710	102,167		
Gashua	Nigeria	1	52,963	82,391		
Gboko	Nigeria	1	184,658	362,100		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Gombe	Nigeria	1	191,795	372,804		
Gusau	Nigeria	1	135,788	242,556	Yes	
Hadejia	Nigeria	1	45,276	94,181		
Ibadan	Nigeria	1	1,711,452	2,911,228	Yes	
Idah	Nigeria	1	82,520	161,370		
Idanre	Nigeria	1	49,885	97,053		
Ife	Nigeria	1	263,879	491,656		
Igbo-Ora	Nigeria	1	31,519	76,914		
Igboho	Nigeria	1	31,854	62,311		
Ihiala	Nigeria	1	96,474		Yes	
Ikare	Nigeria	1	147,132	364,228	Yes	
Ikirun	Nigeria	1	215,476	427,992	Yes	
Ikole	Nigeria	1	56,932	100,183		
Ikom	Nigeria	1	40,718	52,109		
Ikot-Ekpene	Nigeria	1	146,477			
Ikot-Etim	Nigeria	1	87,282	165,044		
Ila	Nigeria	1	43,213	59,975		
Ilesha	Nigeria	1	139,202	332,008	Yes	Yes
Ilorin	Nigeria	1	538,446	833,589	Yes	
Ilutitun	Nigeria	1	45,214	70,917		
Iseyin	Nigeria	1	47,732	174,531	Yes	
Iwo	Nigeria	1	88,314	240,838	Yes	
Jalingo	Nigeria	1	83,219	176,451		
Jega	Nigeria	1	32,799	69,227		
Jibia	Nigeria	1	35,397	56,556		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Jimeta	Nigeria	1	238,746	567,818		
Jos	Nigeria	1	487,013	789,950		Yes
Kaduna	Nigeria	1	849,035	1,139,643	Yes	
Kafanchan	Nigeria	1	41,236	132,111		
Kano	Nigeria	1	1,385,370	3,734,597		
Katsina	Nigeria	1	189,505	425,669	Yes	
Katsina-Ala	Nigeria	1	43,751	74,895		
Kontagora	Nigeria	1	60,584	108,312		
Lafia	Nigeria	1	152,660	312,263		
Lagos	Nigeria	1	6,327,849	14,564,075	Yes	
Langtang	Nigeria	1	65,532	121,295		
Lokoja	Nigeria	1	63,547	375,656		Yes
Maiduguri	Nigeria	1	490,729	694,554	Yes	
Makurdi	Nigeria	1	179,494	301,249		
Malumfashi	Nigeria	1	46,775	58,968	Yes	
Maya-Belwa	Nigeria	1	30,627	42,151		
Michika	Nigeria	1	48,163	74,898		
Minna	Nigeria	1	98,628	459,441		Yes
Mubi	Nigeria	1	80,666	127,945		
Nasarawa	Nigeria	1	30,873	57,046		
New-Bussa	Nigeria	1	40,675	83,317	Yes	
Nguru	Nigeria	1	44,872	103,062	Yes	
Nkume	Nigeria	1	129,318			
Nsukka	Nigeria	1	638,402	1,918,146		Yes
Numan	Nigeria	1	72,049	77,368		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Obudu	Nigeria	1	59,422	167,241		
Ogbomosho	Nigeria	1	134,065	383,364		
Oguma	Nigeria	1	35,039	72,981		
Ogwashi-Uku	Nigeria	1	42,955	67,482		
Okeho	Nigeria	1	41,304	105,183		
Okenne	Nigeria	1	85,307	376,128		
Okigwi	Nigeria	1	33,699	83,387		
Okitipupa	Nigeria	1	68,819	113,745		
Okpakeke	Nigeria	1	31,662	58,191		
Okpo	Nigeria	1	30,700	59,740		
Omu-Aran	Nigeria	1	47,679	81,069		
Omuo-Ekiti	Nigeria	1	31,118	99,172		
Ondo	Nigeria	1	228,481	426,176	Yes	
Onitsha	Nigeria	1	956,207	8,290,101	Yes	
Ore	Nigeria	1	45,689	102,651		
Oro-Esie-Iludin	Nigeria	1	46,096	75,454		
Osogbo	Nigeria	1	497,049	774,670	Yes	Yes
Otun-Ekiti	Nigeria	1	33,762	41,416		
Oturkpo	Nigeria	1	79,827	147,733		
Owo	Nigeria	1	103,021	186,305	Yes	
Oye-Ekiti	Nigeria	1	60,751	80,981		
Oyo	Nigeria	1	188,026	363,371		
Potiskum	Nigeria	1	46,192	241,243		
Saki	Nigeria	1	74,705	253,572		
