THE PERMANENT EFFECTS OF TRANSPORTATION REVOLUTIONS IN POOR COUNTRIES: EVIDENCE FROM AFRICA

Remi Jedwab and Alexander Moradi*

Abstract—We exploit the construction and eventual demise of the colonial railroads in Ghana, and most of the rest of Africa, to study the impact of transportation investments in poor countries. Using new data on railroads and cities spanning over one century, we find that railroads had large effects on the distribution of economic activity during the colonial period and these effects have persisted to date, although railroads collapsed and road networks expanded considerably after independence. Initial transportation investments may thus have large effects in poor countries. As countries develop, increasing returns solidify their spatial distribution, and subsequent investments may have smaller effects.

I. Introduction

Developing countries have extensively invested in railroads and roads over the past century. Transportation investments continue to remain the single largest item in the budgets of developing countries and development aid agencies alike (World Bank, 2008).

We focus on Ghana, for which we create a new data set on railroads and cities at a precise spatial level over one century: 2,091 cells of 0.1 × 0.1 degrees (11 × 11 kilometers) in 1891–2000. We first show how the construction of the colonial railroad had a large impact on city growth. The British colonizer built two lines to link the coast to mining areas and the hinterland. These lines went through dense, low-populated tropical forests, but the decrease in internal trade costs encouraged the local cultivation of cocoa, and Ghana became the world’s largest exporter. Rural populations increased along the lines as cocoa cultivation required more labor in cocoa-producing villages. Urban populations increased because villages used the towns as trading stations. We use various identification strategies in an attempt to measure causal effects. Our results also apply to 39 African countries for which we have similar data for 194,000 cells with the same degree of precision for 1890 to 2010.

Next, we show the persistence of this spatial equilibrium following the demise of the colonial railroad in the post-independence period. Although the railroad locations have lost their initial relative advantage in terms of transportation, we find that they remain relatively more developed today. The effects can be attributed to colonial urbanization. We show that the spatial equilibrium became stable as soon as the rail was built and that subsequent transportation technologies (i.e., roads) did not decentralize economic activity away from the railroad locations. We argue that while colonial sunk investments matter in explaining why the railroad locations are still more attractive today, railroad cities also persisted because their emergence helped coordinate investments across space for each subsequent period.

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1 Due to recent commodity booms, several African countries have initiated various giant transportation projects, such as the Tanzania-Gabon railway ($33 billion), the Mombasa–Kampala–Kigali railway ($14 billion), the Trans-Kalahari railway ($9 billion), and the Abidjan–Lagos motorway ($8 billion).
The literature has argued over the importance of geography versus history for the spatial distribution of economic activity. If geographical factors are the main drivers, any localized historical shock will only temporarily affect the distribution (Davis & Weinstein, 2002, 2008; Miguel & Roland, 2011). Thus, regional policy interventions may be ineffective. However, the literature has also found support for the presence of local increasing returns and that localized historical shocks can have permanent effects (Bosker et al., 2007, 2008; Redding, Sturm, & Wolf, 2011; Bleakley & Lin, 2012; Michaels & Rauch, 2013; Ahlfeldt et al., 2014; Jedwab, Kerby & Moradi, 2014).

In this case, regional policies may have an impact on regional development. In this paper, we use two symmetrical shocks: the construction and demise of colonial railroads. If geographical factors are time invariant, having two symmetrical shocks may help identify the role of local increasing returns. Krugman (1991) contrasts the role of history and expectations in explaining local increasing returns. On the one hand, cities are costly to build. Sunk investments in infrastructure (history) may therefore account for local increasing returns. If there are returns to scale, factors must be colocated in the same locations. There is a spatial coordination problem as it is not obvious which locations should have the factors. Existing cities solve this problem for each subsequent period if people expect them to keep thriving. These effects may be different in poor countries because there are initially fewer cities and no solidified spatial equilibrium as in richer countries. We will argue that the results in our context of mostly rural and poor areas are consistent with the various forces of path dependence in space.

This paper is also related to the literature on transportation infrastructure (see Redding & Turner, 2014, for a survey). First, we study the impact in a poor country. Rail building constituted a transportation revolution, as no modern transportation technology existed before. Contrary to Chandra and Thompson (2000), we find that railroads created a change in the level of economic activity rather than just reorganized existing economic activity. Indeed, there is not much economic activity to reorganize in agrarian countries. Railroads thus produced agricultural change, trade integration, and structural change, as in nineteenth-century America (Atack & Margo, 2009; Atack et al., 2010; Fajgelbaum & Redding, 2014).

Second, these century-old effects have persisted to date. The literature has studied the medium-term effects (0–40 years) of transportation investments, whereas we also study their long-term effects (0–110 years). While transportation infrastructure may facilitate the movement of goods and people, we highlight a new channel by which it has a durable impact. The effects also persisted because the railroads created cities that served as a mechanism to coordinate spatial investments for each subsequent period. Third, we argue that there could be decreasing marginal returns to transportation investments both across and within countries. Such investments may have large effects in poor countries because trade costs are high and there are fewer cities. As countries develop, increasing returns solidify their spatial distribution and subsequent investments may have lower effects on local economic development. In Africa, the spatial equilibrium became stable after the railroads were built, and subsequent investments had smaller effects. Finally, with the exception of Storeygard (2012), the impact of transportation infrastructure in Africa has been understudied.

Finally, our work is related to the literature on the determinants of city growth in developing countries. Transportation infrastructure may promote urbanization, when reduced trade costs boost trade and raise incomes, as in Atack et al. (2010) and Fajgelbaum and Redding (2014). During the colonial period, the decrease in trade costs spurred urbanization outside the few large cities. Transportation infrastructure could thus decentralize economic activity, as in Storeygard (2012), Baum-Snow et al. (2012), and Ghani, Goswami, and Kerr (2012). However, Faber (2014) finds that transportation investments reinforce the large cities if there are core-periphery effects. We find that urban systems were stable in postcolonial Africa, despite increased road investments in areas unrelated to the railroad lines. Second, we observe the emergence of a complex urban system consisting of villages, agrotowns, and trading cities, in line with central place theory (Christaller, 1966). Rural economic conditions feed into the growth of secondary towns servicing the farming sector, consistent with Jedwab (2013) and Henderson, Storeygard, and Deichmann (2013).

The paper proceeds as follows. Sections II and III present the background and the assembled data. Section IV explains the methodology. Sections V and VI display and discuss the results.

II. Historical Background

In this section, we describe the historical context of our natural experiment, from the construction of the railroad one century ago to its demise in the postindependence period.

A. The Railroad Age in Ghana, 1901–1931

Once the British had consolidated their control over Ghana in 1896, they sought to build transport infrastructure to permit military domination and boost trade previously constrained by high trade costs (Gould, 1960; Luntinen, 1996).
Ghana lacked waterways, and draft animals were not used due to the tsetse fly, making head loading the main method of transportation. There were then few trails because of the thick forest. Railroads were the latest and best mass transportation technology, but the British had to choose between a western, central, or eastern route.

