Colonial Investments and African Development: Evidence from Ghanaian Railways*

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June 2012

Abstract

What is the impact of colonial public investments on long-term development? We investigate this by looking at the impact of railway construction on agricultural and economic development in Ghana. Two railway lines were built by the British to link the coast to mining areas and the hinterland capital of Kumasi. Using panel data at a fine spatial level (11x11 km grid cells) in 1901-1931, we find a strong effect of railway connectivity on the production of cocoa, the country's main export commodity, and development, which we proxy by population growth. The population effect is mostly explained by the growth of cocoa-producing villages and the role of towns as trading stations for cocoa. We exploit various strategies to ensure that our effects are causal: we show that pre-railway transportation costs were prohibitively high, we provide evidence that line placement was exogenous, we find no effect for a set of placebo lines, and results are robust to instrumentation and nearest neighbor matching. Lastly, railway construction had a persistent impact: railway districts are more developed today despite a complete displacement of rail by other means of transport.

JEL classification codes: F54; O55; O18; R4; F1
Keywords: Colonialism; Africa; Transportation Infrastructure; Trade

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1 Introduction

What is the impact of colonial investments on long-term development? While the literature has extensively studied the role of colonial institutions, little is known on colonial public investments. Existing studies relate economic outcomes today to the duration of colonization (Feyrer and Sacerdote 2009), the form of colonization (extraction versus settlement: Engerman and Sokoloff 2000, Acemoglu, Johnson and Robinson 2001, 2002, Dell 2010 ; direct versus indirect rule: Banerjee and Iyer 2005, Iyer 2010) or the identity of the colonizer (Porta et al. 1998; Bertocchi and Canova 2002). However, a few articles have also investigated whether colonization could have impacted long-term development through another channel than institutions. Glaeser et al. (2004) explain that settlers might have brought with them their know-how rather than better institutions. They argue more generally that human capital matters more than institutions for the growth of poor countries. Another channel could be investments directly realized by the colonizers, as argued by Huillery (2009) and Huillery (2011). Banerjee and Iyer (2005) and Dell (2010) also argue that colonization has influenced public investments but they either look at current investments or they use proxies for public investments (e.g., literacy and schooling as proxies for public expenditure on schools as in Dell 2010). Lastly, these few papers have mostly focused on investments in human capital (education and health), while investments in physical capital, especially transportation infrastructure, might have had an even larger impact.[1]

One specific type of transportation infrastructure for which we are likely to find long-term effects are railways. First, railways were often the single largest item in the colonial budget of developing countries. For example, railway expenditure has accounted for 31.4% of total public expenditure in our country of study, Ghana, in 1898-1931. Then, around two thirds of railway expenditure is explained by development expenditure, the cost of building the network.[2] Second, railways were mostly a "colonial" transportation technology in Sub-Saharan Africa. Using data

[1]Donaldson (2010), Burgess and Donaldson (2010) and Burgess et al. (2011) also use data on colonial investments in transportation infrastructure (railways and roads) but they do not investigate their effects on long-term development.

[2]By comparison, the share of railway expenditure in total public expenditure was 19.3% in Kenya in 1896-1930.

that we have collected on the history of each railway line in Africa, we find that around 88.3% of total railway mileage was built before independence (or 87.0% if one considers 1960 as the cut-off date). These lines were almost always built by the Whites for the Whites and served various purposes: military domination (against natives or other colonial powers) was mentioned in 35.5% of cases, while it was 36.0% in the case of mining (with the support of European mining companies) and 42.4% in the case of cash crop agriculture (with the support of White settlers and farmers). Yet these lines also affected the economic lives of Africans by permitting spatial economic integration. Lastly, public investments in transportation infrastructure are highly localized, and as such are likely to modify the economic geography of colonies, with potential consequences on long-term spatial inequality.

We investigate this issue by looking at the impact of railway construction on agricultural and economic development in colonial Ghana. Using panel data at a fine spatial level (11x11 km grid cells), we study the effects of two railway lines that were built by the British colonizer between 1898 and 1918 on the production of cocoa beans by Ghanaians in 1901-1927, the country's main export, and development, which we proxy by population and urbanization in 1901-1931. We follow a simple difference-in-difference strategy whereby we compare connected and non-connected cells over time. A logical concern is that the placement of these lines was endogenous and we develop various strategies to ensure that our effects are causal. First, we argue that the placement was mostly exogenous. The first line to be built _ the *Western line* _ connected the coast (the port of Sekondi) to European gold mines and was then extended to the hinterland city of Kumasi for military domination. This line was built by the Whites for the Whites. The second line to be built _ the *Eastern line* _ was meant to connect the coast to the same of city of Kumasi, but from the capital city of Accra. Although cocoa production was mentioned as one of the motivations of the line, we will argue that it was an ad hoc justification. This is confirmed by the facts that we find the same effects for both lines, that the parallel trend assumption is verified using data before 1901, and that there are no effects for a set of placebo lines that were planned but not built for various exogenous reasons we discuss. Given cocoa trees take five years to bear produce, we also check that there are no effects for these lines that were built but not in time to influence cocoa production in 1927. Second, employing data

on pre-railroad transportation networks (rivers and forest tracks), we show that transport costs were prohibitively high before, which constrained cocoa production to the coast without investments in modern transportation infrastructure. Thus, railways were essential to the colonization of the hinterland. Third, we can instrument railway connectivity by the straight lines between the main coastal ports and the city of Kumasi, a strategy which echoes the works of Michaels (2008) and Banerjee, Duflo and Qian (2009). Fourth, we can do some nearest neighbor matching and only use as a control group the placebo cells, these cells that would have been connected if the placebo lines had been built.

We find a strong effect of railway connectivity on cocoa production, population growth and urbanization. First, we argue that the railway effect on rural growth is explained by a *labor* effect, the fact that cocoa production requires more labor in cocoa-producing villages. Second, the railway effect on urbanization is explained by a *trade* effect, the fact that cocoa-producing villages use towns as trading stations, whether these are large railway stations or smaller towns further away from the lines. Cocoa farmers export cocoa to the rest of the world and import mostly foreign consumption goods in exchange. Third, we follow the social savings approach of Fogel (1964) and find that railways account for 8.7% of GDP using cocoa only. Chaves, Engerman and Robinson (2010) also implement this methodology to analyze railway construction in Ghana and we directly compare our results with theirs. Another approach is to show that railways have caused around 30% of cocoa production in 1927, around 7.9%of GDP and an estimated social rent around 6.3% of GDP. Interestingly, half of the rent went to Ghanaians, while the other half went to the colonizer. Lastly, we examine the long-term effects of railway construction by showing that districts connected to the railway system are more urbanized in 2000, have better infrastructure and larger manufacturing and service sectors, despite thirty years of marked decline in rail transportation.

Our focus on the economic impact of railways also connects with the literature on transport infrastructure, trade and development. Recent research has confirmed that trade has large positive effects on income (Acemoglu, Johnson and Robinson 2005, Feyrer 2009, Donaldson 2010, Donaldson and Hornbeck 2011). Similarly, research has suggested that the lack of intercontinental and intracontinental trade integration is a determining factor of African underdevelopment (Rodrik 1998,

Johnson, Ostry and Subramanian 2007, Buys, Deichmann and Wheeler 2010). In this regard, the literature often mentions the conjunction of bad geography and poor infrastructure as the main obstacle to trade expansion in Africa (Radelet and Sachs 1998, Limão and Venables 2001, Buys, Deichmann and Wheeler 2010). African countries are usually underprovided with transport infrastructure and that is why international organizations are advocating massive investments in Africa (African Development Bank 2003, African Union 2006).[3] Despite this recent interest in transportation projects, little is known on their economic effects and more research is needed. A first strand of the literature looks at the macroeconomic impact of transport infrastructure on trade and development (Radelet and Sachs 1998, Limão and Venables 2001). Those studies find that better infrastructure diminish transport costs, especially for landlocked countries, with a positive impact on exports and economic growth. As infrastructure is endogenous to economic conditions, one cannot be sure such effects are causal. A second strand of the literature has focused on the impact of rural roads on neighboring communities (Jacoby 2000, Mu and van de Walle 2007, Dercon et al. 2008, Jacoby and Minten 2009). Those studies find that rural roads reduce poverty in connected villages, by integrating labor and goods markets, thus providing new economic opportunities to their inhabitants. For instance, farmers obtain higher profits thanks to cheaper agricultural inputs and higher farmgate prices for their crops. Yet, this literature also faces identification issues. A last strand studies the impact of large transportation projects, whether highways (Michaels 2008, Rothenberg 2011, Storeygard 2011, Faber 2012) or railroads (Banerjee, Duflo and Qian 2009, Atack and Margo 2009, Atack et al. 2010, Donaldson 2010, Burgess and Donaldson 2010, Donaldson and Hornbeck 2011). They show that there are significant gains from market integration for connected areas.[4]

[3]In 2005, Sub-Saharan Africa had 0.002 km of railroad track per 1000 sq km and Ghana had 4.2 km, while China had 6.5 km, India 21.3 km, the United States 24.8 km and Europe 50.5 km per 1000 sq km (World Bank 2010). Turning to roads now, Sub-Saharan Africa had 85 km of roads per 1000 sq km and Ghana had 239 km, while China had 200.6 km, India 1115.4 km, the United States 702.2 km and European countries 1377.0 km per 1000 sq km. Magnitudes are similar if the lengths of both networks are standardized by population instead of country area.

[4]Those studies also face identification issues, but the placement is more "instrumentable". For example, Michaels (2008), Banerjee, Duflo and Qian (2009) and Atack et al. (2010) use the fact that being on a straight line between two large cities makes it more likely to be connected

Our findings also advances the literature on the historical roots of African underdevelopment. Nunn (2007) proposes a model in which slave trade and colonial rule have caused African countries to switch from "one equilibrium with secure property rights and a high level of production" to another with "insecure property rights and low levels of production". Gennaioli and Rainer (2007) and Michalopoulos and Papaioannou (2011*a*) emphasize the role of pre-colonial centralization in long-term development. Nunn and Puga (2011) and Nunn and Wantchekon (2011) investigate the economic impact of slave trade, while Acemoglu, Johnson and Robinson (2001), Huillery (2009), Huillery (2011) and Michalopoulos and Papaioannou (2011*b*) study the effects of colonial rule, whether colonial institutions, White settlement, colonial public investments or the fact that borders were arbitrarily drawn. This paper shows how colonial infrastructure investments one century ago have shaped the economic geography of Ghana. This is also in line with a more general literature on the existence of spatial equilibria and the role of path dependence in the location of economic activity (e.g., Davis and Weinstein 2002, Bleakley and Lin 2010 or Redding, Sturm and Wolf 2011).

The paper is organized as follows. Section 2 presents the historical background of railway construction, cocoa and cities in Ghana and the data used. Section 3 explains the methodology, while section 4 displays the results. Section 5 discusses them and investigates the long-term effects of railways, and section 6 concludes.

2 Background and Data

We discuss some essential features of the Ghanaian colonial economy and the data we have collected to analyze how railway construction has contributed to booming cocoa production, population growth and urbanization. Appendix A contains more details on how we construct the data.

2.1 New Data on Ghana, 1901-1931

In order to analyze the effect of railway construction on trade and development in Ghana, we have constructed a new data set on 2091 grid cells of 0.1x0.1 degrees

to a highway or a railroad. Donaldson (2010) does not find any effect for railway lines that were approved but never built.

(11x11 km) from 1901 to 1931. We choose a high resolution grid because we have very precise GIS data on railways, cocoa production, population and urbanization. We obtain the layout of railway lines in GIS from *Digital Chart of the World*. We then use various documents to recreate the history of railway construction. For each line, we know when it was started and finished, and when each station was reached and opened. From the same sources, we know lines that were built but not planned. For each real or placebo line, we create cell dummies equal to one if the Euclidean distance of the grid cell centroid to the line is 0-20, 20-40, or 40-60 km. Our main analysis focuses on railway lines in 1918. We also create a dummy equal to one if the cell contains a railway station in 1918. We proceed similarly to construct a GIS database on transportation networks in 1901 (waterways and forest tracks) and motor roads in 1922.[5]

The data on cocoa land suitability was recreated from maps of cocoa soils in Ghana. A cell is defined as *suitable* if it contains cocoa soils. It is *highly suitable* if more than 50% of its area consists of forest ochrosols, the best soils for cocoa cultivation. Production data was collected from a historical map and we use GIS to calculate the amount of cocoa production (tons) for each cell in 1927. Production was almost nil around 1900, and we proceed similarly to recreate cell production in 1901. We also have data on cocoa tonnages brought to each rail station in 1918.

To obtain urbanization figures, we construct a GIS database of localities with more than 1,000 inhabitants using census gazetteers. We have data for 1901 and 1931. Using the 1,000 threshold, Ghana had respectively 164, 143, 438 and 628 towns in 1891, 1901, 1931 and 1948. Since our analysis is at the grid cell level, we use GIS to recreate urban population for each cell-year observation. While we have exhaustive urbanization data for all the country, we only have consistent population data for the South of Ghana in 1901 and 1931. The 1901 census was exhaustively conducted and geospatialized only in the South. We then have population data at a very fine spatial level from the 1931 census. In total, we have population for each Southern cell (756 cells), and we reconstruct rural population by subtracting urban population from total population.