Shendam	Nigeria	1	34,042	42,405		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Sokoto	Nigeria	1	310,603	606,753	Yes	Yes
Takum	Nigeria	1	31,065	53,909		
Uba	Nigeria	1	55,350	70,447		
Ugep	Nigeria	1	34,279	149,847		
Umuahia	Nigeria	1	116,721			
Uromi	Nigeria	1	182,758	365,049		
Uyo	Nigeria	1	197,529	2,513,616		
Vande-Ikya	Nigeria	1	35,671	64,535		
Wukari	Nigeria	1	43,003	83,693		
Yelwa	Nigeria	1	35,055	72,400		
Zaki-Biam	Nigeria	1	54,169	83,361		
Zaria	Nigeria	1	375,845	747,127		
Zuru	Nigeria	1	49,083	110,647		
Brazzaville	Republic of Congo	0	731,625	1,652,847		
Dakar	Senegal	0	1,975,856	3,435,250		
Diourbel	Senegal	0	79,063	104,578		
Kaolack	Senegal	0	153,840	199,066		
Kolda	Senegal	0	36,624	71,134		
Richard-Toll	Senegal	0	36,610	67,954		
Saint-Louis	Senegal	0	118,992	188,160		
Tambacounda	Senegal	0	44,844	90,956		
Touba-Mosquée	Senegal	0	168,853	781,727		
Ziguinchor	Senegal	0	128,061	168,198		
Bo	Sierra Leone	1	76,138	220,890		
Kenema	Sierra Leone	1	66,406	187,158		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Makeni	Sierra Leone	1	48,170	108,671		
Torgbonbu	Sierra Leone	1	95,889	98,014		
Waterloo	Sierra Leone	1	561,004	1,049,768	Yes	Yes
Ad-Damazin	Sudan	1	58,786	255,340		
Ad-Duwaym	Sudan	1	53,580	79,009		
Al-Fashir	Sudan	1	130,226	244,208		
Al-Junaynah	Sudan	1	80,450	229,835		
Al-Manaqil	Sudan	1	60,108	111,669		
An-Nuhud	Sudan	1	52,539	69,668		
Atbara	Sudan	1	121,082	330,905	Yes	
Bur-Sudan	Sudan	1	293,338	421,429		Yes
El-Duein	Sudan	1	64,709	161,998		
El-Obeid	Sudan	1	211,433	384,829	Yes	
Gedaref	Sudan	1	178,488	295,201		
Kaduqli	Sudan	1	61,151	68,492		
Kassala	Sudan	1	223,586	318,335	Yes	
New-Halfa	Sudan	1	52,391	66,386		
Nyala	Sudan	1	194,574	606,115		
Sannar	Sudan	1	58,718	266,989		
Ngwenya	Swaziland	1	82,878		Yes	
Tabankulu	Swaziland	1	30,730			
Arusha	Tanzania	1	122,068	416,442		
Bukoba	Tanzania	1	31,826	128,796		
Dar-es-Salaam	Tanzania	1	1,333,413	4,520,658		Yes
Dodoma	Tanzania	1	90,565	213,636		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Kigoma	Tanzania	1	80,568	215,458		
Lindi	Tanzania	1	39,534	78,841		
Mbeya	Tanzania	1	144,556	385,279		Yes
Mtwara	Tanzania	1	68,149	100,626		
Musoma	Tanzania	1	68,356	134,327		
Mwanza	Tanzania	1	193,317	706,453	Yes	
Shinyanga	Tanzania	1	49,960	103,795		
Singida	Tanzania	1	41,807	85,242		
Songea	Tanzania	1	57,908	203,309		
Sumbawanga	Tanzania	1	51,038	124,204		
Tabora	Tanzania	1	96,935	160,608		
Tanga	Tanzania	1	142,799	221,127	Yes	
Zanzibar	Tanzania	1	174,467	501,459	Yes	
Fort-Portal	Uganda	1	32,130	51,795		
Gulu	Uganda	1	34,535	146,233		
Kampala	Uganda	1	803,069	2,269,969	Yes	
Masaka	Uganda	1	47,671	112,864	Yes	
Mbale	Uganda	1	51,446	117,706		
Mbarara	Uganda	1	39,119	164,150	Yes	
Njeru	Uganda	1	96,824	219,039		
Soroti	Uganda	1	40,903	48,069		
Chipata	Zambia	1	52,213	128,045		
Choma	Zambia	1	30,143	54,492		
Kabwe	Zambia	1	154,318	207,909	Yes	
Kasama	Zambia	1	47,653	108,492		