The first line followed the western route (W in figure 1). Strong interest groups of British capitalists lobbied to connect the gold fields of Tarkwa and Obuasi to the coast, as the mines needed heavy machinery and large quantities of firewood or coal. The colonial administration gave in to the pressure, turning down alternative lines for which surveys attested a higher potential for agricultural exports. The governorship of Maxwell (1895–1897) was instrumental in the decision-making process. Maxwell previously worked in colonial Malaya, where railroads served the tin mines, and he supported the same model of “mining first” for Ghana. There were also military considerations. The British had fought four wars before they annexed the Ashante Kingdom. The railroad was meant to allow the quick dispatch of troops to the Ashante town of Kumasi. The line started from Sekondi (1898) and reached Tarkwa, Obuasi, and Kumasi in 1901, 1902, and 1903, respectively. The line went through virgin forest. Initially, mining accounted for two-thirds of the line’s traffic.

Colonial governors then long favored a central route (C in figure 1), but a series of events led to the governorship of Rodger (1904–1910) who decided that the capital, Accra, should be the terminus of this second line to Kumasi, via the eastern route (E in figure 1). By 1905, several additional motivations were cited for its construction: the export of cash crops, the exploitation of goldfields at Kibi, and the development of tourism (around Abetifi). Construction started in 1908, but completion was delayed by wartime shortages. By 1918, only Tafo had been reached. Kumasi was connected in 1923. A potential concern for the later empirical analysis is whether the placement of this line was exogenous, since cocoa was already grown in small quantities in the area. As the growing industry could be a cause of rail construction, it will be important to show that (a) production would have remained low without the railroad, (b) both lines had similar effects, (c) no positive effects are found for various “placebo” lines, and (d) results are robust to instrumentation.

Five alternative routes were proposed before the first line was built (see figure 1). We can address concerns regarding endogeneity by using these lines as a placebo check of our identification strategy. Random events explain why the construction of these routes did not go ahead. First, the Cape Coast–Kumasi line (1873) was proposed to link the then capital of Cape Coast to Kumasi to send troops to fight the Ashante. The project was dropped because the war came to an abrupt halt in 1874. Second, Governor Griffith wanted a central line from Saltpond to Kumasi (1893) in order to tap the palm oil areas and link the coast to Kumasi. When he retired in 1895, he was replaced by Governor Maxwell, who favored the mining lobbies and built the Western Line. For the third and fourth proposed routes, Maxwell thought that a second line was needed, and two projects had two different termini: Apam–Kumasi and Accra–Kumasi. A conference was to be held in London to discuss the proposals, but Maxwell died before reaching London and neither route was built. Finally, Governor Hodgson favored Accra, but he thought that the line should be built to Kpong rather than Kumasi. He retired in 1904 before work began and was replaced by Governor Rodger, who built the Eastern Line.
instead. In addition, we studied lines that were not built in time to affect cocoa production in 1927, the year for which we have GIS data on cocoa cultivation. Cocoa is a perennial crop, and harvest begins after five years (Ruf, 1995b). Hence, to observe any impact on production in 1927, farmers must have planted cocoa trees before 1922. The extension of the Eastern Line from Tafo to Kumasi in 1923, and the Huni Valley–Kade Line that was built parallel to the coast in 1927 (to connect a diamond field), thus provide another set of counterfactuals.

The rail reduced trade costs. While the freight rate per ton mile was 5 shillings (s) for head loading, 3.2 s for canoes, 2.5 s for lorries, and 1 s for steam launch, it was 0.4 to 0.6 s for railroads. This comparison underestimates the magnitude of trade costs as it only accounts for head loaders who walked along the few trails, the few waterways did not serve the areas suitable for cocoa, and the roads were of poor quality until the late 1920s when the Tarmet Program made some roads suitable for motor traffic year round.6 We verify that prerail trade costs were prohibitively high for cocoa cultivation. Using port prices for cocoa, historical estimates of production costs, and the least-cost route to any port in 1901, we estimate the profitability of cocoa cultivation for each location. We find that without railroads, production would have been limited to a narrow coastal strip, while with railroads, cultivation was profitable in the hinterland (see online appendix figure 1). As Luntinen (1996) commented, “The very existence of the transport network encouraged the production of surplus for the market. It was cocoa that made the Gold Coast the richest colony in Africa. The farmers seized the opportunity as soon as the rail reached them.” This is evident in the fact that after 1910, 80% of the cocoa produced was transported by rail.

B. The Postrailroad Age in Ghana

Rail usage continued to grow from 1,500 ton miles in 1931, averaging 2,500 ton miles over 1944 to 1974 (Luntinen, 1996). However, rail traffic collapsed after 1974. In 1984 and 2000, rail transported only 500 and 900 ton-miles, respectively; total GDP (and presumably also total traffic) has increased sevenfold since 1931, however. Similarly, while railroads accounted for more than 70% of cocoa transport until 1970, this share decreased to 5% in 2000. What caused the obsolescence of rail after independence in 1957? Political and economic instability had a detrimental impact on past public investments and management.7 In 1947, the Ghana Railway Corporation (GRC) employed 15,000 workers, twice as many as in 1957, even though the traffic had not increased. Payroll absorbed 70% of expenditures, and the GRC was often in deficit. Service quality was poor, which reduced traffic and freight revenues, thus delaying the maintenance and accelerating the decline of the network.

Furthermore, an agronomic feature of cocoa is that it is produced by “consuming” the forest (Ruf, 1995b). Cocoa farmers identify a patch of virgin forest and then replace forest trees with cocoa trees. Pod production peaks after about 25 years, and declines thereafter. When trees are too old, young adult males of producing households move to a new forest, while other household members convert the old cocoa plot into farmland for food production. Jedwab (2013) describes how production in the provinces along the Eastern and Western Lines peaked in the late 1930s and 1960s, respectively, and decreased afterward. The railroad locations have thus lost their initial relative advantage in terms of commercial agriculture.

Finally, the postindependence governments significantly invested in the road network. Roads were three times cheaper to build, yet maintenance costs were lower for railroads. Ghana’s road network increased from 6,000 kilometers in 1931 to 40,000 kilometers today. The railroads were replaced by roads at nearby sites over time, so that railroad cities did not lose their absolute access to transportation. Yet they lost their initial relative advantage in terms of transportation. Among the main 554 grid cells we use in our analysis, about 50 cells were crossed by a railroad. Among the 500 non-railroad cells, about 30, 250, and 450 of them were crossed by a road in 1901, 1931, and 2000, respectively. Therefore, while few cells were connected to a transportation network (the rail) in 1918, most cells are now connected (via a road). The population could have spread along the roads over time, away from the old railroad lines. Therefore, a different spatial distribution of economic activity could have potentially arisen as a result. However, we find it did not.

C. Patterns of Economic Transformation in Ghana, 1901–2000

Cocoa has been the main engine of Ghana’s development (Hill 1963; Austin 2008). Although cocoa was introduced by missionaries in 1859, production remained close to 0 in 1901. By 1931, only thirty years later, total production reached 250,000 tons and Ghana was the world’s largest exporter of cocoa.8 Figure 2 shows cells that were suitable or highly suitable for cultivation. Cocoa originally spread out around Aburi, where the British distributed cocoa seedlings. As Ghanaians realized how profitable cocoa was, more and more people specialized in it.9 Whereas Ghana was barely urbanized at the turn of the twentieth century, it is now one of the most urbanized countries in Africa. When arbitrarily

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6 Roads were first complementary to the rail as they were feeders to it. There were only two lorries in 1914, and roads were seasonal or of low quality until 1931. We focus on the railroad age because it gives us a natural experiment to study the impact of modern transportation technology versus no technology.