[5]There were two types of roads at that time: class II (*roads suitable for motor traffic but occasionally closed*) and class III (*roads suitable for motor traffic in dry season only*).

2.2 The Railway Age

2.2.1 Railroads Built

Improvements in transport infrastructure are typically endogenous, driven by the economic potential that would justify them. Hence, a simple comparison of connected and non-connected cells is misleading, and likely to overstate the output created by it. The railway age in Ghana provides us with a quasi natural experiment which we use to identify the effect of reduced transport costs on development. This summary draws on Gould (1960), Tsey (1986) and Luntinen (1996). Figure 1 and Figure 2 show the geographic location of the mentioned lines.

After the defeat of the Ashanti Kingdom in 1874, the British consolidated their power and established the Gold Coast colony in the South. They later extended their domination to the whole country in 1896. Improving transport infrastructure was on the agenda, mainly to permit military domination (against natives or other colonial powers) and boost trade historically constrained by high transport costs. Draft animals could not be used due to the tse-tse fly transmitting trypanosomiasis, which is deadly for livestock. Ghana also lacked navigable waterways, the Volta river being the only noteworthy exception. Headloading was the main means of transport, although palm oil and cocoa beans could also be rolled in barrels along the few forest tracks. Owing to the thick primary forest in Southern Ghana, there were only a few well-cleared tracks and villages along those paths had to maintain them. Railroads were the transport technology of the time, but the British had to choose between a western route, a central route or an eastern route.

The first line to be built followed the western route. Strong interest groups of British capitalists lobbied to connect the gold fields in the hinterland. Mines needed heavy machinery, large quantities of firewood (or coal) and workers from other regions. Headloading made gold production prohibitively costly. The colonial administration gave in to the pressure, turning down alternative lines, for which railroad surveys attested a greater potential for agricultural exports (mostly palm oil) and benefit to the country in general. Appendix B describes how the of Governorship of William E. Maxwell (1895-1897) was instrumental in this evolution: Maxwell, who had previously worked in the Malay States where railways served the tin mines, thought that the same model should be applied to Ghana

with gold and other lines could wait. There were then military reasons to connect the Ashanti capital Kumasi. The British fought over four wars before they annexed the Ashanti Kingdom in 1896. An uprising in 1900 reinforced the perceived threat. The railroad was meant to allow to quickly dispatch troops. The construction of the first railroad begun in 1898. The line started from Sekondi on the coast and reached the gold mines of Tarkwa and Obuasi in May 1901 and December 1902 respectively (see Figure 2). The line indeed represents the shortest distance from the coast to the gold fields. The line was further extended to Kumasi in September 1903. Much of the line went through virgin forest and was opened to traffic in 1904. Clearly, this line was built by Europeans for Europeans, and gold mining accounted for at least two thirds of the line's traffic (in volume) on average in 1904-1912. Cocoa did not play any role in the choice of location, but the line had a strong effect on cocoa cultivation, as argued by Tsey (1986, p.303-306). Cocoa production increased from 0 tons in 1904 to 1,934 tons in 1910 and 19,191 tons by 1915, which confirms the exogeneity of the line.

The second line to be built followed the eastern route. Colonial Governors had long favored the central route to build a second line (e.g., from Saltpond or Apam), but a series of unexpected events led to the Governorship of John P. Rodger (1904-1910) who thought that the capital Accra had to be the terminus of this second line to the interior (and ultimately Kumasi). By 1905, several additional motivations were cited for its construction (Tsey 1986, p.56-63): the export of palm oil, rubber and cocoa, the exploitation of the Eastern Akim Goldfields around Kibi and the possibility to develop tourism on the Kwahu Plateau around Abetifi. Construction started early in 1909 and the line reached Mangoase in late 1909. However, serious floodings in 1910 and 1911 meant that the line was not opened to traffic before 1912. It was extended to Koforidua in 1915 and Tafo in 1916, but Tafo station was only opened in July 1917. Rail construction then had to stop due to wartime shortages, and Kumasi was only connected in 1923. The issue with the Eastern line is to what extent its placement was exogenous to cocoa cultivation. It originally spread out in the Eastern province from Aburi Botanical Gardens, where the British sold cocoa seedlings at a very low price (see section 2.2.3 below). Provincial production was already growing before the Mangoase line was built in 1909: around 1,000 tons in 1901, 5,000 tons in 1905, 15,000 tons in 1910, 40,000

tons in 1915, 65,000 tons in 1920 and 100,000 tons in 1925. As cocoa trees take five years to bear produce, production before 1913 (ca. 30,000 tons) cannot be imputed to the line.[6] As soon as the line was opened, cocoa farmers decided to use it to transport cocoa, which immediately accounted for 62.7% of the line's traffic in 1912-1913 (this share decreased over time). That is why it will be important to show that: (i) transport costs were prohibitively high before, so that production would have remained constrained to pre-railroad levels, (ii) we find similar effects for the Western and Eastern lines, (iii) results are robust to controlling for the spatial diffusion of cocoa from Aburi, (iv) no positive effects are found for the extension Tafo-Kumasi (1923) since cocoa trees take five years to bear produce, as well as for other lines that were proposed for the central and eastern routes (see the description of placebo lines below), (v) results are robust to instrumentation (using the distance to the straight line Accra-Kumasi as an instrument) or nearest neighbor matching (using placebo cells as a control group, as discussed below).

2.2.2 Reduction in Transport Costs

Railroads permitted a massive decrease in transportation costs. While the freight rate per ton mile was 5s for headloading, 3.2s for canoe, 2.5s for lorries (1910, against 1s from 1925), 1.9s for cask rolling and 1s for steam launch, it was only 0.4-0.6s for railways. Yet this simple comparison of freight rates underestimates the magnitude of transport costs: (i) the cost above only concerns headloaders that walk along a forest track. There were only a few well-cleared tracks and headloaders often had to go through the dense tropical forest, which made it even more costly, (ii) cask rolling necessitated good quality roads and there were only a few of them then, (iii) Ghana lacked navigable waterways and these did not serve the areas where cocoa could be grown, and (iv) roads were of poor quality until 1924 when the government started the "Tarmet Program" which made roads suitable to motor traffic throughout the year (Gould 1960). To conclude, until the late 1920s, railways were by far the best transport technology for Southern Ghana.

[6] The line was officially opened to traffic in 1912, but it reached Mangoase three years before in 1909. There is some evidence that many farmers went there as soon as 1909 to grow cocoa, expecting the railway to be opened that year. Given cocoa trees take five years to bear produce, we should not see any effect on total production before 1913.

Using a GIS map of transportation networks in 1901 (see Figure 3), we estimate for each cell the minimal transport cost of one ton of cocoa (£) to any coastal port. From Cardinal (1931), we get an estimate of the production cost of one ton of cocoa, around £16 on average.[7] Given the coastal producer price was £38.4 on average before 1931 (but £29.8 in 1920-1931), cell production is only profitable if 38.4 - 16 - transport costs > 0, or transport costs < £22.4 (£13.8 in 1920-1931).[8] As in Donaldson and Hornbeck (2011), the reduction in transport costs permitted by rail construction is likely to have expanded production in the "feasible" region, where production was already profitable ex-ante but is now even more profitable, and in the "infeasible" region, where production was not profitable ex-ante but is now profitable. The treatment is thus a combination of the two effects. Figure 3 displays the feasible and infeasible regions for the two producer prices considered. As can be seen, the Eastern line already belonged to the feasible region, while the Western line had a much larger impact in the infeasible region. Comparing the results of the two lines will be useful to study the two types of regions.

From 1912 on, the share of cocoa transported by rail was around 80% (see Figure 4). According to Luntinen (1996, p.107), "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 railway reached them, so eagerly that foodstuffs had to be imported." The main effect of railroads was thus to make cocoa cultivation even more profitable. Roads were first complementary to the railways as they were feeders to them. Roads were of poor quality until 1924 when the government started the "Tarmet Program" which made them suitable to motor traffic throughout the year (Gould 1960). Roads became serious competitor for the railway and opened new areas to cocoa cultivation. Even if no railway had been built, roads would have permitted the cocoa boom. But our goal is not to compare the respective impacts of railways and roads. We focus on the railway age in 1901- 1931 because

[7]This includes the cost of establishing a farm in the forest (five years with no production) and the annual cost of labor when trees bear produce, assuming a farm lifetime of 30 years.

[8]£22.4 and £13.8 are probably upper bounds as there are various costs that we cannot account for when a subsistence farmer decides to launch herself into cocoa production: fees of cocoa brokers, risk premium due to risk aversion, losses during transport to the coast because of thief or rotting, higher poll taxes for cash crop farmers, etc.

it provides us with a natural experiment which we use to identify the effect of reduced transport costs on development. The first lorry was imported in 1903, but there were only two lorries in the colony in 1914 (Luntinen 1996).

2.2.3 Placebo Lines

The British had to choose between a western route, a central route or an eastern route, and various private and government lines were proposed before the Western and Eastern lines were built. We can thus address concerns regarding endogeneity by using these alternative railroad routes as a placebo check of our identification strategy. Placebo control mimics the tested treatment in all ways except the treatment. Appendix B gives a brief background of each placebo line.

Five alternative railroad routes were proposed before the first line was actually built. These lines were driven by the same model. The aim was to ensure military domination and increase exports (mostly palm oil). Judged by observables, the proposed lines were influenced by population density, soil quality, altitude in a similar way as the actual lines built. But the proposed lines are not completely identical to the lines built. We argue in Appendix B that these lines all had the same probability of being built as the two lines that were indeed built, and only random events (e.g., a change in the colonial Governor) explain why construction did not go ahead. First, the line Cape Coast-Kumasi (1873) was supposed to link the capital Cape Coast to Kumasi so as to send troops to fight the Ashanti. The project was dropped because the war broke out too rapidly. Second, Governor Griffith advocated the construction of central line from Saltpond to Oda and Kumasi (1893) so as to tap palm oil areas and link the coast to Kumasi. When he retired in 1895, he was replaced Governor Maxwell who favored the mining lobbies and the Western line. Third, even if the construction of the Western line was about to start, Governor Maxwell still though that the colony needed a central line. There were two competing projects, Apam-Oda-Kumasi (1897) and Accra-Oda-Kumasi (1897), and the main issue was to know whether Apam or Accra should be the terminus of the new line. A conference was to be held in London in late 1897 to discuss the various proposals but unexpectedly Governor Maxwell died before reaching London. Fourth, Maxwell was replaced by Governor Hodgson who favored Accra, mostly because it was the capital and chief trading town. However,

he thought that the Accra line should be built to Kpong on the Volta river (1898), so as to boost palm oil production and cotton cultivation there. The construction of the line was approved in 1903 but Governor Nathan retired in 1904 before works even begun. Fifth, Governor Rodger, who replaced Governor Nathan, did not see any interest in a line to Kpong and he proposed the Eastern line.

The rail network was subsequently expanded. Hence, we also consider lines that were actually built, but not in time to affect cocoa production in 1927. Note that cocoa is a perennial crop. Pod production of the type of cocoa predominantly grown in Ghana starts after 5 years, peaks after 25 years, and declines thereafter. Hence, for observing an impact on cocoa production in 1927, farmers must have grown cocoa trees before 1923. The extension of the Eastern line from Tafo to Kumasi (1923) is a good counterfactual for the Accra-Tafo line (1918). Another line was also built from Huni Valley to Kade in 1927. It connected the diamonds mine at Kade and was supposed to encourage cocoa, kola, palm oil and timber exports. So we verify that we find no effects for these lines in 1927.

2.3 The Cash Crop Revolution and Development in Ghana

Cocoa has been the main motor of Ghana's economic development (Teal 2002; Austin 2008), and this made it a leader of the African "cash crop revolution" (Tosh 1980). Yet, as cocoa is produced by consuming the forest, this success has been a major factor of deforestation in Ghana. Cocoa farmers go to a patch of virgin forest and replace forest trees with cocoa trees. Pod production starts after 5 years, peaks after 25 years, and declines thereafter. When cocoa trees are too old, cocoa farmers start a new cycle in a new forest (Jedwab 2011).[9]

Cocoa was introduced by missionaries in 1859, but it took 30 years before cocoa was widely grown, making Ghana the world's largest exporter as soon as 1911. Figure 4 shows aggregate cocoa production and the export share of cocoa from 1900 to 1927. Figure 5 shows grid cells that are suitable for cocoa cultivation and cocoa production in 1927. Cocoa production originally spread out in the Eastern province from Aburi Botanical Gardens, where the British sold cocoa seedlings

[9] Removing forest trees alters the original environmental conditions and replanted cocoa trees die or are much less productive (Ruf 1995).

at a very low price (Hill 1963, p.173-176).[10] As Ghanaian farmers realized how much profit they could make out of cocoa, more and more people specialized in the crop. The Accra-Tafo railway line was instrumental in opening new land to cocoa cultivation. Production also boomed around Kumasi when the railway line was opened in 1904. Why did production boom in Ashanti and not in the South-West, around Sekondi? Transportation costs were certainly lower there as it was closer to the coast. But the South-West of Ghana is characterized by poor cocoa soils and too much rainfall.[11] The railway line to Kumasi thus made the Ashanti more competitive than the South-West for the development of cocoa cultivation.