Continue: Table A1 sample cities and population

City name	Country	Anglphone dummy	Projected population 1990	Projected population 2012	Strict colonial origin sample	40 cities sample
Kitwe	Zambia	1	355,793	1,066,992	Yes	Yes
Livingstone	Zambia	1	76,875	143,249	Yes	
Luanshya	Zambia	1	118,143	133,187	Yes	
Lusaka	Zambia	1	813,154	2,000,916	Yes	
Mansa	Zambia	1	37,882	88,890		
Ndola	Zambia	1	329,228	468,324	Yes	
Bulawayo	Zimbabwe	1	611,307	653,337	Yes	
Chinhoyi	Zimbabwe	1	41,969	68,273	Yes	
Gweru	Zimbabwe	1	125,626	154,825	Yes	
Harare	Zimbabwe	1	1,405,753	2,133,801	Yes	
Hwange	Zimbabwe	1	44,297	19,870		
Kadoma	Zimbabwe	1	66,150	91,633	Yes	
Kwekwe	Zimbabwe	1	101,681	136,804	Yes	
Marondera	Zimbabwe	1	37,277	61,998		
Masvingo	Zimbabwe	1	48,780	87,886		
Mutare	Zimbabwe	1	124,697	186,208	Yes	
Zvishavane	Zimbabwe	1	32,571	45,230		

Notes: Two cities are only included in the 40 cities sample, but not included in the 333 cities full sample. They are Bimbo in Central African Republic, Libreville in Gabon.