7 This instability includes the overthrow of President Nkrumah and the succession of military coups after 1966, the economic downturn over 1966 to 1969, and the major economic crisis from 1974 to 1983.

8 The real value of total exports per capita increased fourfold from 1901 to 1931, which can explained by the export of cocoa. Whereas production was nil in 1901, it amounted to 80% of exports by 1931.

9 Production boomed in Ashanti, around Kumasi, and not in the southwest, closer to Sekondi, because of very poor cocoa soils in the southwest.
defining any locality with more than 1,000 inhabitants as a town, Ghana’s urbanization rate increased from about 20% in 1901 to 40% in 1931 and to 70% in 2000. Figure 3 shows the spatial distribution of these towns over the past century. Before 1901, towns were chieftaincy towns or coastal trading centers (Dickson, 1968). In the twentieth century, most urban growth took place in the forest zone, with the development of modern transportation, cocoa production, and mining.

III. Data Description

We construct a new data set of 2,091 grid cells of 0.1 × 0.1 degrees (11 × 11 kilometers) for the following census years: 1891, 1901, 1931, 1948, 1960 (three years after independence), 1970, 1984, and 2000. We obtain the layout of the railroads (in GIS) from the Digital Chart of the World. We use various documents to re-create the history of each line and station, including lines that were planned but not built. Our analysis focuses on the rail network in 1918. We also construct a GIS database on rivers, tracks, and roads for 1850 to 2000.

The data on cocoa land suitability were derived from a survey of soil quality for cocoa. A cell is defined as suitable if it contains cocoa soils. It is highly suitable or very highly suitable if more than 50% of its area consists of forest ochrosols, the best cocoa soils. Each dot represents 100 tons of cocoa production. See the online appendix for data sources.

10 See the online appendix for data sources and construction of variables.
or first-class or second-class forest ochrosols, respectively. We use an administrative map of cocoa production and GIS to calculate the amount produced (tons) for each cell in 1927. There was no production in 1901. We also have data on cocoa tonnages brought to each railroad station in 1918. We use an administrative map of cocoa production and GIS to calculate the amount produced (tons) for each cell in 1927. We also have data on cocoa tonnages brought to each railroad station in 1918. We then use census gazetteers to construct a GIS database of localities above 1,000 inhabitants. While we have exhaustive urban data for all census years, we have only georeferenced population data for southern Ghana in 1901 and the whole country in 1931, 1970, and 2000. All cells have the same area, so population levels are equivalent to population densities. Finally, we have data on local public goods in 1901, 1931, and 2000.

We also construct a new data set of 194,000 grid cells of 0.1 x 0.1 degrees (11 x 11 kilometers) for 39 sub-Saharan African countries for the following years: 1890, 1900, 1960, 1970, 1980, 1990, 2000, and 2010. As we did for Ghana, we reconstruct the history of each actual or planned railroad line, and we also create a GIS database on rivers and roads in 2000. We then use census gazetteers and other sources to reconstruct a GIS database of localities above 10,000 inhabitants. We select 10,000 and not 1,000 because consistent historical urban data do not exist below that threshold for most countries. Figure 4 shows the spatial distribution of the colonial railroads and the cities for the 39 countries in 1960 and 2010. There were 73,436, and 2,911 cities in 1900 (not shown), 1960, and 2011, respectively.11

In this section, we describe the main specifications and identification strategies. Our analysis consists of two steps. First, we show that the construction of the colonial railroad gave rise to a specific spatial equilibrium. Second, we test the persistence of this spatial equilibrium, despite the demise of the colonial railroad after independence.

A. Econometric Specifications

First, to study if rail construction gave rise to a specific spatial equilibrium during the railroad age in Ghana (1901–1931), we run the following models for cells, c, for 1901 to 1931:

\[
\tilde{C}_{c,31} = \alpha + \text{Rail}_{c,18} \beta + \lambda \tilde{R}_{c,01} + \rho \tilde{U}_{c,01} + X_{c,01}' \gamma + u_c, \\
\tilde{P}_{c,31} = \alpha' + \text{Rail}_{c,18} \beta' + \lambda' \tilde{R}_{c,01} + \rho' \tilde{U}_{c,01} + X_{c,01}' \gamma' + u'_c,
\]

where our dependent variables are the standard scores, or z-scores, of cocoa production in tons (\(\tilde{C}_{c,31}\)) and rural and urban population (\(\tilde{P}_{c,31}\)) of cell c in 1931 (e.g., \(\tilde{P}_{c,31} = (P_{c,31} - E(P_{c,31})) / \sigma_{P_{c,31}}\)). \(\text{Rail}_{c,18}\) are cell dummies capturing rail connectivity of being 0 to 10, 10 to 20, 20 to 30, or 30 to 40 kilometers away from a line. We control for initial population conditions by including the z-scores of the rural and urban populations in 1901 (\(\tilde{R}_{c,01}; \tilde{U}_{c,01}\)) (cocoa production was nil). Population has been growing over time, so the coefficients will mechanically increase for later periods.

IV. Econometric Model

For the period between 1960 and 2010, data for 33 countries were obtained from Africapolis I: West Africa and Africapolis II: Central and Eastern Africa. Africapolis is an attempt by a team of geographers to recreate a consistent database for all African cities using as many sources as possible: population censuses (reports and gazetteers), administrative counts, demographic surveys, and electoral counts. We used the same types of sources to create the data for the 6 remaining countries. For the years 1890 and 1900, we used colonial census reports and colonial handbooks. The sources used for each country are listed in table 12 in the online appendix.

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Our hypothesis is that railroads have positive effects (\(\beta > 0\)) on cocoa production and population growth. We then include \(\tilde{C}_{c, 31}\) in model (2) to see if rail connectivity has an effect on population growth through more cocoa production along the lines. To investigate if that spatial equilibrium is persistent after the demise of the colonial railroad, we run the following model for cell \(c\), for 1901 to 2000,

\[
\tilde{P}_{c, 100} = \alpha + \text{Rail}_{c, 1918}\beta + \lambda\tilde{R}_{c, 01} + \rho U_{c, 01} + X_{c, 01}\gamma + u_{c, 01},
\]

where our dependent variables are the \(z\)-scores of the population variables for cell \(c\) in 2000 (\(\tilde{P}_{c, 100}\)). We control for the initial population conditions in 1901. We hypothesize that the long-term effects (\(\beta\)) (i.e., after the demise of the railroads) do not differ from the short-term effects (\(\beta\)) (i.e., when the railroads were built). Our analysis is performed on the sample of cells suitable for cocoa—the cells of the forested South (see figure 3). If we use the full sample of 2091 cells, we run the risk of comparing the southern and northern parts of Ghana, whose geography and history are different (Austin, 2007). In addition, if unobservable factors explain why the south is more developed than the north, excluding the northern cells will provide more conservative estimates. We also restrict our sample to those cells for which we have data on rural population in 1901. This leaves us with 554 cells.