Ghana has then experienced dramatic population growth after 1901, due to rising livings of standard, international migrations and large-scale health campaigns organized by the British colonizer. Its population increased from 1,9 millions in 1901 to 3,2 millions in 1931 (Austin (2008)). 31.9% of this growth took place in the Gold Coast Colony, 10.6% in Ashanti, 21.6% in Northern Territories and 9.0% in British Togoland (see Figure 1). Figure 6 display rural population in 1901 and 1931 for Southern cells. The comparison with Figure 5 suggests that rural population increased in areas where cocoa production boomed. Austin (2008, p.8-14) describes how the labor-land ratio increased as a result of migration related to cocoa and how some areas in the forest zone were already approaching the "critical population density" for foodcrop growing.

Then, while Ghana was almost unurbanized at the turn of the 20th century, it is now one of the most urbanized countries in Africa. It has also started its urban transition earlier than most African countries, due to the boom in cocoa exports (Jedwab 2011). Defining as urban any locality superior to 1,000 inhabitants, Ghana's urbanization rate increased from 23.5% in 1901 to 48.6% in 1931. Our period of study thus captures an important phase of the urban transition in Ghana. The two largest cities were then Accra, the national capital, and Kumasi, the hinterland capital. Altogether, they have accounted for 9.5% of total urban growth in 1901-1931. 41.4% of it has come from the Gold Coast Colony, 21.5% from the

[10] The British established the Government Botanical Gardens in Aburi in 1890, because of its health climate and its proximity to the capital city, Accra.

[11] Most of the South-West area consists of oxysols or intergrades, which are poor cocoa soils. The lack of soil minerals leads to low yields and premature tree aging. Annual rainfall often exceeds 2,000mm, with a dry season that is very wet, which favors cocoa diseases.

Ashanti, 24.0% from Northern Territories and 3.6% from British Togoland. Thus, around 66.5% of urban growth has come from areas suitable for cocoa cultivation. Figure 7 shows towns in 1901 and 1931, using the 1,000 population threshold. Before the 20th century, towns were state capitals or trading centres (see Dickson 1968, p.70-71). Most of the latter were on the coast, where European merchants would meet local merchants from the interior. But there were also trading centres in the North, which benefitted from their location on historical trade routes. In the early 20th century, most of urban growth took place in the forest zone, with the development of mining, modern transportation and cocoa production (see Dickson 1968, p.246-261). In particular, many towns grew because they were cocoa buying centres, the homes of wealthy cocoa farmers or market towns where cocoa farmers would spend their income.

3 Empirical Strategy

Having data on railway connectivity, cocoa production and population and urban growths at the grid cell level in 1901 and 1931, we test if connected cells experience a boom in cocoa production and population and urban growths. We explain the various strategies we implement to obtain causal effects.

3.1 Main Econometric Specification

The main hypothesis we test is whether railway connectivity drives cash crop production and demographic and urban growths, focusing on 1901-1931 Ghana. We first run the following model for cells c:

$$\triangle Cocoa_{c,\mathtt{1927}} = \alpha + \theta Pop_{c,\mathtt{1901}} + \gamma Cocoa_{c,\mathtt{1901}} + \beta Rail_{c,\mathtt{1918}} + +u_c \qquad (1)$$

where our dependent variable is cocoa production (tons) of cell c in 1927. Given aggregate production was almost nil in 1901 (ca. 1,000 tons), it is as if we studied the change in production. Our variables of interest $Rail_{c,\mathtt{1918}}$ are cell dummies capturing railway connectivity: for being 0-20, 20-40 and 40-60 km away from a railway line in 1918 and having a railway station in 1918. Besides, we know cocoa tonnages brought to each station in 1918. We then run a second model for cells s:

$$\triangle Pop_{c,1931} = \alpha' + \theta' Pop_{c,1901} + \gamma' Cocoa_{c,1901} + \delta Rail_{c,1918} + +v_c \tag{2}$$

where our dependent variable is population of cell c in 1931, simultaneously controlling for cell population in 1901 ($Pop_{c,1901}$). We actually include just urban population in 1901 and rural population in 1901, as we are then better able to control for initial conditions. We expect railway connectivity to have a positive and significant effect on cocoa production ($\beta > 0$), and population ($\delta > 0$). We then include $Cocoa_{c,1927}$ in model (2) to see if cocoa captures the effect of rail dummies on population. If that is the case, it means that railway connectivity has an effect on population growth mostly through more cocoa production along the railway lines. There could still be an independent railway effect of population, so our goal is not to instrument production with railway connectivity. We just want to highlight some mechanisms. We can then look at rural and urban growths to understand the nature of population growth.

We have a cross-section of 2091 cells. Our main analysis is performed on the restricted sample of suitable cells. We run the risk of just comparing the Southern and Northern parts of Ghana if we use the full sample. We also restrict our sample to those cells for which we have data on the cell population distribution in 1901 as this data is only available for a set of Southern cells that year.[12] We end up with 542 observations and we believe such restriction gives us very conservative estimates. We will show later that our results are robust to removing such restrictions. We privilege OLS regressions and the issue is whether railway construction was endogenous to cocoa production and demographic and urban growths. We argue in section 2.2.1 that this was not necessarily a concern, but we now describe the various tests we perform to ensure these effects are causal.

3.2 Exogeneity Assumptions and Controls

We could just assume that the placement was exogenous. First, even if the development of cocoa production could have been instrumental in the construction of the Eastern line, the Western line was clearly built for mining and military domina-

[12] As explained in data appendix A, localities with less than 1,000 inhabitants were exhaustively surveyed and georeferenced only in those parts of the country.

tion. Endogeneity is not a concern if we find similar effects for both lines. Second, even if the Eastern line had been built for cocoa production only, production could have remained nil without modern transportation infrastructure because transport costs were prohibitively high before. The analysis in section 2.2.2 provides evidence that production would have been much more limited "spatially" without railroads. Most of suitable cells along the Western line belonged to the infeasible region, so production would have never occurred otherwise. This is similar to arguing that the timing of line construction was exogenous. Third, we include controls at the cell level to account for potentially contaminating factors. First, we control for economic activity in 1901, such as cocoa production in 1901 and through a dummy equal to one if the cell has a mine.[13] second, we control for demography in 1901, by including urban population, rural populations, and the number of large towns, towns (> 500 inhabitants), headchief towns, large villages ($100 - 500$ inhabitants) and villages (< 100 inhabitants). Third, we add physical geography variables such as the shares of soils which are ochrosol class 1, class 2, class 3 and unsuitable, oxysols or intergrades to directly control of land suitability to cocoa cultivation, or the mean and standard deviation of altitude (m) and average annual rainfall (mm) in 1900-1960. Lastly, we control for economic geography by having Euclidean distances (km) to Accra, Kumasi, Aburi and the coast and dummies for bordering another country or the sea.[14] Euclidean distance to Aburi is a very important control since it ensures that our effects are not contaminated by the spatial diffusion of cocoa cultivation from Aburi Botanical Gardens, as discussed in section 2.2.1.

3.3 Parallel Trends

First, if the placement or the timing is exogenous, we should not observe any effect for the railway cells before the railway lines were indeed built. Having data on urbanization in 1891, we can directly test the parallel trends assumption.[15]

[13]There were five mines in 1931: three gold mines, one diamond field and one manganese mine. Mineral exports amounted to 24.2% of exports in 1930 and the number of Africans engaged in mining was 12,048. Cocoa and mineral products thus accounted for 94.5% of exports in 1930.

[14]Those dummies also capture the fact that border cells are by construction not entirely contained in the territory of Ghana.

[15]Cocoa production was nil in 1891 and almost nil in 1901 (ca. 1,000 tons), so it does not make sense to test it for cocoa production. We have no data on rural population in 1891, so our

We run the same model as model (2) except we consider urban population of cell c in 1901 as the outcome ($UrbPop_{c,1901}$), simultaneously controlling for cell urban population in 1891 ($UrbPop_{c,1891}$). There are no significant positive effects of railway connectivity in 1891-1901, while we show later that we have strong positive effects of railway connectivity in 1901-1931.[16] Second, it is also informative to look at urban growth and cocoa production in 1931-1948, after the two railway lines are built. We run the same model as model (2) except we now consider urban population of cell c in 1948 as the outcome ($UrbPop_{c,1948}$), simultaneously controlling for cell urban populations in 1901 ($UrbPop_{c,1901}$). We do not find any independent effect of railway connectivity on urbanization in 1948, once we control for the effect in 1931 ($UrbPop_{c,1931}$).[17] We proceed similarly for cocoa production in 1950, for which we also have data at the grid cell level. Again, we do not find independent effect of railway connectivity when we control for the effect on production in 1927 (results not shown but available upon request).

3.4 Placebo Regressions

As explained in section 2.2.3 and shown in Figure 2, five major railway lines were planned but never built: Cape Coast-Kumasi (1873), Saltpond-Oda-Kumasi (1893), Apam-Oda-Kumasi (1897), Accra-Oda-Kumasi (1897) and Kpong-Kumasi (1898). Two lines were built after 1918: Tafo-Kumasi (1923) and Huni Valley-Kade (1927). The expansion of cocoa cultivation was mentioned as one of the objectives of the two latter lines, but they were unlikely to have any impact on cocoa production in 1927 and urbanization in 1931 given cocoa trees take five years to bear produce. For each planned but not built or not built yet line, we create a placebo treatment dummy equal to one if the cell is less than X km from the placebo line (counterfactually connected). We run the same model as model (2) except the treatment dummies are only the placebo dummies. We expect no effect on both cocoa production and population growth for cells that would have gained

analysis is limited to urbanization.

[16]We get the following coefficients (p-values) for 0-20, 20-40 and 40-60 km rail dummies in 1891-1901: -119 (0.696), 55 (0.884) and -204 (0.476). In 1901-1931, we get 443 and 190 significant at 1% for 0-20 and 20-40 km respectively, and -63 not significant for 40-60 km.

[17]We obtain the following coefficients and p-values for 0-20 km, 20-40 km and 40-60 km rail dummies in 1891-1931: 5 (0.983), 159 (0.470) and -67 (0.693).

access if the placebo had additionally been built before 1918. One issue here is that some of these placebo lines "intersect" with the area of influence (0-20 or 0-40 km) of the two existing railway lines, so that there might be a strong correlation between the treatment dummies and the placebo dummies. That is why we verify that there are no effects for the segments of these lines that do not intersect with the existing railway lines.

3.5 Instrumentation

We can instrument the treated cells with the distance from the straight lines between the two main ports on the coast _ Sekondi and Accra _ and the hinterland city of Kumasi. This strategy echoes the works of Michaels (2008) and Banerjee, Duflo and Qian (2009), who respectively instrument U.S. highways and Chinese railways with the distance from the straight line joining two major cities, exploiting the fact that transportation networks tend to connect large cities. This is a valid instrument as long as the distance from the straight line is not correlated with any variable that we do not control for but also affects the outcome. As argued in section 2.2.1, the Western line was built to link Sekondi to the mining areas of Tarkwa and Obuasi and was later extended to Kumasi for military domination. It went through dense tropical forest and it can be argued that the random location of the mines explained why this interior line was indeed built from Sekondi to Kumasi. Regarding the Eastern line, Accra was the administrative and economic capital of Southern Ghana while Kumasi performed the same role for the hinterland. It was obvious that the two largest cities of Ghana would be connected at one point.

3.6 Nearest Neighbor Matching

We can compare connected cells to non-connected cells, or connected cells to cells that would have been connected if the placebo lines had been built before 1918. This guarantees that treatment and control cells are similar in terms of both observables and inobservables, in the spirit of nearest neighbor matching. The only difference between the two just comes from the fact that connected cells were effectively treated. We can alternatively consider cells counterfactually connected to lines that were planned but not built or lines that were not built yet in 1918 or

both. The lines that were planned but not built mostly followed historical trade routes and had more population in 1901 along their potential layout, as indicated by the comparison of Figures 2 and 6. We then regress each available control on a dummy equal to one if the cell is less than 20 km from a 1918 railway line. We alternatively consider as a control group all the suitable cells (see col. (1) of Table 1), placebo cells (see col. (2)) and placebo cells using Cape Coast-Kumasi only (see col. (3)). Placebo cells are similarly defined as cells that are less than 20 km from a placebo line. First, when compared to all suitable cells, treated cells have a larger rural population and are closer to main cities, which could lead to an upward bias, and have worse cocoa soil quality (less ochrosols), which could lead to an downward bias. So it is not obvious in which direction we should expect coefficients to be biased. Second, when compared to all placebo cells, treated cells have a larger rural population (upward bias) but are farther from main cities and have worse cocoa soil quality and (downward bias). Third, we can compare treated cells with each placebo line individually, as some of them might prove a "better" counterfactual. For example, when compared to cells along the placebo line Cape Coast-Kumasi (1873), treated cell are "worse" (soil quality, altitude and distance to Accra or the coast) or similar across all dimensions.[18] Using these cells as a control group should lead to a downward bias, which is not problematical at all as it only gives us a conservative estimate of the effect we wish to measure. We will test the various control groups and see how results differ across all of them.

4 Results

In this section, we display the main results, examine their robustness and investigate the mechanisms behind the effects of railway connectivity on cocoa production and population growth.