Table A2: Intensity at grids level

	Has developed in 2014	Has developed in 2014		Ln intensity 2014	Difference of ln intensification 90-14		Ln intensity 2014
	All grids	Undeveloped grids in 1990		Developed grids in 1990	Developed grids in 1990		New developed grids
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Anglophone country	-0.0691	0.0142	0.0294	-0.252**	0.265***	0.0461	-0.0882
	(0.0421)	(0.0263)	(0.0234)	(0.118)	(0.0715)	(0.0752)	(0.156)
Distance to center	-0.00841***	-0.00310***	-0.00157***	-0.0356***	0.00636***	-0.0114***	-0.0257***
	(0.00102)	(0.000546)	(0.000448)	(0.00452)	(0.00236)	(0.00261)	(0.00444)
Distance to center × Anglophone	0.00617***	0.00224***	0.00101	0.0209***	-0.00373	0.00671**	0.0152***
	(0.00177)	(0.000840)	(0.000631)	(0.00663)	(0.00247)	(0.00305)	(0.00509)
Ln intensity 1990						-0.423***	
						(0.0156)	
Fraction of undeveloped area in ring 1990			-0.947***				
			(0.0878)				
Ln income per capita 1990	0.00548	0.00697	0.00767	-0.0326	-0.0132	-0.0214	0.0561
	(0.0239)	(0.0166)	(0.0155)	(0.0755)	(0.0568)	(0.0563)	(0.0756)
Ln projected city population 1990	0.0796***	0.0445***	0.0348***	0.201***	-0.0295	0.0681***	0.138***
	(0.0131)	(0.00916)	(0.00831)	(0.0290)	(0.0265)	(0.0235)	(0.0425)
Ln country light growth 92 to 12 excluding own city	-0.0186	0.00594	0.00727	-0.00975	0.0864	0.0457	-0.0620
	(0.0325)	(0.0245)	(0.0229)	(0.0875)	(0.0678)	(0.0653)	(0.123)
Ln ruggedness	0.00683	0.00270	0.00414	-0.0446	0.0383	0.00320	-0.0634
	(0.0160)	(0.00999)	(0.00914)	(0.0414)	(0.0424)	(0.0360)	(0.0515)
Ln rainfall	0.0738**	0.0631***	0.0538***	0.124	0.138**	0.132**	0.0860
	(0.0302)	(0.0184)	(0.0159)	(0.0911)	(0.0555)	(0.0638)	(0.103)
Ln elevation range	-0.0486**	-0.0261*	-0.0228*	-0.0466	0.0146	-0.0113	0.0262
	(0.0219)	(0.0136)	(0.0121)	(0.0672)	(0.0579)	(0.0546)	(0.0872)
Coast dummy	-0.361	-0.470	-0.457	-3.167**	-1.932	-2.454**	-4.872*
	(0.578)	(0.325)	(0.294)	(1.456)	(1.471)	(1.220)	(2.737)
Ln coast length × coast dummy	0.0826	0.0594**	0.0513*	0.324**	0.114	0.202*	0.506**
	(0.0533)	(0.0297)	(0.0266)	(0.134)	(0.127)	(0.105)	(0.216)
Ln distance to coast × coast dummy	-0.0708**	-0.0290*	-0.0237*	-0.0579	0.0704	0.0161	-0.0822
	(0.0286)	(0.0172)	(0.0140)	(0.0691)	(0.0535)	(0.0455)	(0.110)
Fraction of river area	0.167	-0.0534	-0.138	-0.132	-1.132	-0.708	-0.862
	(0.506)	(0.255)	(0.224)	(1.233)	(1.489)	(1.141)	(1.781)
Fraction of lake area	0.522	0.00995	-0.0140	2.465*	-1.521	0.166	0.451
	(0.560)	(0.363)	(0.290)	(1.451)	(1.258)	(1.101)	(2.312)
Fraction of forest	0.0871	0.0156	-0.00303	-0.113	-0.460***	-0.313**	-0.0607
	(0.0752)	(0.0477)	(0.0414)	(0.214)	(0.152)	(0.152)	(0.216)
Fraction of shrubs	0.133*	0.0874	0.0821*	0.130	-0.0873	0.00473	0.136
	(0.0768)	(0.0542)	(0.0495)	(0.184)	(0.152)	(0.140)	(0.220)
Fraction of crops	0.0951	0.0539	0.0342	0.350*	-0.0812	0.101	0.316
	(0.0715)	(0.0478)	(0.0423)	(0.191)	(0.132)	(0.143)	(0.207)
Fraction of wetlands and water	0.800***	0.625***	0.259	2.249***	0.362	1.161**	2.152*
	(0.274)	(0.193)	(0.199)	(0.714)	(0.575)	(0.533)	(1.216)
Fraction of sparse vege and bare land	0.0471	0.0378	0.0296	0.408	-0.193	0.0611	0.541
	(0.0912)	(0.0527)	(0.0452)	(0.378)	(0.192)	(0.207)	(0.499)
Observations	487,693	379,987	379,987	107,706	107,706	107,706	71,579
R-squared	0.096	0.046	0.074	0.116	0.026	0.435	0.043

Notes: Column 1 estimates a linear probability model (LPM) of whether a grid square is developed or not in 2014 for all grids. Columns 2 and 3 estimates an LPM of whether the undeveloped grid squares in 1990 have developed in 2014. Column 4 shows 2014 development intensity of 1990 grid squares which had built areas. Columns 5 and 6 show intensification within 1990 developed grid squares. Column 7 shows 2014 intensity in newly developed grid squares