To show that railroads also gave rise to a specific spatial equilibrium in colonial Africa (1900–1960) and that the spatial equilibrium also persisted after independence, we run the following models for 194,000 cells, \(c\), in 39 countries, \(s\), for 1900 to 1960 and 1900 to 2010:

\[
\tilde{U}_{c,s, 60} = \alpha_{ssa} + \text{Rail}_{c,s, 60}\beta_{ssa} + \rho_{ssa} \tilde{U}_{c,s, 00} + \pi_{s} + X_{c,s, 60}\gamma_{ssa} + v_{c,s},
\]

(4)

\[
\tilde{U}_{c,s, 110} = \alpha'_{ssa} + \text{Rail}_{c,s, 60}\beta'_{ssa} + \rho'_{ssa} \tilde{U}_{c,s, 00} + \pi'_s + X_{c,s, 00}\gamma_{ssa} + v_{c,s},
\]

(5)

where our dependent variables are the \(z\)-score of the urban population of cell, \(c\), in country, \(s\), in 1900 and 2010 (\(\tilde{U}_{c,s, 60}; \tilde{U}_{c,s, 110}\)), and we control for the \(z\)-score of the urban population in 1900 (\(\tilde{U}_{c,s, 00}\)). \(\text{Rail}_{c,s, 60}\) are the four rail dummies (defined in 1960). We include 39 country fixed effects (\(\pi_s\)). We also drop 77 cells that contain the capital city, largest city, and second largest city of each country, as they may have grown for political reasons.

### B. Identification Strategies

We include various controls to account for contaminating factors. For Ghana (\(X_{c, 01}\)), we add geography variables such as the proportions of suitable, highly suitable, and very highly suitable cocoa soils; the mean and standard deviation of altitude; and average annual rainfall from 1900 to 1960. We control for economic geography by adding dummies for bordering another country or the sea and Euclidean distances to the coast, a port, a navigable river, Accra, Kumasi, and Aburi (the town of origin of cocoa). We also add a dummy equal to 1 if the cell has a mine in 1901 and add the value of mineral production in 1931.\(^{12}\) Table 1 shows the mean of

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**Table 1.—Summary Statistics (Mean) for Treated and Control Cells in 1901**

<table>
<thead>
<tr>
<th>Group of Cells:</th>
<th>0–10 km</th>
<th>10+ km</th>
<th>10–20 km</th>
<th>Placebo 0–10 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine dummy</td>
<td>0.04</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Urban population 1901 ((z)-score)</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.16</td>
<td>0.43*</td>
</tr>
<tr>
<td>Rural population 1901 ((z)-score)</td>
<td>0.73</td>
<td>-0.07**</td>
<td>0.28*</td>
<td>0.46*</td>
</tr>
<tr>
<td>Soils suitable for cocoa (%)</td>
<td>0.76</td>
<td>0.89**</td>
<td>0.83</td>
<td>0.89**</td>
</tr>
<tr>
<td>Soils highly suitable (%)</td>
<td>0.43</td>
<td>0.64***</td>
<td>0.46</td>
<td>0.72***</td>
</tr>
<tr>
<td>Soils very highly suitable (%)</td>
<td>0.11</td>
<td>0.09</td>
<td>0.07</td>
<td>0.13</td>
</tr>
<tr>
<td>Altitude: mean (m)</td>
<td>153</td>
<td>182**</td>
<td>175</td>
<td>167</td>
</tr>
<tr>
<td>Altitude: Standard deviation (m)</td>
<td>36</td>
<td>40.4</td>
<td>44</td>
<td>37</td>
</tr>
<tr>
<td>Border dummy</td>
<td>0.00</td>
<td>0.05***</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Coastal dummy</td>
<td>0.06</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Distance to the coast (km)</td>
<td>82</td>
<td>111***</td>
<td>83</td>
<td>79</td>
</tr>
<tr>
<td>Distance to port 1901 (km)</td>
<td>97</td>
<td>144***</td>
<td>99</td>
<td>107</td>
</tr>
<tr>
<td>Distance to a river (km)</td>
<td>174</td>
<td>161</td>
<td>170</td>
<td>137***</td>
</tr>
<tr>
<td>Distance to Accra (km)</td>
<td>149</td>
<td>188***</td>
<td>152</td>
<td>116***</td>
</tr>
<tr>
<td>Distance to Kumasi (km)</td>
<td>107</td>
<td>119</td>
<td>110</td>
<td>102</td>
</tr>
<tr>
<td>Distance to Aburi (km)</td>
<td>149</td>
<td>185***</td>
<td>150</td>
<td>115***</td>
</tr>
<tr>
<td>Mineral production 1931 ((z)-score)</td>
<td>0.45</td>
<td>-0.04</td>
<td>-0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>Number of cells</td>
<td>49</td>
<td>505</td>
<td>55</td>
<td>129</td>
</tr>
</tbody>
</table>

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\(^{12}\) For the regressions for Africa, we include the following controls for physical and economic geography (\(X_{c, 01}\)): the shares (%) of class 1, class 2, class 3, undetermined, sparsely vegetated, and submerged soils in the cell, mean, and standard deviation of altitude (m), average annual rainfall (mm) for 1900 to 1960, two dummies equal to 1 if the cell is within 10 kilometers from the coast or a navigable river, Euclidean distances (km) to the coast, a navigable river, the largest city, the second largest city, or the capital city, respectively.
each variable for various groups of cells for Ghana. Columns 1 and 2 report the means for the cells within and beyond 10 kilometers from a railroad line, respectively. To test whether the railroad cells (column 1) differ from the other cells (column 2), we regress each variable on a dummy equal to 1 if the cell is within 10 kilometers from a line and test if the difference is significant. The 0–10 kilometer railroad cells have higher rural densities and are closer to main cities, which suggests an upward bias. However, these cells also have worse cocoa soils, which suggests a downward bias. Thus, the directionality of any bias is not obvious. We implement a battery of strategies to attempt to measure causal effects.13

Spatial discontinuities. The cells have the same area as Manhattan. Therefore, neighboring cells should have similar characteristics. In columns 1 and 3 of table 1, we compare for Ghana the cells 0–10 kilometers with the cells 10–20 kilometers from a line, and find no differences in observables. We can also include 9 ethnic groups’ (62 districts) fixed effects to compare the neighboring cells within a same group (district), as in Michalopoulos and Papaioannou (2013). For the all-Africa sample, we can include 755 ethnic group and (district), as in Michalopoulos and Papaioannou (2013). For the neighboring cells within a same group (district), as in Michalopoulos and Papaioannou (2013). For the all-Africa sample, we can include 755 ethnic group (district), as in Michalopoulos and Papaioannou (2013).

We can also include a fourth-order polynomial of the longitude and latitude of the cell centroid in order to flexibly control for unobservable spatial factors. The effects are identified from spatial discontinuities, as in Dell (2010).14

Mining and military lines. In Ghana, while the Eastern Line was potentially endogenous, the Western Line was built for mining and military domination, making its placement less endogenous to cocoa production. Endogeneity is less of a concern if we find similar effects for both lines. And, for each line in Africa, we know if it was built for military domination (because a colonial power wanted to put a claim on a territory or control the native population by being able to dispatch troops) or to connect a mine to the coast. We will test whether the railroad effects are the same when considering only the military and mining lines to create the rail dummies (online appendix figure 6 shows these lines).