4.1 Main Results

Table 2 contains our main results for cocoa production and population growth, distinguishing urban and rural growths. Column 1 reports the results for regression

[18]Treated cells have less rainfall but the effect is small: 65 mm against an average of 1477 mm.

(1), while columns (2)-(13) display the results for regression (2). All regressions include controls, but unconditional results are discussed in Table 3. We find a strong effect of railway connectivity on cocoa production, but this effect decreases as we move further away from the line and is nil after 40 km (see col. (1)). There is then a strong effect of railway connectivity on population growth but only for those cells less than 20 km away from the line (see col. (2)). This indicates that people tend to live in the vicinity of the line, although there is some production beyond 20 km. Interestingly, the rail effect is twice lower when we include cocoa production, which then has a strong effect on population growth (see col. (3)). This means the railway lines have a strong effect on population growth, and that this growth is coming from opportunities in the cocoa sector, and other sectors if there are intersectoral linkages.[19] The remaining rail effect is then picked up by the cell dummy for having a railway station in 1918 (see col. (4)). But the latter effect also becomes lower and non-significant when we include the amount brought to the station in 1918 (see col. (5)).

Railway connectivity has thus two positive effects on population growth, which we investigate by looking at rural growth (see col. (6)-(9)) and urban growth (see col. (10)-(13)). We call the first effect (1.37***) the "labor effect", as more cocoa being produced requires more labor. The comparison of columns (5), (9) and (13) indicates that most of the "labor effect" takes place in villages (1.03***) compared to towns (0.34*). This is logical as cocoa is produced on farms surrounding cocoa-producing villages (see Jedwab 2011). We call the second effect (0.83*) the "trade effect", as more cocoa being transported necessitates larger railway stations. The comparison of columns (5), (9) and (13) shows that the "trade effect" occurs in towns (0.82*) rather than villages (0.01). This is obvious as railway stations are mostly towns, according to our definition.

If we look at column (13), we have both the labor and trade effects. How do these effects vary if we consider various size categories of towns: 1,000-2,000, 2,000-5,000 and 5,000-+?[20] First, we run the same model as in column (10) except we

[19]Including urban population in 1931 in regression (1) does not change the effect of railway connectivity on cocoa production in 1927. This confirms that the relationship is not from railway connectivity to population and then to cocoa production.

[20]Using the full sample, there were 438 localities with more than 1,000 inhabitants in 1931 against 143 in 1901. Then, there were very few localities above 10,000: 5 in 1901 and 8 in 1931.

now consider the urban population each size category of towns so as to decompose the urban effect (671***). Interestingly, we find no effect for 1,000-2,000 towns, while 2,000-5,000 towns explain 55.9% of the urban effect and 5,000-10,000 towns explain the rest. If we now run the same model as in column (13), we find that the labor effect is mostly explained by 2,000-5,000 towns and many of them did not exist (< 1,000 inh.) in 1901. The trade effect is then mostly explained by 5,000-10,000 towns and many of them already existed (> 1,000 inh.) in 1901. To sump up, railway connectivity has induced a boom in cocoa production, which then had various effects on population growth: more cocoa-producing villages till 40 km, cocoa-producing towns (2,000-5,000) till 20 km and trading stations along the railway lines (5,000-+). Actually, 2,000-5,000 towns probably serve both functions, production and trade, and they must be intermediary towns between cocoa-producing villages and the railway stations, along the existing roads. That is why we are collecting data on road networks and local depots.

4.2 Alternative Identification Strategies and Robustness

Table 3 displays the results when we implement the various identification strategies listed in Section 3 as well as robustness checks. Panel A and Panel B of Table 3 replicate our main results from columns (1) and (2) of Table 2. For the sake of simplicity, we only focus on the 0-20 and 20-40 km dummies for cocoa production and the 0-20 km dummy for population as there are no effects beyond. Table 4 shows results for the placebo lines.

Western line vs. Eastern line. Column (2) of Table 3 shows that we have much stronger effects for cocoa production for highly suitable cells, so the railway effect comes from the interaction with suitability. When comparing the results for the Western and Eastern lines (see col. (3) and (4)), we find that we have much lower effects for the Western line, but this is explained by the fact that the Western line goes through many poorly suitable cells. If we restrict the analysis to highly suitable cells only, the effects are not significantly different for each line.

Placebo Regressions. Columns (1)-(7) of Table 4 display the results of the

placebo regressions, for each line individually, while column (8) consider all placebo lines altogether. Panel A and B show the results for cocoa production, while Panel C and D show the results for population. For the sake of simplicity, we only use 0-20 km dummies, so that we test whether there are any positive effects just along the placebo lines. The only two concerns are cocoa production for Accra-Oda-Kumasi 1897 (see col.(4)) and Accra-Kpong 1898 (see col.(5)). But these two effects are explained by the fact that these two placebo lines "intersect" with the area of influence (0-20 or 0-40 km) of the two existing railway lines. That is why we verify that there are no effects for the segments of these lines that do not intersect with the existing railway lines, as we show in Panel B.

Nearest neighbor matching. Columns (5) and (6) of Table 3 display the same results when we consider as a control group all the placebo cells or just the cells along the Cape Coast-Kumasi placebo line (< 20 km). Coefficients are even higher now. Results are also robust to using each placebo line individually (results not shown but available upon request).

Instrumentation. We instrument the railway dummies by dummies for being 0-20 and/or 20-40 km from the straight lines Sekondi-Kumasi and Accra-Kumasi. In both cases, the IV F-statistic is strong enough and results are similar to the main results (see col.(7) of Table 3), except the 0-20 km effects are larger.

Robustness. We now perform a few robustness checks to ensure our results are stable. First, there could some spatial autocorrelation, and we would underestimate standard errors as a result. Column (8) shows the results when we have Conley standard errors using a distance threshold of 50 km (around 5 cells). Results are robust to using other distance thresholds or just clustering standard errors at a more aggregate spatial level, such as the province in 1931 or 2000. Second, results are very similar if we use the Euclidean distance to railway stations instead (see col.(9)). Third, point estimates are larger if we drop the controls (see col.(10)). Fourth, estimates are rather similar if we use the full sample of 2,091 cells (see col.(11)), but we cannot control for the rural population in 1901 as we have no data for the whole territory. Fifth, we also verify that our results are robust to

including province fixed effects, (results not shown but available upon request).

Results on height. We also have data on Ghanaian male recruits in the British Army in 1888-1960. For all of them, we know the year and place of birth, the year they were enlisted and their height. We restrict our analysis to those soldiers that have served during World War I or later on. As a result, we have height data for several cohorts for 3,991 soldiers across 302 suitable grid cells. Using a regression similar to model (2), with the same controls as before plus individual controls for age, farming and religion, we compare soldiers born in railway vs. non-railway cells before and after 1923.[21] Clearly, better standards of living in railway cells over time should lead to increasing height for native soldiers born just after the boom in cocoa production. We find that railway cells start with a disadvantage (-0.76 cm), which they almost cancel over time (+0.69** cm). The estimated effect of 0.69 cm is actually quite large since it represents half of the change for the sample as a whole over the same period (+1.41 cm).[22] Interestingly, this effect is halved and becomes not significant, when we control for cocoa production in 1927, which becomes significant. This confirms that the railway effect on height goes through more cocoa production and better standards of living as a result.

4.3 Discussion on Channels

Although this paper does not make any theoretical contribution, here is the conceptual framework that we have in mind. Assume a country is divided into grid cells and there are no transportation networks. Each cell lives in autarky, and agricultural productivity is such that everyone lives at the subsistence level. Most cells are a tropical forest where human settlement is limited given disease conditions. Cash crops could be produced there but there are no means of transportation to permit their export. For some exogenous reasons, some of those cells are directly connected to the rest of the world (the coast) via a new transportation network. Those cells experience a major decrease in the trade costs they face to export their

[21] We cluster observations at the province level using province boundaries in 1916 (N = 4).

[22] If we compare soldiers born before and after 1914, thus also including the potential effects of better standards of living on these soldiers who were already 1-7 year-old when cocoa production was booming, the effect increases to +0.84** cm.

products and import other products. Their comparative advantage in producing cash crops can now be exploited and they export them against food and non-food imports. Non-connected cells remain in autarky and close to the subsistence level. In this framework, towns grow as intermediary trading stations between cocoa-producing areas and the coastal ports.

Our results are clearly in line with these theoretical intuitions. The export share of cocoa has increased from 0% in 1900 to almost 80% in 1927, and the increase in cocoa production has happened along the railway lines (or along the coast, where there are a few good-quality roads). The production of cocoa beans involves cocoa-producing villages, cocoa-producing towns and trading stations. We now use aggregate data on imports, railway traffic and the employment composition of Ghanaian towns to provide more evidence on channels.

Railway Traffic and Imports. First, we find that trade has accounted for 74% of railway traffic (in volume) on average in 1904-1931. More precisely, it was 35% for exports, 39% for imports and 26% for internal traffic. In the period 1904-1918, imports have accounted for 58%, mostly because the Western line was used to import building materials, machinery and coal for the gold mines. In the later period 1919-1931, exports have accounted for 55%, mostly because because cocoa production has boomed on both lines, as well as manganese and timber exports. Second, we can easily link the export structure and railway traffic for export. The export structure was the following in 1930: cocoa 76%, mining 23% and timber 1%. The traffic structure for export was: cocoa 72%, mining 24% and timber 1%. Third, the import structure was the following in 1930: food, drinks and tobacco 30%, clothing 20%, other consumption goods 15%, construction 9%, fuels 4%, machinery 6% and transport equipment 10%. We find a rather similar traffic structure for import, although it is not as clear as for exports: food, drinks and tobacco 31%, clothing 11%, construction 12%, fuels 16%, machinery 9% and transport equipment 6%. The analysis above confirms the role of railways in promoting trade integration with the rest of the world.

Railways and Urbanization Why did railway connectivity accelerate urbanization? There are three effects here. First, many farmers settle in towns as they

offer better conditions of living that villages in the forest. Using data from the 1931 census, we find that 48.5% of the urban male workforce works in agriculture. The census does not distinguish cocoa farmers and other farmers, but this figure indicates that many farmers use towns as their main residence to work on farms outside the city limits.[23] Second, towns serve as trading stations for towns served as trading stations for cocoa exports (transportation to the coast) and food and non-food imports (transportation from the coast). Trade and transport account for 20.6% of urban male employment, with 15.2% being traders, 1.2% being cocoa brokers and 4.2% working in the transport sector. Third, cocoa farmers are relatively wealthy compared to non-cocoa subsistence farmers. The production of cocoa allowed them to generate a surplus, and the Engel curve implied that they spent more on "urban" goods and services which are produced in town (?). The analysis above shows that food, drinks and tobacco, clothing and other consumption goods altogether amount to around two thirds of imports. But some of these goods were also produced "locally", as we find that light manufacturing and services account for 30.9% of urban male employment. This includes domestic servants (6.6%), carpenters (4.5%), tailors (2.4%), government civil servants (2.3%), masons (2.0%), goldsmiths (1.3%), policemen (1.3%), teachers (1.1%) and washermen (1.0%).

5 Discussion/Extensions

We now provide two extensions to our results. First, we compare them to the social savings methodology. Second, we investigate the long-term effects of railroads.

5.1 Welfare Effects

The railway proofed to be profitable. The private rate of return was 1% in 1903, steadily increased to 9% in 1909, and varied in the period 1910-1928 thereafter

[23] The criterion to define cities differs from the 1,000 threshold we use. The total urban population we find for Ghana is three times larger than the one reported in the census. This implies that the urban sample in the census includes larger towns, and given larger towns are probably less "agricultural", the analysis above underestimates the employment share of farmers in our urban sample.

around 7%.[24] Chaves, Engerman and Robinson (2010) have estimated the social savings of railroads in the Gold Coast and arrived at a value of 9% of GDP in 1925. The social savings approach is based on Fogel (1964) and is defined as the cost difference to the next-best transportation alternative in the absence of railroads:

$$\text{Social savings} = (c_a - c_r)R \tag{3}$$

where c_r and c_a represent marginal costs of the railroad and the next-best alternative transport respectively; R is the total volume transported by rail. Methodologically, it is best to think of a simple supply demand framework of transportation where cocoa producers represent transport consumers: Under perfect competition (where price p equals c) and completely inelastic demand for transport (a horizontal supply and vertical demand curve), social savings are identical to the change in consumer surplus brought about by the railroad. Where those conditions do not hold, the social savings estimate will exceed the actual increase in consumer surplus (Fogel 1979, Leunig 2010). In particular, the bias increases with price elasticity and $\frac{pa}{pr}$. Hence, for Ghana, the two measures may disagree quite considerably. Demand was highly elastic: our results suggest that railways triggered significant cocoa production inland. Secondly, the railroad was much more efficient than available alternatives in 1900; $\frac{pa}{pr}$ was around 10 when head porterage is considered. In sum, assuming R under c_a implies a deadweight loss that the social savings approach counts as a gain. In the following, we calculate the social rate of return based on cocoa income alone using: (i) the social savings approach, and (ii) a more direct approach estimating producer rents.