Standard errors are clustered at city level

*** p<0.01, ** p<0.05, * p<0.1

Table A3: Intensity and convergence: Robustness to city boundary definitions

	Ln ring built cover		Long Difference of ln ring built cover			
	30km light 0	Trim light 5 drop mins and maxes	30km light 0	30km light 0	Trim light 5 drop mins and maxes	Trim light 5 drop mins and maxes
	(1)	(2)	(3)	(4)	(5)	(6)
Anglophone country	-0.509**	-0.658***	0.256***	0.0804	0.355***	0.0811
	(0.201)	(0.233)	(0.0953)	(0.0848)	(0.101)	(0.0972)
Ring distance	-0.170***	-0.250***	0.0230**	-0.0298***	0.0666***	-0.0288*
	(0.0172)	(0.0299)	(0.00900)	(0.00731)	(0.0127)	(0.0156)
Ring distance × Anglophone	0.0433**	0.108***	-0.000565	0.0119	-0.0246*	0.0174
	(0.0187)	(0.0326)	(0.00973)	(0.00739)	(0.0136)	(0.0145)
Ln ring total pixel	0.731***	0.691***	0.167***	0.302***	0.217***	0.332***
	(0.0417)	(0.0451)	(0.0268)	(0.0235)	(0.0296)	(0.0236)
Ln ring built cover in 1990				-0.296***		-0.319***
				(0.0161)		(0.0200)
Ln income per Capita 1990	-0.0447	-0.0990	0.148	0.0791	0.160*	0.0775
	(0.145)	(0.147)	(0.0922)	(0.0833)	(0.0875)	(0.0700)
Ln projected city population 1990	0.830***	0.899***	-0.151***	0.117***	-0.200***	0.126***
	(0.0739)	(0.0869)	(0.0323)	(0.0321)	(0.0371)	(0.0413)
Ln country light growth 92 to 12 excluding own city	0.00573	0.244	0.0269	0.0753	-0.0264	0.114
	(0.153)	(0.203)	(0.108)	(0.0909)	(0.103)	(0.0855)
Ln ruggedness	-0.0218	-0.0499	0.0709	0.0478	0.0863**	0.0455
	(0.0657)	(0.0638)	(0.0433)	(0.0362)	(0.0394)	(0.0322)
Ln rainfall	0.125	0.0996	0.292***	0.256***	0.326***	0.263***
	(0.149)	(0.136)	(0.0725)	(0.0752)	(0.0706)	(0.0599)
Ln elevation range	0.240**	0.244**	-0.136**	-0.0454	-0.189***	-0.0776
	(0.100)	(0.111)	(0.0638)	(0.0570)	(0.0629)	(0.0506)
Coastal Dummy	0.368	-8.758	0.143	-0.498	-4.158*	-6.326***
	(3.367)	(6.354)	(1.044)	(1.332)	(2.331)	(2.244)
Ln coast length × coast dummy	0.0656	0.459	0.0303	0.0811	0.298*	0.392**
	(0.304)	(0.519)	(0.0855)	(0.122)	(0.168)	(0.191)
Ln distance to coast × coast dummy	-0.0353	0.647*	-0.0577	-0.0232	0.168	0.346***
	(0.152)	(0.358)	(0.0737)	(0.0714)	(0.143)	(0.101)
Fraction of river area	-1.135	-1.103	0.544	0.0103	1.430	0.463
	(2.195)	(2.177)	(1.104)	(0.950)	(1.070)	(0.877)
Fraction of lake area	-2.439	-0.913	-0.402	-0.669	-0.221	0.104
	(3.307)	(3.738)	(1.119)	(1.044)	(1.130)	(0.856)
forest percent Ring	0.0764	-0.0118	-0.391**	-0.314**	-0.268	-0.272
	(0.359)	(0.420)	(0.161)	(0.153)	(0.196)	(0.189)
Shrubs percent Ring	-0.0461	-0.177	0.0447	0.0463	-0.00473	-0.0422
	(0.332)	(0.364)	(0.143)	(0.147)	(0.173)	(0.163)
Crops percent Ring	0.286	0.332	-0.295*	-0.190	-0.166	-0.102
	(0.275)	(0.306)	(0.150)	(0.143)	(0.170)	(0.152)
Wetlands and water percent Ring	2.184*	3.102**	-1.556***	-0.544	-1.308***	-0.143
	(1.209)	(1.499)	(0.598)	(0.544)	(0.504)	(0.569)
SparseVege and Bare percent Ring	-2.187***	-2.095***	-0.224	-0.820***	-0.185	-0.798***
	(0.506)	(0.553)	(0.194)	(0.235)	(0.253)	(0.219)
Observations	4,082	2,945	3,755	3,755	2,680	2,680
R-squared	0.451	0.417	0.124	0.470	0.143	0.502

Notes: Column 1, 3 and 4 defines city boundary by a light threshold of 0, and cut the rings off after 30kms from the centre; Column 2, 5 and 6 defines city boundary by a light threshold of 5, and trims the top and bottom 5 % of cities in terms of maximum distance from the centre to the outer lights boundary
Standard errors are clustered at city level
*** p<0.01, ** p<0.05, * p<0.1