Placebo lines. We can test that there are no spurious effects for cells along the placebo lines, as in Donaldson (2013). We can also use the placebo cells as a control group for the railroad cells, assuming they had the same economic potential. Column 4 of table 1 reports the means of the controls for the cells within 10 kilometers from a placebo line in Ghana. The placebo cells differ from the railroad cells, but it is not obvious in which direction the estimates could be biased for this control group. We can also compare the railroad lines with each placebo line, as some of them could prove to be a better counterfactual. Likewise, we will use for the 39 African countries various placebo lines that were proposed by the colonizers in 1916 and 1922 but never built (online appendix figure 6 shows these placebo lines).

Instrumentation (IV). We can use as an instrument for the rail in Ghana the distance from the straight lines Sekondi–Tarkwa–Obuasi–Kumasi and Accra–Kumasi (online appendix figure 3 displays the lines). This strategy echoes the work of Michaels (2008), who also uses straight lines. For the all-Africa sample, we use GIS to create a Euclidean minimum spanning tree (EMST) network based on the initial urban network in 1900 (including the capital, the largest and second-largest cities, and the other cities of each country). We can then use as an instrument for the rail the distance from the EMST straight lines.15

V. Estimation Results

We now present the main results of our analysis. We describe the emergence of the spatial equilibrium between 1901 and 1931 and then show its persistence over 1931 to 2000.

A. Emergence of the Spatial Equilibrium in Ghana, 1901–1931

Main results. Table 2 reports the results for models (1) and (2) for the period 1901 to 1931. Rail connectivity has a strong effect on cocoa production (column 1), but the effect decreases as we move away from the line. There is then a strong effect on rural population growth up to 30 kilometers (column 2) and urban population growth up to 10 kilometers (column 4). In columns 3 and 5, we include the z-scores of the amounts of cocoa produced and cocoa brought to railroad stations in the cell (and a dummy equal to 1 if the cell contains a train station) to see if rail connectivity drives population growth through more cocoa production along the lines. The population effects are indeed picked up by the cocoa variables. The rail effect on rural growth can be explained by the fact that more production requires more rural labor (column 3). Cocoa is often produced on the farms surrounding villages (Ruf, 1995b).16 The rail effect on urban growth can then be explained by the fact that the more cocoa being transported requires larger rail and trading stations (column 5). Cocoa farmers also established small producing towns (Hill, 1963). In column 6, the dependent

13 We find no effects before the lines are built for Ghana. When estimating model (2) with urban population in 1901 as the dependent variable (1891 is the previous year), the coefficients (p-values) of the 0–10, 10–20, 20–30 and 30–40 kilometer railroad dummies are −0.12 (0.16), −0.05 (0.14), −0.09 (0.15) and 0.02 (0.15), respectively.
14 Online appendix figures 2 and 5 map the ethnic groups and districts for Ghana and Africa, respectively.
15 Online appendix figure 7 shows the EMST and the nodes used to compute it for Africa. The EMST is the network that the colonial powers would have built if they had collaborated to optimally connect the initial cities while minimizing construction costs (using the Euclidean distance between them).
16 The relationship is not from railroads to population and then to production. Settlement was limited in the forest due to thick vegetation and high humidity (Ruf, 1995b). However, farmers overcame these constraints to grow cocoa. Additionally, cocoa production required only nonurban inputs: land, axes, machetes, and labor.
variable is the \( z \)-score of a dummy equal to 1 if there is a town in the cell in 1931 (we already control for urban population in 1901). The rail led to the creation of new towns. Railroads thus induced a cocoa boom, which contributed to rural and urban growth.\(^{17}\)

Table 3 displays the results when we implement the identification strategies described above. Column 1 replicates our main results from table 2 (columns 1 and 4). For simplicity, we focus on the \( 0–40 \) kilometer dummy for cocoa production (panel A) and the \( 0–10 \) kilometer dummy for urban population (panel B), as there are no effects beyond.\(^{18}\) The results are robust to (a) adding ethnic group or district fixed effects (columns 2–3), (b) including a fourth-order polynomial in longitude and latitude (column 4), (c) creating the rail dummies using the Western Line only (column 5), and (d) restricting the control group to all placebo cells (column 7).

We verify in column 6 that there are no spurious effects for the placebo lines,\(^{19}\) and (e) instrument the rail dummy by a dummy equal to 1 if the cell contains a railroad station in 1918 (coefficient not shown). See the online appendix for data sources.

These results hold if we (see the online appendix, table 3) (a) drop the controls, (b) use the full sample, (c) drop the railroad nodes, (d) drop the nodes and their neighboring cells to account for spatial spillovers from the nodes, (e) use the distance to rail stations to create the rail dummies, (f) use the distance to the rail (kilometers) instead of the rail dummies, since it is a variable of interest that has been often used in the literature, and (g) use the change in the \( z \)-score between 1901 and 1931 as the dependent variable.\(^{21}\) (h) run a panel regression including cell and year fixed effects,\(^{22}\) (i) follow Black and Henderson (1999) in normalizing the dependent variable (for \( P_t, P_t = P_t / E(P_t) \)) instead of standardizing it, (j) use the same specification as in their paper (the dependent variable is \( P_t - P_{t-1} \)), (k) regress the log of the dependent variable on the rail dummies, (l) use a log-log specification (population density falls by 53% with a doubling of the distance to the rail), and (m) use Conley standard errors (100 kilometers) to account for spatial autocorrelation.

### Other measures of development

For each cell, we know the number of schools, hospitals, and churches and whether the cell is crossed by a road in both 1901 and 1931. We use model (2) to examine whether railroad cells had better infrastructure by 1931, although no difference is observed on 1901 (not shown). Results are shown in panel A of table 6 (for the sake of space, the coefficients of the 20–30 kilometer and 30–40 kilometer dummies are not reported). We along the lines. Total production was 218,200 tons in the map, against 210,600 tons registered at the ports. We use exhaustive census data for population estimates.

\( \dagger \) Fifty percent of urban males worked in agriculture according to the 1931 census. Wealthy farmers settled in towns as they offered better living conditions (Hill, 1963). These towns also served as trading stations for exports and imports, as trade accounted for 20% of urban male employment. Also, cocoa generated an income surplus that was spent on urban goods and services (Jedwab, 2013). Manufacturing and services accounted for two-thirds of imports.

\( \dagger \dagger \) Table 1 in the online appendix shows that the effects are also strong for rural and total population growth when using the same identification strategies as for cocoa production and urban population growth.

\( \dagger \dagger \dagger \) We create a dummy equal to 1 if the cell is within \( X \) kilometers from a placebo line (where \( X = 40 \) and 10 kilometers). We find no spurious effects for each of the seven placebo lines (see table 2 in the online appendix).