5.1.1 Social Savings Approach

As described in section 2.2.1, these were the transport technologies in 1901: headloading, cask rolling, steam launch, canoe and lorries. However, farmers privileged headloading given the lack of good quality roads and navigable rivers. That is why we consider head porterage as the alternative to railroads.[25] Chaves, Engerman

[24]The interest rate on the loan amounted to 3.5% till the early 1920s, before increasing to 6% (Luntinen 1996).

[25]With the expansion of the road network from the 1920s on, the next-best alternative and biggest competitor to railroads was lorry transport, with costs of 2s3d per ton mile in 1922 and falling. In this exercise, however, we do not consider motor transport as counterfactual, but

and Robinson (2010) assumed costs of 3s per ton mile for head porterage, which is derived from a daily wage of 9d that was paid to forced labor and in poorer regions of West Africa. Our preferred estimate of costs is 5s per ton mile, which is more in line with what contemporaries reported and the relatively high wage for free labor in the Gold Coast colony.[26] The railroad transported a total of ca. 15 million ton miles of cocoa in 1927. Under zero profits freight revenues equal costs. Available evidence suggests that supernormal profits are indeed largely negligible.Lorry transport was a strong competitor, to which the Gold Coast railway responded with price reductions (Gould (1960)). Moreover, the private rate of return was only slightly higher than the interest on capital. Nevertheless, relaxing this assumption of perfect competition, allowing for positive profits lowering railroad costs, would not change results, because in our case social savings are overwhelmingly determined by the very high costs of the alternative transport method. We then calculate the hypothetical costs, if the same volume of cocoa was moved by these other transport methods. The cost difference are the social savings, which we find to amount to 8.7% of GDP. Cocoa accounted for 30% of revenues. Applying the costs of 5s per ton mile to all goods would give social savings of about 27% of GDP. This estimate is considerably larger than the 9% from Chaves, Engerman and Robinson (2010).[27] But we also believe that this estimate overestimates the welfare effects, as the deadweight loss is counted as a gain.

5.1.2 Distributional Analysis of the Social Rent

We also estimate the rent generated by rail-induced cocoa production for the society as a whole, and for the Whites and the Ghanaians separately. Using estimates from Table 2 column (1), we find that cocoa production would have been ca. 30% lower without railroads. Given the average export price in 1920-1930, this gives 7.9% of GDP in 1927. Yet this does not take into account the costs of producing and transporting cocoa and the distribution of the gains across the two groups.

Ghanaians were paid the producer price in Accra, which was around 65% of

rather as part of modern transport technology introduced in the Gold Coast colony.

[26]This 5s per ton mile is still a lower bound, as it only concerns headloading along well-cleared forest tracks. It is certainly far more costly if one has to go through the dense tropical forest.

[27]Besides the low wage rate for carriers, Chaves, Engerman and Robinson (2010) used an inflated figure for GDP. This demonstrates how sensitive conclusions are to measurement issues.

the export price on average in 1920-1930. This export tax was then captured by the colonizer. This implies that Ghanaians received around 5.2% of GDP. When removing the transport costs (railway tariffs) and the production costs (including the opportunity costs), we find that they received 3.1% of GDP. The Whites received the export tax, around 2.7% of GDP. They also received railway tariffs but had to incur the costs of building and operating the railway lines. Our calculations indicate that the rent generated for the Whites was around 3.2% of GDP. In the end, the total rent amounted to 3.1 + 3.2 = 6.3% of GDP and Ghanaians received 49.4% of it while the Whites 50.6% of it. This indicates an almost equal sharing of the rents, with positive gains for Ghanaians. These gains are in line with an increase in per capita GDP and an acceleration of urbanization.[28]

5.2 The Long-Term Effects of Railways

In 1931, the railways were transporting 760,000 tons of goods and 1,340,000 passengers. By the end of the 1960s, the railways were transporting 3,500,000 tons of goods and 6,000,000 passengers. Yet, massive investments in road infrastructure and underinvestments and management issues in the railway sector caused a significant decline of the latter. In 1984, the railways were only transporting 374,000 tons of goods _ the same amount as in 1921 _ and 2,180,000 passengers. Although recent investments have permitted the railways to be competitive again, they still transport much less than what they could do at independence.

We now study whether districts that are connected to the railways are relatively more developed today despite thirty years of marked decline in rail transportation. In other words, has railway construction at the beginning of the 20th century durably transformed the economic geography of Ghana? We use the 2000 *Population and Housing Census* and the 2000 *Facility Census* to see if districts connected to the railways today are now more urbanized, have better infrastruc-

[28]The issue here is why the Whites did not capture the whole rent. First, the Whites could not produce cocoa themselves as the mortality rate of settlers was high in the tropical forests of West Africa. Second, they were taken aback by the magnitude of the cash crop revolution in Ghana and did not have a clear view of the total gains that accrued to the Ghanaians. Third, the colonial strategy in Ghana was both extractive and non-extractive. The Whites did exploit the gold mines and did tax the cash crop sector, but they also thought that they were there to bring civilization, whether christianity or capitalism (through trade).

ture and larger manufacturing and service sectors. We have data for 110 districts but we just want to compare connected districts to their nearest neighbors. We thus restrict our analysis to those Southern districts that are suitable to cocoa cultivation. We run the following model for districts d:

$$Dvt_{d,\mathtt{2000}} = c + \lambda Rail_{d,\mathtt{2000}} + \zeta X_{d,\mathtt{2000}} + w_c \tag{4}$$

where our dependent variable $Dvt_{d,\mathtt{2000}}$ is a development outcome of district d in 2000: urban density, access to infrastructure and sectoral shares.[29] $Rail_{d,\mathtt{2000}}$ is a dummy equal to one if the centroid of the district is less than 20 km from a railway line in 2000.[30] $X_{d,\mathtt{2000}}$ is then a set of district-level controls which we can include to account for potentially contaminating factors, whether political economy or economic geography: dummies for containing a national city or a regional capital, being a coastal district, and Euclidean distances to the coast, Accra and Kumasi.

Regression results for model (3) are then reported in Table 5. We find that railway districts are relatively more urbanized (+136.7 inhabitants per sq km), have a better access to infrastructure _ especially for non-universal public goods such as senior secondary schools (+12.14%), hospitals (+20.42%) or electricity (+12.70%) _ and larger manufacturing (+4.66%) and service (+8.73%) sectors. We are now collecting census data (population and urbanization) for each grid cell for each census year: 1901, 1931, 1948, 1960, 1970, 1984 and 2000. This will give us a dynamic panel which will allow us to understand the dynamics of population and urban growths. We are also collecting census data on employment and infrastructure at the grid cell level for 2000. In the end, we will be able to investigate the long-term effects of railway connectivity.

6 Conclusion

Using railroad construction in colonial Ghana as a natural experiment, we have analyzed the impact of colonial investments on agricultural and economic development. We find a strong effect of railroad connectivity on cocoa production. The

[29] Urban density is total population in localities with more than 1,000 inhabitants per sq km.

[30] There were very few lines built after 1931. The layout of those lines that were built after 1931 was strongly influenced by the layout of the railway network in 1931. We use the network in 2000, although we could have been using the network in 1931 or 1918.

cash crop boom is then associated with demographic growth. The population effect is mostly explained by the growth of cocoa-producing villages and the role of towns as trading stations for cocoa. We exploit various strategies to ensure that our effects are causal: we show that pre-railway transportation costs were prohibitively high, we provide evidence that line placement was exogenous, we find no effect for a set of placebo lines, and results are robust to instrumentation and nearest neighbor matching. Our study has shown that transportation infrastructure investments had large welfare effects, that were equally shared between the colonizer and the Ghanaians. These investments also exhibit path dependence, as districts connected to the railway system are now more developed, despite thirty years of marked decline in rail transportation. The channels and pattern that we discussed for Ghana appear to be paralleled in other African countries, e.g. cotton in Burkina-Faso, coffee and tea in Kenya, or groundnuts in Senegal. Ghana is now planning to build a new railway line to the North. Whether this line will have similar effects is difficult to say, as this is a very different geographical environment and there is already a widespread road network. But our study has shown that transportation infrastructure investments could have large welfare externalities, as they promote trade integration and economic growth.

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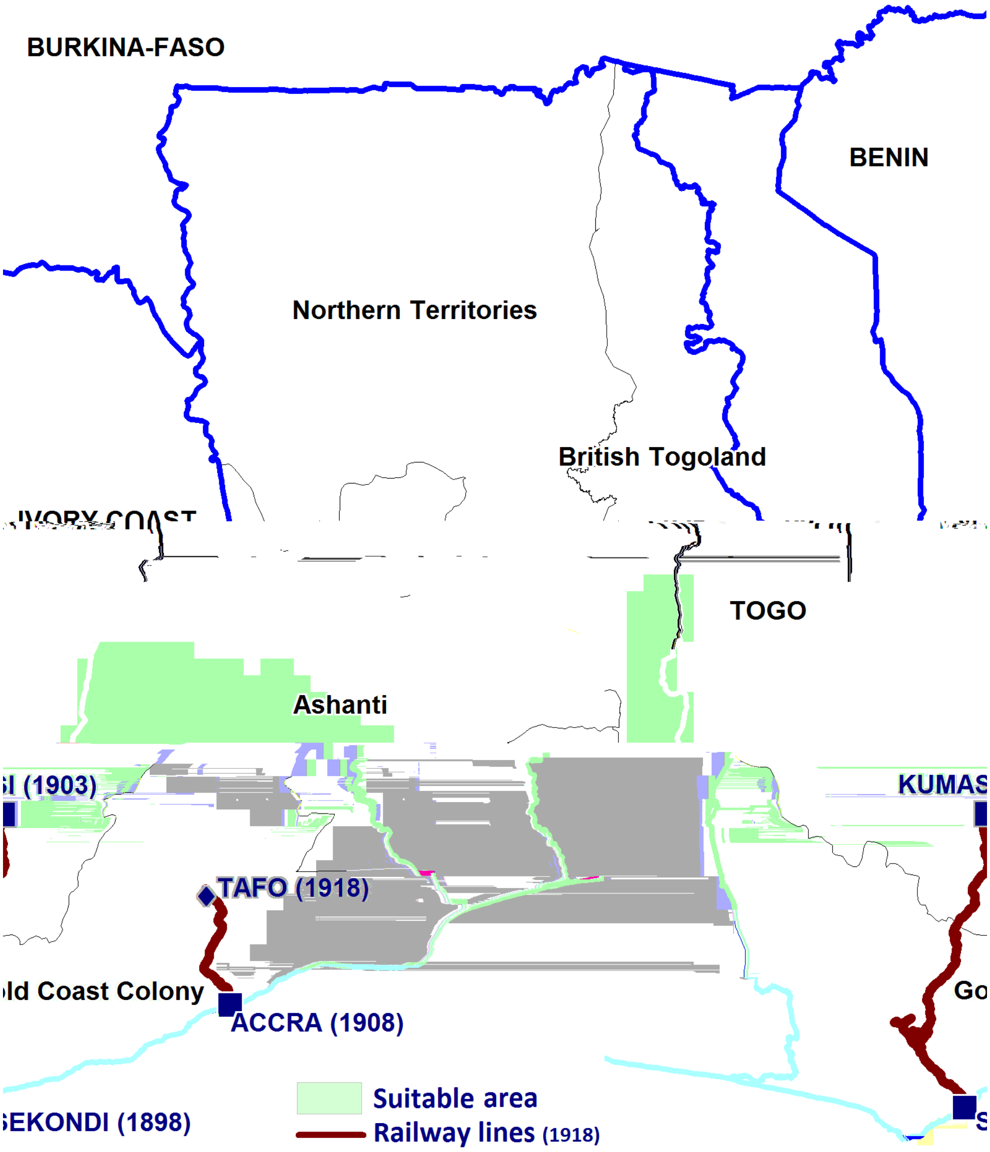
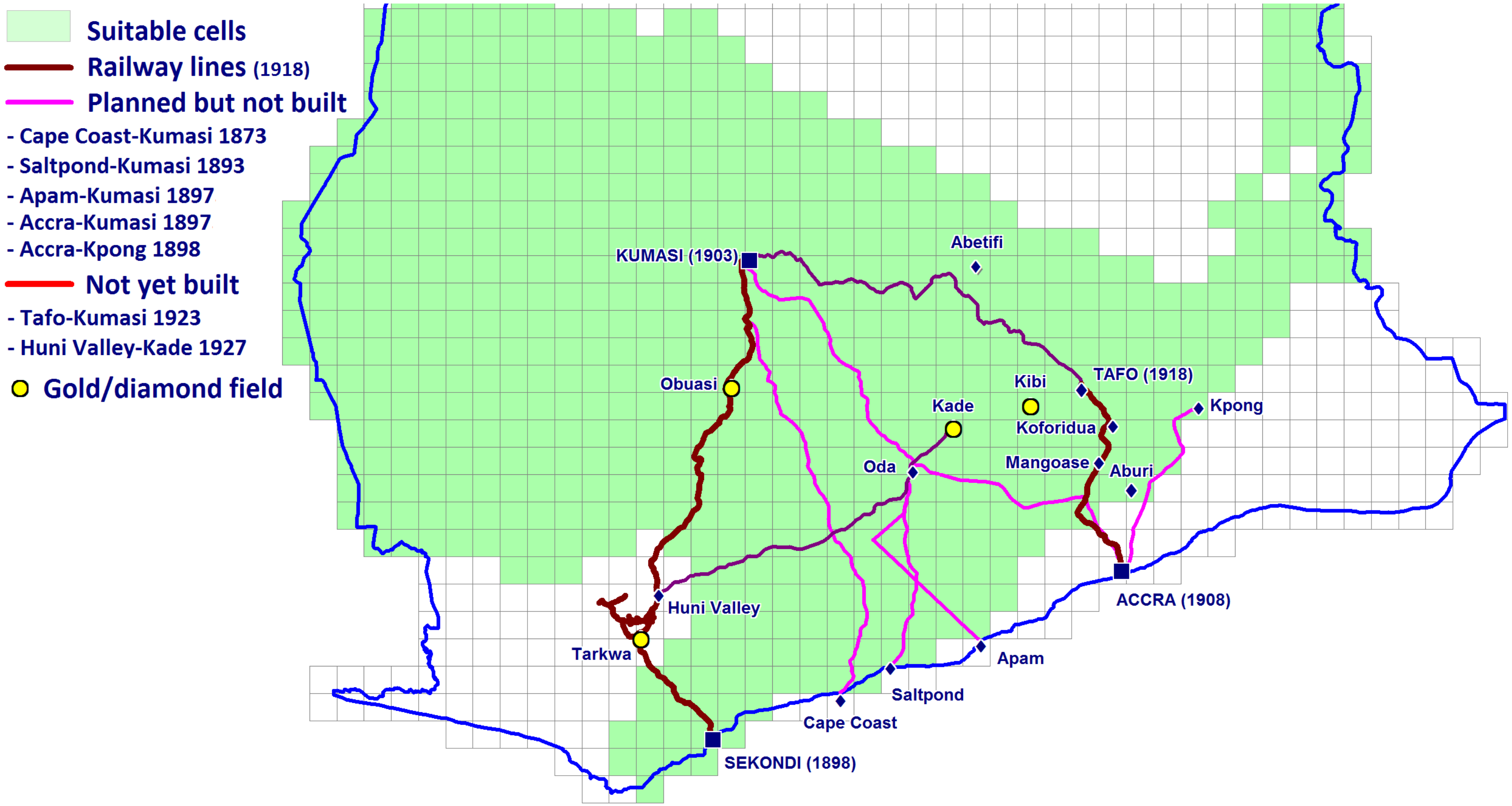
Figure 1: Cocoa Land Suitability and Railway Lines in 1918.