Table A4: Leapfrogging other specifications

	Count of LF patches Poisson (1)	Ln count of leapfrog OLS (2)	Ln count of leapfrog Tobit (3)	Ln LF minus Ln total OLS (4)
Anglophone country	0.480**	0.681***	0.762***	0.274**
	(0.190)	(0.142)	(0.148)	(0.104)
Ln initial built cover 1990	0.407***	0.357***	0.354***	-0.251***
	(0.0615)	(0.0456)	(0.0504)	(0.0248)
Year Dummy 2014	0.580***	0.469***	0.493***	0.117*
	(0.0925)	(0.101)	(0.102)	(0.0627)
Ln income per capita t-1	0.199	0.245**	0.225	0.0199
	(0.132)	(0.0988)	(0.156)	(0.0477)
Ln projected city population 1990	0.437***	0.548***	0.647***	0.319***
	(0.0911)	(0.0817)	(0.0863)	(0.0434)
Ln country light growth excluding own city	0.446***	0.631***	0.650***	0.430***
	(0.173)	(0.138)	(0.177)	(0.0768)
Ln ruggedness	-0.0417	-0.0151	-0.0153	-0.0838**
	(0.0531)	(0.0564)	(0.0592)	(0.0340)
Ln rainfall	-0.371***	-0.253**	-0.365***	-0.0930
	(0.113)	(0.0962)	(0.113)	(0.0730)
Ln elevation range	0.433***	0.491***	0.489***	0.245***
	(0.0752)	(0.0592)	(0.0708)	(0.0431)
Coast dummy	-5.893*	-7.498***	-7.415**	-8.212***
	(3.162)	(2.777)	(3.041)	(1.793)
Ln coast length × coast dummy	0.354	0.513*	0.490	0.522***
	(0.296)	(0.265)	(0.299)	(0.156)
Ln distance to coast × coast dummy	0.198**	0.210	0.239	0.309**
	(0.0910)	(0.137)	(0.158)	(0.118)
Fraction of river area	-3.502*	1.896	1.149	0.530
	(2.056)	(1.661)	(1.907)	(0.999)
Fraction of lake area	-0.858	-3.379**	-3.086**	-3.392**
	(1.613)	(1.367)	(1.448)	(1.325)
Fraction of forest	0.194	0.00879	-0.0758	-0.216
	(0.379)	(0.229)	(0.287)	(0.139)
Fraction of shrubs	0.714***	0.462*	0.575**	0.0556
	(0.272)	(0.243)	(0.247)	(0.125)
Fraction of crops	0.341	0.0377	-0.0314	-0.0952
	(0.321)	(0.195)	(0.234)	(0.133)
Fraction of wetlands and water	1.258	0.498	1.017	0.826
	(1.336)	(0.890)	(0.928)	(0.586)
Fraction of sparse vege and bare land	-0.993**	-1.134***	-1.973***	-0.807***
	(0.389)	(0.324)	(0.527)	(0.228)
Observations	606	578	606	578
R-squared		0.622		0.236

Notes: Standard errors are clustered at country year level
*** p<0.01, ** p<0.05, * p<0.1

Table A5: Balance test for leapfrogging regressions

	(1) Full sample	(2) Border sample	(3) Border sample
Ln initial built cover 1990	-.297**	-.554***	-.237
	(.132)	(.21)	(.236)
Ln ratio of light 1992 to pop 1990	.982***	.259	-.023
	(.195)	(.442)	(.313)
Ln projected city population 1990	.104	-.165	-.049
	(.08)	(.169)	(.173)
Ln city light growth	-.441***	-.203	-.127
	(.115)	(.268)	(.253)
Ln ruggedness	.578***	.437**	.038
	(.114)	(.199)	(.087)
Ln rainfall	.032	-.006	.148***
	(.056)	(.098)	(.027)
Ln elevation range	.298***	.019	.016
	(.06)	(.135)	(.103)
Coast dummy	-.036*	.029	.086
	(.019)	(.045)	(.056)
Fraction of river area	-.007***	-.006	-.005
	(.003)	(.005)	(.003)
Fraction of lake area	.002	0	0
	(.002)	(.001)	(.001)
Ln coast length × coast dummy	-.376*	.335	.956
	(.203)	(.485)	(.609)
City cluster FE	No	No	Yes
Observations	606	113	113

Notes: Border sample does not include cities in Anglophone and Francophone Cameroon border area. Robust standard errors are applied.
*** p<0.01, ** p<0.05, * p<0.1

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