\( \dagger \ddagger \) The IV \( F \)-statistics are high: 164 and 20, respectively. The IV minimizes measurement errors. We also verify that production was not better measured.
find positive effects on the number of schools (column 1) and the probabilities of having a hospital (column 2) or being crossed by a class 1 road (column 4, for 10–20 kilometers as roads were feeders to the rail). We do not find any effect for churches (column 3). These positive effects decrease when we include the \( z \)-scores of the urban and rural populations in 1931 (panel B). This suggests that railroads increased population density, and public goods were then created.\(^{23}\)

Anthropometric data indicate that living standards increased along the lines. Using individual data on Africans recruited by the British Army before independence (Moradi, 2009), we run the following regression on height (H) for 5,725 soldiers, born in cell, c, in year, \( t \), (1867–1937):

\[
H_{s,c,t} = a + \xi \text{Rail}_{c,t} + \tau 1(t \geq 1918) + \beta_b \text{Rail}_{c,t} \times 1(t \geq 1918) + \chi_{c,t} + \phi + \upsilon_{c,t}.
\]

We compare soldiers born in railroad to nonrailroad cells (10 kilometers is the cutoff) after and before 1918. We include the same controls as in the previous model and add individual controls for age, farming, literacy, and ethnicity. While railroad cells were not different from other cells ex ante (\( \zeta = -0.04 \)), the height of the soldiers was \( \beta_b = 0.66 \) cm higher for those born along the lines after 1918 (see table 4 in the online appendix).

### Investigation of general equilibrium effects

We analyze whether the railroads created new economic activity or simply reorganized economic activity across space. Existing precolonial cities may have declined as a result of rail building and the emergence of new cities. The railroad effects would then be overestimated. First, there have been few urban collapses. Only six cells with a city in 1901 did not have a city in 1931. Next, we test whether population increases in railroad cells were accompanied by population decreases in adjacent cells. Column 4 of table 2 shows

### Table 3.—Identification Strategies, 1901–1931–2000

<table>
<thead>
<tr>
<th>Strategy:</th>
<th>OLS (1)</th>
<th>Ethnic (2)</th>
<th>District (3)</th>
<th>Longitude Latitude (4)</th>
<th>Mining and Military Domination (5)</th>
<th>Placebo (6)</th>
<th>C:Placebo (7)</th>
<th>IV (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail 1918, 0–40 km</td>
<td>0.65*** (12)</td>
<td>0.83*** (11)</td>
<td>0.44*** (10)</td>
<td>0.42*** (10)</td>
<td>0.32** (10)</td>
<td>-0.04 (10)</td>
<td>1.03*** (12)</td>
<td>0.79*** (12)</td>
</tr>
<tr>
<td>(Col. 6: Placebo)</td>
<td>(0.14)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.10)</td>
<td>(0.14)</td>
<td>(0.18)</td>
<td>(0.12)</td>
<td>(0.23)</td>
</tr>
</tbody>
</table>

### Table 4.—Colonial Railroads and Historical Factors, 1901–1931

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>(1) Number of Schools 1931</th>
<th>(2) Hospital 1/0 1931</th>
<th>(3) Number of Churches 1/0 1931</th>
<th>(4) Class 1 Road 1/0 1931</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail 1918, 0–10 km</td>
<td>0.60*** (0.22)</td>
<td>0.12*** (0.04)</td>
<td>-0.00 (0.01)</td>
<td>0.29 (0.04)</td>
</tr>
<tr>
<td>Rail 1918, 1–20 km</td>
<td>0.12 (0.08)</td>
<td>-0.00 (0.01)</td>
<td>0.18*** (0.34)</td>
<td>0.02 (0.06)</td>
</tr>
<tr>
<td>Rail 1918, 0–10 km</td>
<td>0.17 (0.16)</td>
<td>0.07*** (0.03)</td>
<td>-0.76 (0.04)</td>
<td>-0.00 (0.07)</td>
</tr>
<tr>
<td>Rail 1918, 10–20 km</td>
<td>0.09 (0.09)</td>
<td>-0.01 (0.01)</td>
<td>-0.45 (0.33)</td>
<td>0.19*** (0.33)</td>
</tr>
</tbody>
</table>

### Notes

\(^{23}\) Another interpretation could be that the colonizer invested in public goods at the same time as it was building the rail. In that case, the rail effects on population could be explained by the other investments. However, we do not find that public goods in 1901 were located along the lines (not shown). A second interpretation could be that railroads influenced the placement of the other public goods between 1901 and 1931, which could cause population to increase. While we cannot rule out this possibility, controlling for public goods in 1901 and 1931 does not alter the relationship between railroads and population (not shown).
that the adjacent 10–40 kilometer cells did not lose urban population relative to the control cells. Nor do we find negative effects for any group of adjacent cells (e.g., 10–20 kilometers) when compared to adjacent cells farther away (e.g., 20 or more kilometer), as shown until 80 kilometers in table 5, columns 1 to 8. We also use model (2) on the full sample \((N = 2,091)\) to test if cells that were relatively more developed before the rail lost urban population relative to other cells. The new urban residents also came from the nonforested areas, hence the need to also study them. We create a Pre-Rail dummy equal to 1 if the cell already had a city or had access to transportation before 1901, which we interact with two dummies equal to 1 if the cell belongs to the Forest \((N = 554)\) and the Nonforest \((N = 1,537)\), respectively. We drop the 0–10 kilometer railroad cells in order to compare the prerail cells with the other cells. In columns 9 to 12 of table 5, the prerail dummy is equal to 1 if the cell already had a city in 1901 or if the cell was within 10 kilometers from the coast, a trade route in 1850, or a road in 1901, respectively. We find no negative effect for these other competing cells.

Our results suggest that rural-to-urban migration accounts for city growth. Since the new urban residents in the railroad cells were not coming from the same cells (their rural population also increased), they should have come from villages in the rest of the country. Hill (1963), Ruf (1995a) and Austin (2007, 2008) document how the cocoa farmers who populated the towns of the forest were previously farmers who lived in other parts of the country. The rail gave access to a new factor of production, forested land, that increased productivity, as it was used to grow cocoa for export. Data on production costs in 1931 indicate that cocoa farmers were 90% wealthier than subsistence farmers (not shown). The employment share in the cocoa sector was almost one-third then. More generally, the number of cities increased by 150 towns and the urbanization rate of the forest by 10 percentage points between 1901 and 1931 (see figure 5a). We find the same patterns for the whole country (see figure 5b). This structural break in the urban pattern is related to the structural breaks observed in the cocoa exports, total exports, and GDP series (see figure 5c).

How much of the aggregate changes in urbanization can be attributed to the rail?24 When estimating model (2) with the cell urbanization rate (%) in 1931 as the dependent variable while controlling for the cell urbanization rate in 1901, we find a positive railroad effect until 10 kilometers (table 2 column 7). Since the fast urban growth along the lines was not due to urban reorganization, the aggregate urban population of the forest increased. We thus multiply the number of cells for which the 0–10 kilometer railroad dummy is equal to 1 by the 0–10 kilometer railroad effect when using the nonstandardized urban population as a dependent variable. The product gives the net increase in the urban population caused by the rail from 1901 to 1931. As these urban residents would have remained rural without the railroad, we can estimate by how much lower the total urban population and the urbanization rate of the forest would have been in 1931 without the introduction of the rail. In particular, we estimate that the rail was potentially responsible for 75% of the change in the urbanization rate of the forest and 36% of the national change in the urbanization rate.25

### B. Persistence of the Spatial Equilibrium in Ghana, 1931–2000

Column 1 of table 6 confirms that the long-term effect for the urban populations in 2000 (see model [3]) is similar to the short-term effect for the urban population in 1931 (see...
model [2], and table 2, column 4). Panel C of table 3 then shows that the long-term effect (0–10 kilometer) is robust to using the same identification strategies as before. Using the same methodology as in section VA, we find that the long-term effects may have potentially accounted for 42% of the change in the urbanization rate of the country over 1901 to 2000. The long-term effects are also strong for the other population variables (e.g., rural population; see table 5 in the online appendix). Likewise, railroad cells also have better infrastructure today. For example, we find that railroad cells are more likely to be crossed by a paved (bitumenized) or improved (laterite) road, and their residents also live closer to a secondary school, a clinic, and a hospital (see table 5 in the online appendix).