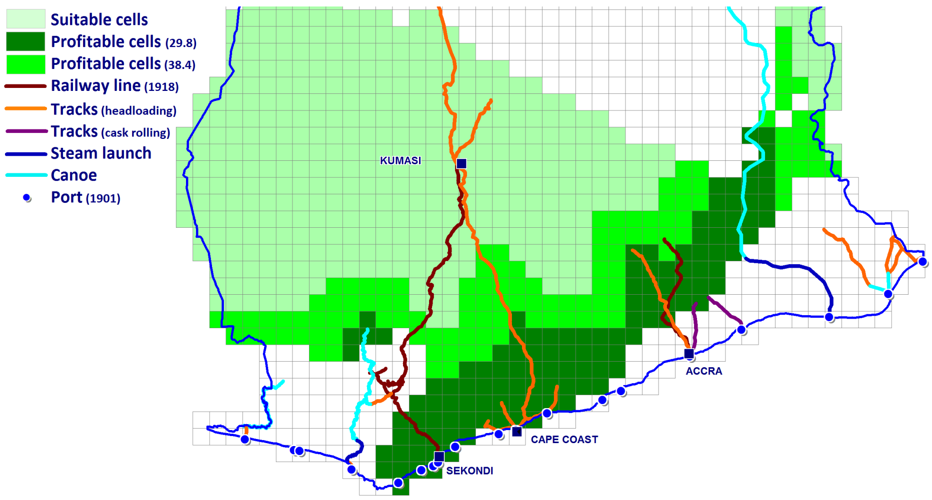
Note: The suitable area corresponds to the tropical forest. Province boundaries date from 1916. See Data Appendix A for sources.

Figure 2: Railway Lines in 1918 and Placebo Lines.



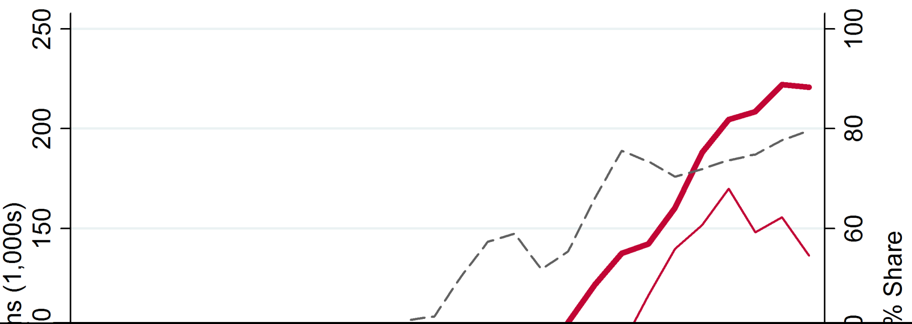
Note: The map only shows Southern Ghana. A cell is defined as suitable if it contains cocoa soils. The map displays the railway lines in 1918 and the placebo lines: lines that were planned but not built and lines that were not built yet to affect cocoa production in 1927.

Figure 3: Transportation Networks in 1901 and Area of Profitable Production.



Note: The map shows transportation networks in 1901, railway lines in 1918, cells suitable for cocoa production and cells for which cocoa production is profitable given cell transportation costs in 1901 and the price offered to farmers at the port (before transport costs) = [29.8; 38.4]. See Data Appendix A for sources.

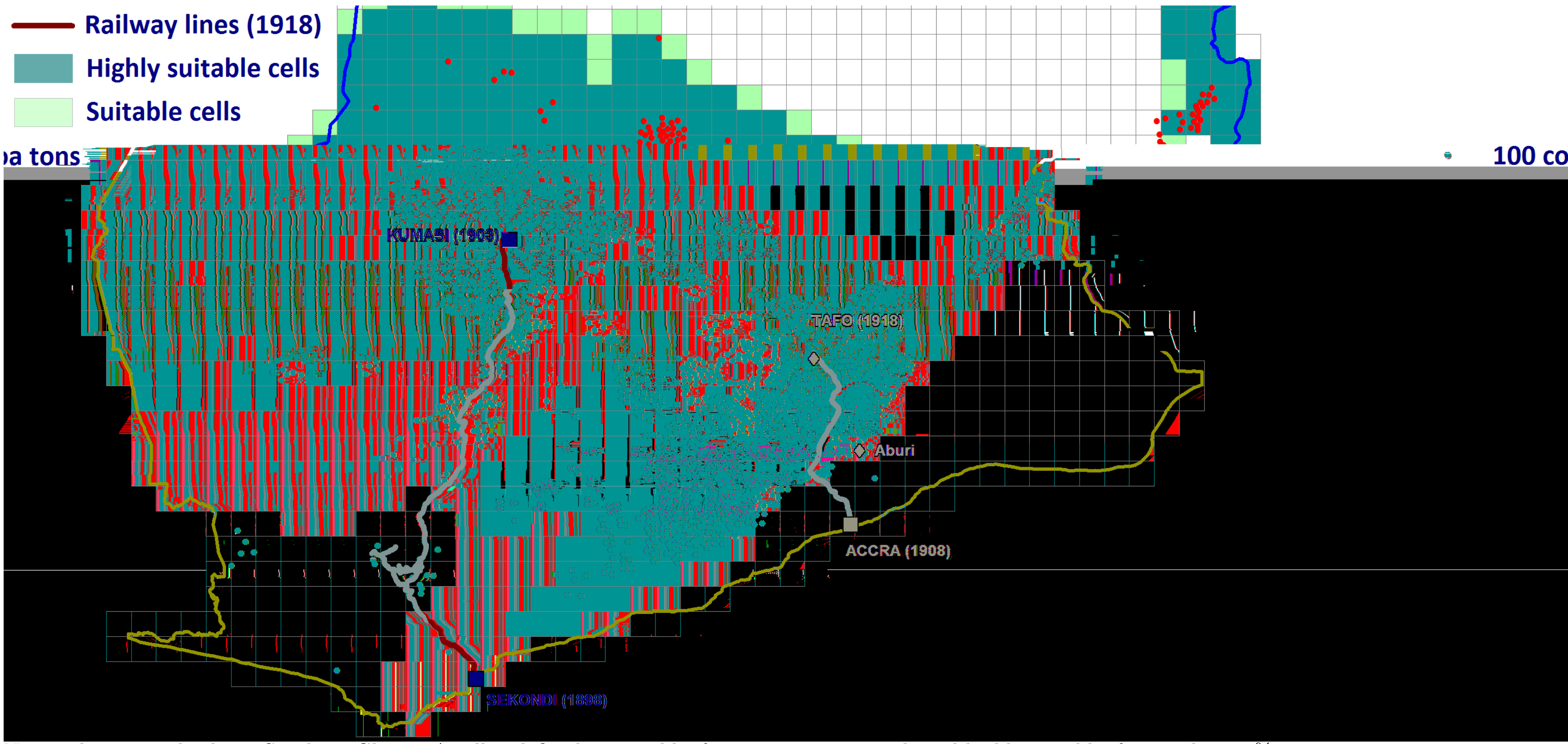
Figure 4: Cocoa Production, Exports and Transportation, 1900-1927.



[redacted]

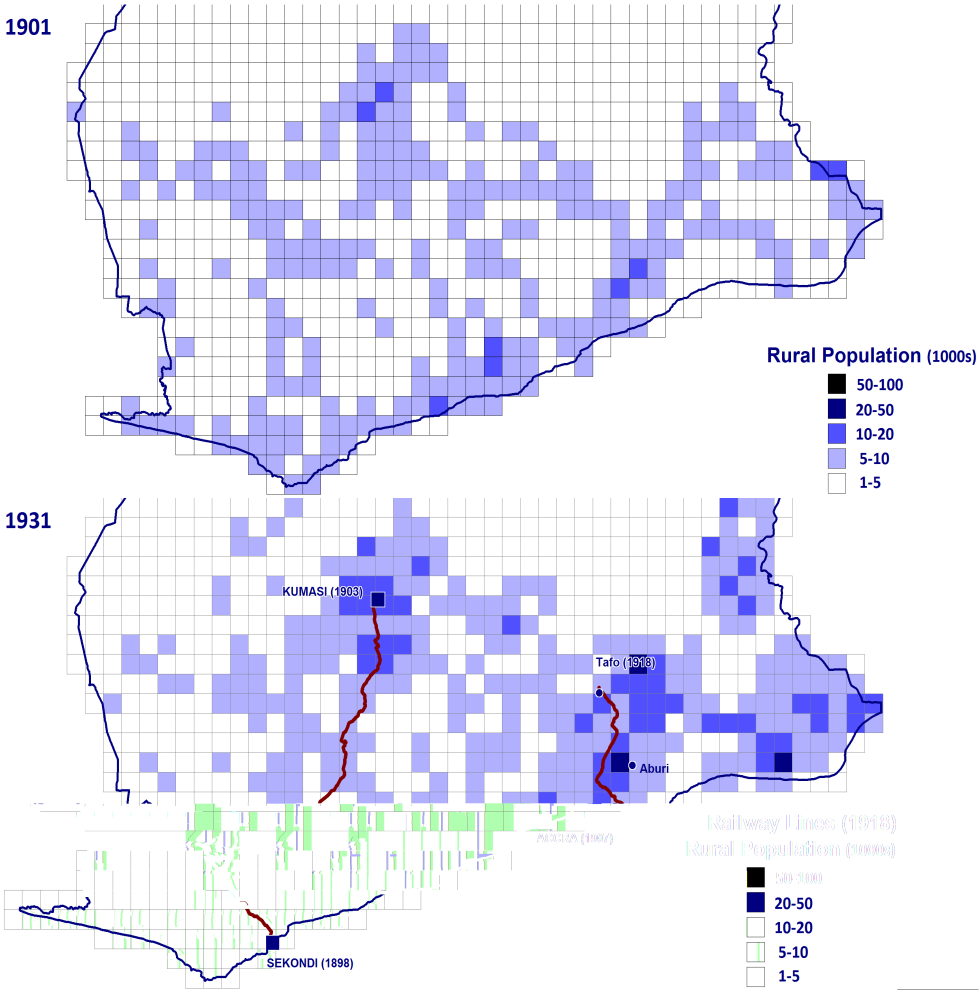
Note: The figure displays three-year moving averages for cocoa production, cocoa tonnages transported by rail to a coastal port, and the share of cocoa exports in total exports from 1901 to 1927. See Data Appendix A for sources.

Figure 5: Railway Lines in 1918, Land Suitability and Cocoa Production in 1927.



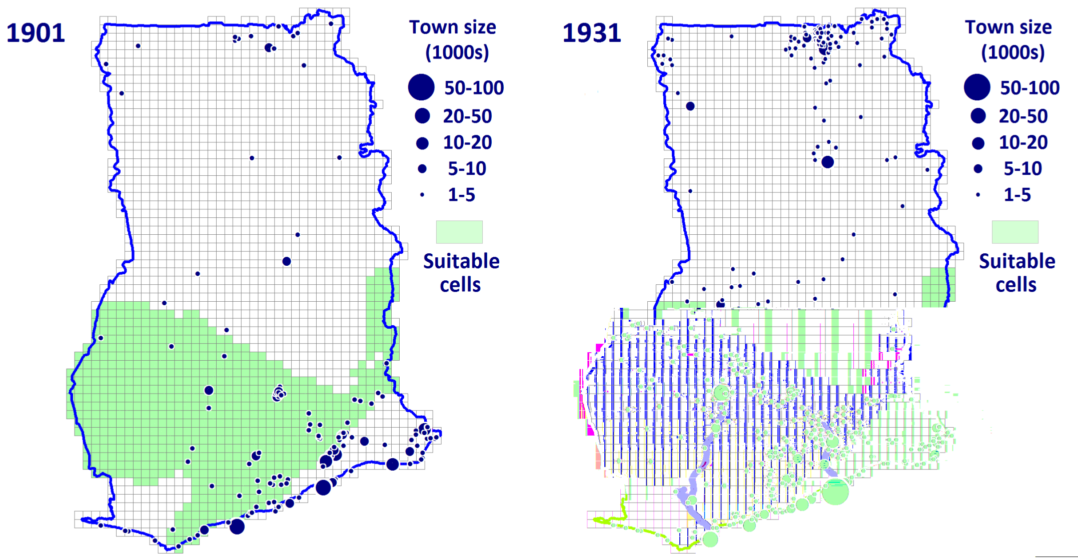
Note: The map only shows Southern Ghana. A cell is defined as suitable if it contains cocoa soils and highly suitable if more than 50% of its area consists of forest ochrosols, the best cocoa soils. The map displays the railway lines in 1918, suitable cells, highly suitable cells and cocoa production in 1927.

Figure 6: Railway Lines in 1918 and Rural Population in 1901-1931.



Note: The maps displays the rural population (sum of the population of all localities < 1,000 inhabitants) for each cell in 1901-1931. See ata Appendix for sources.

Figure 7: Railway Lines in 1918 and Towns in 1901-1931.



Note: A town is any locality > 1,000 inhabitants. See Data Appendix A for sources.

TABLE 1: OBSERVABLES FOR TREATED CELLS VERSUS CONTROL CELLS

RHS Variable:	**Dummy Rail 1918, 0-20 km**		
Control Cells:	All	Placebo	C.Coast-Kumasi
LHS Variable:	(1)	(2)	(3)
	Panel A: Economic Variables		
Dummy \the cell contains a mine"	0.01	0.00	0.01
Cocoa production in 1901	10.4**	10.4	10.4
	Panel B: Demographic Variables		
Urban population in 1901	293	-229	279
Rural population in 1901	686***	421**	287
Number of large towns in 1901	0.01	-0.05	-0.03
Number of towns in 1901	0.04	-0.24*	0.05
Number of headchief towns in 1901	-0.01	-0.05	-0.02
Number of large villages in 1901	1.99***	1.55***	0.87
Number of villages in 1901	6.73***	5.21***	2.92
	Panel C: Physical Geography Variables		
Share ochrosols class 1 (%)	0.02**	0.02***	0.02
Share ochrosols class 2 (%)	-0.02	-0.06**	-0.01
Share ochrosols class 3 (%)	-0.26***	-0.26***	-0.37***
Share ochrosols unsuitable (%)	0.08***	0.08**	0.07
Share intergrades (%)	0.02**	0.03***	0.04**
Share oxysols (%)	0.19***	0.20***	0.26***
Altitude: mean (m)	-13.96	4.10	53.39***
Altitude: standard deviation (m)	1.30	2.52	19.52***
Average annual rainfall (mm)	-30.02	8.52	64.46*
	Panel D: Economic Geography Variables		
Distance to Accra (km)	-44.4***	35.6***	28.4***
Distance to Kumasi (km)	-13.4**	-0.6	-8.3
Distance to Aburi (km)	-42.9***	34.6***	14.3
Distance to the coast (km)	-30.7***	8.2	30.8***
N Treated Cells:	96	96	96
N Control Cells:	446	152	44

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. We regress each control variable on a dummy equal to one if the cell is less than 20 km from a 1918 railway line. We thus run 66 di erent regressions.

TABLE 2: RAILROADS, COCOA PRODUCTION AND POPULATION GROWTH

Dependent Variable:	Cocoa 1927 (Tons)	Population 1931 (Number of Inhabitants)				Rural Population 1931 (in Localities < 1000)				Urban Population 1931 (in Localities > 1000)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Dummy Rail 1918, 0-20 km	443***	1,400***	709*	20	274	728***	271	244	248	671**	438	-224	26
	[72]	[401]	[386]	[497]	[348]	[245]	[218]	[234]	[236]	[296]	[310]	[433]	[261]
Dummy Rail 1918, 20-40 km	190***	97	-200	-196	-57	355*	159	159	161	-258	-359	-355	-218
	[63]	[382]	[380]	[358]	[286]	[182]	[176]	[176]	[176]	[315]	[320]	[295]	[214]
Dummy Rail 1918, 40-60 km	-63	-159	-61	-51	1	-52	13	13	14	-107	-74	-65	-13
	[54]	[242]	[228]	[222]	[214]	[151]	[145]	[145]	[146]	[175]	[169]	[162]	[153]
Cocoa (Tons Produced) 1927			1.56***	1.52***	1.37***		1.03***	1.03***	1.03***		0.53***	0.49***	0.34*
			[0.23]	[0.24]	[0.26]		[0.17]	[0.18]	[0.18]		[0.16]	[0.17]	[0.18]
Dummy Rail Station 1918				4,163*	817			162	120			4,001*	698
				[2,144]	[1,621]			[318]	[310]			[2,056]	[1,495]
Cocoa at Rail St. (Tons) 1918					0.83*				0.01				0.82*
					[0.50]				[0.06]				[0.49]
Observations	542	542	542	542	542	542	542	542	542	542	542	542	542
R-squared	0.59	0.63	0.65	0.68	0.73	0.65	0.69	0.69	0.69	0.49	0.5	0.56	0.65
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Standard errors are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01. Additional controls: dummy \the cell contains a mine in 1931", cocoa production in 1901, urban population in 1901, rural population in 1901, number of large towns, towns (> 500), headchief towns, large villages (100-500) and villages (< 100) in 1901, share (%) of ochrosols class 1, class 2, class 3, unsuitable, intergrades, oxysols, mean and standard deviation (m) of altitude, average annual rainfall (mm), Euclidean distances (km) to Accra, Kumasi, Aburi and the coast.

TABLE 3: RAILROADS, COCOA PRODUCTION AND POPULATION GROWTH, ROBUSTNESS

Regression:	*Main*	*Highly Suitable Cells*	*West vs. East*	*West vs. East Highly Suitable*	*Nearest Neighbor = Placebo Cells*	*Nearest Neighbor = C.Coast-Kumasi*	*IV Straight Lines*	*Conley s.e., 50kms*	*Distance To Rail Station*	*No Controls*	*Full Sample*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A: Dependent Variable = Cocoa (Tons Produced) in 1927											
Dummy Rail 1918, 0-20 km	483***	832***	240***	641***	635***	599***	691***	483*	499***	599***	371***
	[62]	[122]	[58]	[164]	[88]	[116]	[172]	[115]	[64]	[85]	[53]
Dummy Rail 1918, 20-40 km	228***	318***	69	249***	348***	346***	162	228*	217***	379***	203***
	[55]	[79]	[49]	[86]	[76]	[113]	[285]	[78]	[56]	[69]	[43]
Rail 1918 x East. Line, 0-20 km			855***	362*							
			[143]	[219]							
Rail 1918 x East. Line, 20-40 km			513***	184							
			[139]	[185]							
Panel B: Dependent Variable = Population (Number of Inhabitants) in 1931											
Dummy Rail 1918, 0-20 km	1,411***	1,291**	853**	1,018	1,239***	1,116***	2,037*	1,411*	1409***	2,332***	2,368***
	[363]	[559]	[396]	[866]	[405]	[411]	[1,149]	[447]	[374]	[535]	[462]
Rail 1918 x East. Line, 0-20 km			3,031***	1,544							
			[903]	[1,109]							
Observations	542	354	524	354	306	237	542	542	542	542	2,091
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Standard errors are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01. Additional controls: dummy \the cell contains a mine in 1931", cocoa production in 1901, urban population in 1901, rural population in 1901, number of large towns, towns (> 500), headchief towns, large villages (100-500) and villages (< 100) in 1901, share (%) of ochrosols class 1, class 2, class 3, unsuitable, intergrades, oxysols, mean and standard deviation (m) of altitude, average annual rainfall (mm), Euclidean distances (km) to Accra, Kumasi, Aburi and the coast. Only cocoa production, urban population and rural population in 1901 are included in column (10). Control variables on the rural population and the number of towns and villages in 1901 are omitted in column (11) as we have no such data for the rest of the country.

TABLE 4: RAILROADS, COCOA PRODUCTION AND POPULATION GROWTH, PLACEBO LINES

Type of Placebo Line:	Planned But Never Built (From West to East)					Not Built Yet		All Lines
Placebo Line:	C.Coast Kumasi 1873	Saltpond Kumasi 1893	Apam Kumasi 1897	Accra Kumasi 1897	Accra Kpong 1898	Tafo Kumasi 1923	H.Valley Kade 1927	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Dependent Variable = Cocoa (Tons Produced) in 1927								
Dummy Placebo 1918, 0-20 km	-197***	-12	-53	250***	409*	66	-285***	68
	[72]	[72]	[70]	[79]	[227]	[81]	[91]	[66]
Panel B: Dependent Variable = Cocoa (Tons Produced) in 1927								
Dummy Placebo 1918, 0-20 km	-462***	-119	-169**	84	-204	-117	-285***	-706**
x Dummy Rail 1918, 0-20 km = 0	[69]	[76]	[76]	[92]	[215]	[89]	[103]	[296]
Panel C: Dependent Variable = Population (Number of Inhabitants) in 1931								
Dummy Placebo 1918, 0-20 km	-474	113	221	350	205	988	-1,554***	33
	[443]	[514]	[515]	[486]	[1,577]	[720]	[336]	[335]
Panel D: Dependent Variable = Population (Number of Inhabitants) in 1931								
Dummy Placebo 1918, 0-20 km	-1,314***	-339	-210	-516	-996	310	-1,634***	-436**
x Dummy Rail 1918, 0-20 km = 0	[359]	[333]	[329]	[377]	[2,083]	[352]	[369]	[200]
Observations	542	542	542	542	542	542	542	542
Controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Standard errors are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01. Additional controls: dummy \the cell contains a mine in 1931", cocoa production in 1901, urban population in 1901, rural population in 1901, number of large towns, towns (> 500), headchief towns, large villages (100-500) and villages (< 100) in 1901, share (%) of ochrosols class 1, class 2, class 3, unsuitable, intergrades, oxysols, mean and standard deviation (m) of altitude, average annual rainfall (mm), Euclidean distances (km) to Accra, Kumasi, Aburi and the coast.

TABLE 5: RAILWAYS AND ECONOMIC DEVELOPMENT IN 2000

RHS Variable:	**Dummy Rail 2000, 0-20 km**	
LHS Variable:	Coe . (1)	Sample Mean
Urban population in 2000 / Sq.Km.	137.56*	166.8
Share of district pop. < 10 km from primary school (%)	0.87***	99.3
Share of district pop. < 10 km from junior sec. school (%)	1.68**	98.3
Share of district pop. < 10 km from senior sec. school (%)	12.14*	69.0
Share of district pop. < 10 km from health clinic (%)	7.36**	85.6
Share of district pop. < 10 km from hospital (%)	20.42***	57.0
Share of district pop. < 10 km from post o ce (%)	16.92**	74.3
Share of district pop. < 10 km from telephone (%)	12.09	68.2
Share of district pop. with access to electricity (%)	12.70**	35.6
Share of district pop. with access to tapwater (%)	0.23	27.3
Employment share of primary sector (%)	-13.39***	63.1
Employment share of secondary sector (%)	4.66***	12.9
Employment share of tertiary sector (%)	8.73***	23.9
N Treated Districts:	29	
N Control Districts:	31	
Controls	Y	

Notes: * p<0.10, ** p<0.05, *** p<0.01. We regress each outcome variable on a dummy equal to one if the district centroid is less than 20 km from a 2000 railway line (13 regressions). We use the 2000 *Facility Census* and the 2000 *Demographic and Housing Census* to reconstruct those outcome variables at the district level (110). As we restrict our sample to suitable districts only, we obtain 60 districts. Controls: dummies for containing a national city (Accra, Kumasi) or a provincial capital, or being a coastal district, and Euclidean distances (km) to the coast, Accra and Kumasi.

Appendices

A Data Description

This appendix describes in details the data we use in our analysis.