We further investigate the dynamics of urban growth between 1891 and 2000. We run the following model separately for each year where 

\[
U_{c,t} = \alpha_t + Rail_{c,18} \beta_t + \rho_t U_{c,t-1} + \lambda_t R_{c,01} + X_{c,01} \gamma_t + u_{c,t}.
\]

The coefficient \(\beta_t\) indicates the rail effects for each period \([t-1; t] = [1891–1901, 1901–1931, \ldots, 1984–2000]\). Figure 6 displays only the effect of the 0–10 kilometer rail dummy, because the coefficients of the other rail dummies are 0. There was no effect over 1891 to 1901, a strong effect in 1901 to 1931, and no additional effect of the railroad post-1931. Cells that had an initial advantage during the railroad age remain relatively more developed today. We also estimate \(\rho_t\), the coefficient of autocorrelation of the urban population. A coefficient of 1 shows that the ranking of the cells in terms of urban population is the same in year \(t\) as in year \(t-1\). Here, the coefficient jumps immediately after 1931, from about 0.50 to 0.90, and converges toward 1. This shows how stable the spatial equilibrium became over time. The stability of the equilibrium can also be observed from the evolution of the city size distributions (Black & Henderson, 1999). Changes in the distribution can be described as a stationary, first-order homogeneous Markov process from 1960 onward (see table 8 in the online appendix). In particular, the relative size distribution of cities in 2000 is not different from the steady-state size distribution.

27 The rail dummies are defined using the lines in 1918, since they are more exogenous. 28 Results hold when running panel regressions with cell and year fixed effects and cell-specific trends (see figure 4 in the online appendix). We cannot add a lag of the dependent variable in the panel regressions (Nickell, 1981), so the change in the \(z\)-score is the dependent variable: 

\[
U_{c,t} - U_{c,t-1} = \alpha_t + Rail_{c,18} \beta_t + \lambda_t R_{c,01} + X_{c,01} \gamma_t + u_{c,t}.
\]
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Rail 1918, 0–10 km</td>
<td>0.87**</td>
<td>0.83**</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>(0.37)</td>
<td>(0.37)</td>
<td>(0.24)</td>
</tr>
<tr>
<td>Rail 1918, 10–20 km</td>
<td>0.20**</td>
<td>0.18*</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.09)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Paved Road 2000, 0–10 km</td>
<td>0.22***</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.09)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Improved Road 2000, 0–10 km</td>
<td>0.23**</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.12)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Urban Pop. (2) 1931</td>
<td>0.64***</td>
<td>0.53***</td>
<td>-0.10</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.18)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Rural Pop. (2) 1931</td>
<td>0.19***</td>
<td>0.17**</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.08)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Urban Pop. (2) 1960</td>
<td>0.87***</td>
<td>0.82***</td>
<td>-1.07*</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.47)</td>
</tr>
<tr>
<td>Rural Pop. (2) 1970</td>
<td>-0.03</td>
<td>-0.02</td>
<td>-0.32</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Urban Pop. (2) 2000</td>
<td>2.82***</td>
<td>4.44***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.62)</td>
<td>(0.62)</td>
<td></td>
</tr>
<tr>
<td>Rural Pop. (2) 2000</td>
<td></td>
<td></td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.11)</td>
</tr>
</tbody>
</table>

C. External Validity: Results for Sub-Saharan Africa

We find similar results for the rest of the continent. Column 1 of panel D in table 3 uses model (4) to show a positive effect of the 0–10 kilometer rail dummy on the urban population in 1960. Columns 2 to 8 then show that the 0–10 kilometer effect is robust to using the same identification strategies as for Ghana. We also do not find evidence for urban reorganization, since there is no negative effect for the adjacent cells and other competing cells (see columns 9–16 of table 13 in the online appendix). Additionally, the total number of cities and urbanization rate of the 39 countries increased by 250 cities and 8 percentage points in 1900–1960, whereas they remained stable over 1890 to 1900 (see figure 8 in the online appendix). These effects are large. Indeed, Europe’s urbanization rate also increased by 8 percentage points during the Industrial Revolution (1700–1870) when using the same city threshold of 10,000 (Malanima & Volckart, 2010). This structural break of urban patterns is related to the structural break observed in GDP per capita after 1900. Using the same methodology as for Ghana, the 0–10 kilometer railroad effects potentially account for 55%
of the aggregate change in urbanization (excluding the largest cities). These effects are large when considering that the 0–10 kilometer railroad cells represent only 3% of Africa’s habitable area. Finally, we run the main regression for each country individually (the urban population is standardized using only the observations of that country). The mean effect is 0.35, but there are countries where the effect was large, such as Ghana (0.65), and countries where it was nil, such as Namibia (0.00). We then find that the aggregate change in urbanization and the rail effect across countries over 1900 to 1960 are positively correlated (see figure 5d).

The long-term effect on the urban population in 2010 is not different from the short-term effect in 1960 (0.34*** for 0–10 kilometers in column 1 of table 7, versus 0.37*** in column 1 of panel D in table 3). We then investigate the dynamics of urban growth between 1890 and 2010 and run the following model separately for each year where

\[ \hat{U}_{c,t} = \alpha_{t} + \beta_{1} \text{Rail}_{c,1900} + \beta_{2} \text{Improved Road}_{c,2000} + \beta_{3} \text{Urban Population}_{c,1900} + \beta_{4} \text{Urban Population}_{c,2000} + \epsilon_{c,t}. \]

Figure 6 displays the rail effect (0–10 kilometers) for each period. There was no rail effect over 1890 to 1900, a strong effect over 1900 to 1960, and no additional effect after 1960. The coefficient of urban autocorrelation, \( \rho \), jumps after 1960, from about 0.50 to 0.90, and converges toward 1 (it decreased to 0.83 in the 2000s, as economic growth led to urban growth in areas that were not previously developed). Africa’s city size distribution in 2010 is also different from its steady-state distribution (see table 17 in the online appendix).

1. We test that the long-term effect is causal using the main identification strategies (table 16 in the online appendix). The long-term effects also hold when using higher cutoffs in 2010 (table 15 in the online appendix).

2. The results hold if we run panel regressions with cell and year fixed effects (figure 9 in the online appendix).

### VI. Discussion

In this section, we investigate the potential channels of path dependence. We focus our analysis on Ghana, as we have better data than for the rest of Africa. We then conclude.

#### A. Discussion on the Channels of Path Dependence

Column 1 of table 6 shows the baseline long-term effects (0.87 for 0–10 kilometers) for Ghana. They remain unchanged when adding two dummy variables equal to 1 if the cell is within 10 kilometers from a paved road or an improved road in 2000 (column 2). Thus, railroad cells are not more developed today simply because they are the only cells with good-quality roads. While few cells were connected to the rail network in 1919, most cells are now connected to the road network. The population could have spread along the roads over time, away from the railroads, but it barely did. The effects of the railroads (0.83) are four times larger for the roads (0.23). However, the road effects are not necessarily causal. Using the same identification strategies as before, when possible, the road effects still remain lower than the railroad effects (see table 9 in the online appendix). The long-term rail effects are then greatly reduced when we control for the z-scores of urban and rural population in 1931 (column 3). Thus, the rail effects...
in 2000 are explained by the rail effects in 1931.34 Moreover, the road effects become small, which suggests that only the roads built before 1931 had long-term effects. In Table 10 in the online appendix, we compare the short-term effects of new railroads and roads during the periods 1901–1931, 1931–1960, and 1960–2000. We find positive effects of the transportation investments over 1901 to 1931. After 1931, new cities were created along the roads, but they are too small to modify the equilibrium. This persistence in spatial patterns is consistent with the existence of local increasing returns, which we now examine.

In section VA, we showed that connected cells had better infrastructure (schools, hospitals, and roads) by 1931. If these colonial sunk investments account for urban population today, including them in the model should capture some of the effects of population in 1931 on urban population in 2000. Including the historical factors in 1901 and 1931 reduces the coefficient of urban population in 1931 by 20% (from 0.64 to 0.53, column 4). One potential concern here is that we may not correctly measure sunk investments and thus underestimate their contribution to path dependence. Our analysis is biased if we omit other expensive public assets in existence in 1931. However, there were no universities, airports, or dams at that time, so we may properly capture the historical factors. Thus, 20% of urban persistence could be potentially explained by colonial sunk investments.35

If there are increasing returns, factors of production must also be co-located in the same locations. There is a spatial coordination problem as it is not obvious which locations should have the factors. Initially, it is reasonable to co-locate factors in locations that are already developed (i.e., in the railroad cells). The location of factors today depends on past population density, without it being explained by sunk investments. First, we find that urban population in 1931 had a large effect on urban population in 2000 because it led to higher urban densities in 1960 without being explained by sunk investments in 1931 (table 6, column 5). Second, in section VB, we explained that connected cells had better infrastructure in 2000 than nonconnected cells because they were more populated. In column 6 of table 6, we show that controlling for various contemporary factors (see the table notes) does not modify the relationship between urban population in 1960 and urban population in 2000. This could lead us to believe that the population in the past drives the population today, which then attracts other factors. The factors would simply “follow” people. Third, the stability of the spatial equilibrium after 1931 is consistent with the coordination hypothesis. One implication of the coordination hypothesis is that there could be marginal decreasing returns to new transportation investments. If initial (rail) investments have created enough large cities, subsequent (road) investments may not create new cities large enough to modify the equilibrium, which is what our results seem to suggest.

Are railroad cities wealthier than nonrailroad cities? We estimate model (3) except we use average night light intensity (table 6, column 7) and the employment share (%) of industry and services (column 8) in 2000 as dependent variables. We control for the z-scores of the urban and rural population in 2000 to compare cities of similar sizes. We find a positive effect for railroad cities. While railroad cells are not necessarily better endowed per capita in observable factors than other cells today (see panel B of table 5 in the online appendix), there could be unobservable factors that were repeatedly co-located along the lines. For example, the railroad cities initially specialized in the export of cocoa and the import of foreign goods and the production of local goods to satisfy the needs of farmers. Seventy years later, they may still have a comparative advantage in the production of nonfood goods and services.

The scarcity of data for Africa does not allow us to precisely examine the channels of path dependence for the rest of the continent. We use the information we have on the year of connection of each cell to test if the lines built relatively earlier have larger effects today. Rail building in colonial Africa can be separated into three episodes: 1890–1918, 1919–1945, and 1946–1960. Sixty percent of the cells were connected during the scramble for Africa (1890–1918), and World Wars I and II reduced the number of new connections due to budget restrictions in Europe (see figure 10 in the online appendix). Whether a line was built over 1890–1918, 1919–1945, or 1946–1960 should not make a major difference in terms of sunk investments. All the lines were built more than 50 years ago, and sunk capital could be equally depreciated for all these periods now. In column 2 of table 7, we interact the rail dummy with three dummies for each episode of rail building. The rail effect is higher the earlier the period (the 1946–1960 dummy is omitted). In column 3, these differences are attenuated when controlling for the existence of roads in 2000. The pre-1918 effect remains higher than the post-1946 effect. The rail effects then disappear when controlling for urban population in 1960 (column 4). This finding is consistent with the coordination problem hypothesis: the cells connected earlier became large cities in 1960, as they solved a coordination problem earlier, and they remain large cities to date. The sudden increase in the coefficient of urban autocorrelation after 1960 is also consistent with the hypothesis. The road

34 Rural growth should not explain path dependence. Here we control for rural population in 1901 and 1931, and thus their effects on urban population today. The effects are then robust to using other city thresholds.

35 We find that the coefficient of urban population in 1931 is unchanged when we include (see Table 11 in the online appendix) (a) the square of the numbers of each subtype of infrastructure, to account for nonlinearities in the effects of infrastructure on population today; (b) multiple interactions of these factors, to account for complementarities between the different subtypes; and (c) cocoa production (1927) and the amount of cocoa brought to the rail station (1918), to account for income and thus private capital. The few stone houses that existed in 1931 were built by the wealthy cocoa farmers living in town (Hill, 1963). Otherwise, the towns consisted of houses built using thatch or wood, two materials that are not highly resistant. Therefore, the housing stock in 1931 is unlikely to explain why the railroad cells are more populated today.

36 We find similar results when using the intermediary years of 1948, 1970, and 1984 (not shown).
effects (0.12–0.20, column 3) also remain smaller than the railroad effects (0.34, column 1). Road investments then led to some economic decentralization after 1960, as the road effects remain positive and significant when controlling for urban population in 1960 (column 4). While the roads were associated with the creation of cities (column 5), these cities were small since the population effects are lower than the city creation effects (column 4 versus column 5). In column 6, we use average night light intensity in 2010 as the dependent variable and find that railroad cities are wealthier than nonrailroad cities of similar sizes.

To summarize, the persistence of the railroad effects in both Ghana and Africa is consistent with the existence of various forces giving rise to local increasing returns.

B. Conclusion

To study the impact of transportation investments in poor agrarian countries, this paper exploited the construction and later demise of colonial railroads in Ghana and also Africa as a whole. Railroads constituted a transportation revolution and had large effects on the spatial distribution and aggregate level of economic activity during the colonial period. These effects have persisted to date, although the railroad systems have collapsed and road networks were considerably expanded in the postindependence period. Our results on the channels of path dependence are then consistent with the existence of local increasing returns.

Our findings suggest that the impact of transportation investments could be heterogeneous. Initial investments may have larger effects in poor countries with basic infrastructure and high trade costs induced agricultural adaption, trade integration, and structural change. Then, as countries develop, increasing returns may solidify their spatial distribution, and subsequent investments may have lower effects on local economic development. Whether the giant transportation infrastructure projects recently initiated in Africa will have the same local and aggregate effects as the transportation investments that took place over a century ago could thus potentially depend on the context in which they take place.

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