Spatial Units:

We assemble data for 2091 grid cells of 0.1x0.1 degrees in Ghana from 1901 to 1931.[1] We choose such a high resolution grid because we have very precise GIS data on railways, cocoa production, population and urbanization. Each grid cell has the same size, except those cells that are coastal or crossed by a border. We create two dummies equal to one if the grid cell is coastal or bordering another country to control for this issue. Grid cells then belong to 4 provinces.[2]

Railway Data:

We obtain the layout of railway lines in GIS from *Digital Chart of the World*. We then use Gould (1960), Dickson (1968) and Luntinen (1996) to recreate the history of railway construction. For each line, we know when it was surveyed, planned, started and finished, and when each station was reached and opened. From the same sources, we know lines that were built but not planned. Most of those placebo lines follow historical trade routes and have become roads later. Using the GIS road network also available from *Digital Chart of the World*, we recreate in GIS those placebo lines. We calculate for each grid cell the Euclidean distance (km) from the cell centroid to each real or placebo line. Lastly, we create a set of dummies equal to one if the grid cell is less than X km away from the railway line: 0-20, 20-40 and 40-60 km. We create a dummy equal to one if the grid cell contains a rail station in 1918. We also know how many tons of cocoa were brought to each station in 1918.[3] Data on railway traffic for both lines was obtained from various sources.[4]

Cash Crop Production and Price Data:

A very precise map of cash crop production in 1927 was obtained from the *1927 Yearbook of the Gold Coast* and digitized. This map displays dots for each 100

[1] 0.1x0.1 degrees more or less correspond to 11x11 km.

[2] We cannot use districts as district boundaries are too different between 1901 and 1931.

[3] This information was retrieved for the main railway stations from the *Administration Report of Gold Coast Railways for the Year 1921*.

[4] These sources are: *Government Gazette Supplement of Accra, Gold Coast, West Africa* 1914 and *Administration Report of Gold Coast Railways for the Year* 1920, 1921, 1929-30 and 1931-32.

tons of cocoa production.[5] We then use GIS to reconstruct total cocoa production (tons) for each grid cell using 1927 as an approximation for 1931. We proceed similarly to create cocoa production in 1950 using a production map published in the *Report on the Cocoa Industry in Sierra Leone and Notes on the Cocoa Industry of the Gold Coast* by Cadbury Brothers LTD in 1955. We then use Bateman (1965) to obtain the international and national producer price.

Population and Urban Data, 1891, 1901, 1931 and 1948:

We collect population data from the gazetteers of the *Population and Housing Censuses* 1891, 1901, 1931 and 1948. They list localities and their population size. Defining as a city any locality with more than 1,000 inhabitants, we obtain a geospatialized sample of 1378 cities in Ghana for all these years. Using GIS, we recalculate total urban population for each grid cell. It was then impossible to find the geographical coordinates of all the villages in 1901 and 1931. Yet, the 1901 census was exhaustively conducted and geospatialized in the South of Ghana (756 cells). We know for each cell the number of *large towns*, *towns* (more than 500 inhabitants), *head chief towns*, *large villages* (100-500 inhabitants) and *villages* (less than 100 inhabitants). Using GIS, we can deduce for each cell the number of villages that are less than 100 inhabitants, the number of villages that have between 100 and 500 inhabitants and the number of villages that have between 500 and 1,000 inhabitants. From the census, we know the average settlement size for each category and we can reconstruct total rural population for each cell in 1901. For 1931, we have a map of the distribution of population for the whole country.[6] This map displays at a very fine spatial level settlements that have less than 500 inhabitants and settlements that have between 500 and 1,000 inhabitants. From the census, we know the average settlement size for each category and we can reconstruct total rural population for each cell in 1931. To conclude, we have the total urban population for each cell in 1901 and 1931. We then have the total rural population for each Southern cell in 1901 and 1931. We can then reconstruct total population for the southern cells in 1901 and 1931.[7] In our main analysis, we restrict our sample to those cells for which we have rural population data in 1901.

[5] Aggregating all the dots, we obtain 209,100 tons of cocoa production in 1927, which is very comparable with what we find from national estimates (see Gunnarsson 1978).

[6] The map was obtained from the 1960 *Ghana Population Atlas*.

[7] We then obtain a total population of 1,085,557 people for Southern Ghana in 1901, compared to 1,043,000 as officially recorded for the Gold Coast Colony. In 1931, we obtain 3,283,660 people for the whole country, against 3,164,000 as officially recorded in the census report. We believe our estimates are entirely reliable.

Height Data:
Data on Ghanaian soldiers enlisted in the British Army was collected by Alexander Moradi using official soldier files. The data set is described in Moradi (2009).

Transportation Networks in 1901 and Road Data:
Transportation networks in 1901 are obtained from Dickson (1968). The layout of historical trade routes is obtained from Dickson (1968) (p.215), and digitized in GIS. We use various sources to reconstruct a GIS database of roads in 1922: Gould 1960 and *Map of The Gold Coast with Togoland Under British Mandate*, published in 1930 by the Survey Headquarters. Those road map have a consistent legend showing class 1 roads ("*roads suitable for motor traffic throughout the year*"), class 2 roads ("*roads suitable for motor traffic but occasionally closed*") and class 3 roads ("*roads suitable for motor traffic in dry season only*") and other roads. Other roads are not suitable to motor traffic and are not consider here.

Mining Production and Price Data:
We use annual production data for Ghanaian mines in 1901-1931 for four commodities: gold, manganese and diamond.[8] As we have the geographical coordinates of each mine, we create a dummy equal to one if the cell contains a mine.

Geographical Data:
Forest data comes from land cover GIS data compiled by Globcover (2009). The data displays those areas with virgin forest or mixed virgin forest/croplands, which were areas with virgin forest before it was cleared for cash crop production. Soil data comes from the *1958 Survey of Ghana Classification Map of Cocoa Soils for Southern Ghana*. This map was digitized in GIS and we calculated for each cell the share of land which is suitable to cocoa cultivation. We also know the respective shares of land which consists of ochrosols (first class, second class, third class, unsuitable), oxysols and intergrades. A cell is defined as suitable if it contains cocoa soils. It is then highly suitable if more than 50% of its area consists of forest ochrosols, the best soils for cocoa cultivation. Climate data comes from *Terrestrial Air Temperature and Precipitation: 1900-2007 Gridded Monthly Time Series, Version 1.01*, 2007, University of Delaware. We estimate for each grid cell average annual precipitations (mms) in 1900-1960. Topography comes from SRTM3 data. We estimate for each grid cell the mean and standard deviation of altitude (meters). The standard deviation captures the slope and ruggedness of

[8]Mining production and price data is collected from the following documents: *The Mineral Industry of the British Empire and Foreign Countries 1913-1919*; *Reports of the Mines Department of the Gold Coast* 1931-1958.

the terrain. Lastly, we use GIS to obtain the Euclidean distance (km) from each cell centroid to the coast.

Economic Geography Data:
For each grid cell, we use GIS to get the Euclidean distances (km) to Accra, the capital city, Kumasi, the largest hinterland city, Aburi, the city where Ghanaian cocoa production originated, and the coast.

Urbanization, Infrastructure and Employment Data in 2000:
We use the 2000 *Facility Census* and the 2000 *Population and Housing Census* to recreate welfare data at the district level (110) in 2000: urban density (number of people in localities with more than 1,000 inhabitants per sq km), share of people (%) living less than 10 km from various types of infrastructure, and employment shares in the primary, secondary and tertiary sectors. We divide districts between suitable (having some cocoa soil) and non-suitable districts. We create a dummy equal to one if the district centroid is less than 20 km from a railway line in 2000.

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B Placebo Lines

This appendix presents background information on the placebo lines. It draws heavily from Gould (1960), Tsey (1986) and Luntinen (1996). Figure 1 shows the location of the lines.

B.1 Lines Proposed But Never Built

Several private initiatives submitted proposals trying to convince the Colonial O ce of the pro tability of their railway schemes. All asked for a government guarantee of interest on capital outlay. The government opposed this, with reference to the obvious incentive problems of such a guarantee, subsidizing British investors and leading, as in India, to over-capitalization. These initiatives did not enter a phase of concrete planning, nor were they able to raise the capital necessary for their schemes. Yet pressure mounted to build railways in Ghana, as the French and the Germans were already building their own networks in West Africa. Tsey (1986, p.17) writes: \Indeed this had become all the more urgent in view of the fact that the Brussels Conference of 1889-1890 had called on all the European powers to back up their claims to colonial territories in Africa by the establishment of e ective administrations particularly through the construction of railways and roads." Eventually, the state favored public ownership. The government proposals described below can be considered as counterfactual alternatives to the two routes built. We argue that these lines all had the same probability of being built, and only random events (e.g., a change in the colonial Governor) explain why construction did not go ahead.

<u>Cape Coast-Kumasi 1873</u>

The rst proposal to build a railway was made in 1873 to connect Cape Coast to Kumasi via Prasu. The British planned to use the line to send troops to ght the Ashanti. Some railway materials were landed at Cape Coast, but the project was dropped, since it was not possible to build the line in time for the military operation. The line was also proposed in 1891 and 1892 by private consortia (Luntinen 1996, p.18). Cape Coast was the capital of the Gold Coast colony before it was moved to Accra in 1877. The latter had a drier climate and was believed to be a healthier place for Europeans. In 1901 Cape Coast was similar in size to Accra (respectively 28,948 and 30,144). Moreover, Cape Coast was the starting point of an important historical trade route to Kumasi. Villages clustered along this road

like pearls on a string (see Figures ...). This permitted Cape Coast to achieve the largest trade volume of the coastal towns in 1900 (Gould 1960, p.17). Hence, in terms of existing tra c, the line also had some potential.

Saltpond-Oda-Kumasi 1893

In 1893, the colonial government commissioned a survey for a railroad network that would bene t the whole country, not only the mining industry. Government and engineers favored a trunk route. Saltpond was chosen as starting point for its central location and because construction materials could be landed easily. The line was to reach Kumasi, crossing densely populated and rich palm kernel and palm oil areas. The line had the support of Governor Gri th. Tsey (1986, p.19) writes: \A major step towards a full railway proposal came when Governor Gri th suggested a 300-400 mile network, the rst phase of which was to form a trunk route from the most central port of the colony into the interior. Such a central line through the agricultural districts, the Governor argued, not only o ered some hope of nancial return, but in addition, it would form a suitable basis for future railway development." Yet Governor Gri th retired in April 1895, and the new Governor Maxwell changed course and again favored the mining industry. Tsey (1986, p.32) explains that Governor Maxwell, who previously worked in the Malay States where railways served the tin mines, thought that the same model should be applied to Ghana with gold.

Apam-Oda-Kumasi 1897, Accra-Oda-Kumasi 1897

Although the construction of the Western line to mining areas was about to start, it was still widely accepted that the colony needed a central line to be built to tap the palm oil areas. Yet the Saltpond-Oda-Kumasi project was eventually dropped because of the relatively higher capital outlay compared to Apam as starting point. The Apam-Oda-Kumasi line was slightly shorter, thus cheaper, and had all the advantages of a central railway route. Calculations of the consulting engineer indicated the pro tability of the line. However, discontent grew amongst Accra merchants who thought that the capital and chief trading town should be connected rst. The Accra-Oda-Kumasi was also surveyed, and \the railway surveys led to the conclusion that Apam was the better terminus for a Kumasi railway" (Luntinen 1996, p.33). A conference was to be held in London before the end of 1897 to discuss the various proposals but unexpectedly Governor Maxwell died before reaching London. He was replaced by Governor Hodgson who \was of the opinion that the principal railways of the colony should converge upon Accra.

This town had been selected as the seat of the Government, and it was the most healthy site on the coast for Europeans. Much money had been invested there and he thought that it would be a mistake to raise a rival port." (Luntinen 1996, p.34). Besides, he thought that a central line from Accra would be useless as it would not directly traverse the palm oil areas below Apam, so he favored another railway line to Kpong, on the Volta River. Eventually, the possible extension of the Sekondi-Tarkwa line - though originally intended as a short, local mining railway - to Kumasi undermined the central route strategy.

Accra-Kpong 1898

The main objective of this line was to tap palm oil areas to the north-east of Accra and boost cotton cultivation in the Volta districts bordering Togo. It would also link Accra to the Volta river, in order to facilitate the transport of government stores to the North, and to the \Government Sanatorium and Botanical Station at Aburi, 1400 feet above sea level, [...] so that Europeans will be able to reside in this delightful spot, coming daily to their o ces in Accra" (Tsey 1986, p.55). The line was approved for construction, but it was decided that works would not begin before the extension to Kumasi was completed in late 1903. However, Governor Nathan decided to retire in February 1904. He was replaced by Governor Rodger, who thought that a railway line from Accra to Kumasi was more important and that the Volta river was already being used from the coastal port of Apam. The mercantile representative on the Legislative Council also strongly opposed the Accra-Kpong line, given \he was operating a boat service on the Volta" between Kpong and Apam and did not want the competition of the rail (Tsey 1986, p.57).

B.2 Lines Not Yet Built

The rail network was subsequently expanded. Hence, we also consider lines that were actually built, but not in time to a ect cocoa production in 1927. Note that cocoa is a perennial crop. Pod production of the type of cocoa predominantly grown in Ghana starts after 5 years, peaks after 25 years, and declines thereafter. Hence, for observing an impact on cocoa production in 1927, farmers must have grown cocoa trees before 1923. There is no qualitative evidence that this happened to a signi cant degree. If the prospect of railway connectivity did indeed induce much production in advance, it would add to the positive correlation expected from reverse causality (cocoa production attracted the railroad). However, we do not nd any positive e ect of the two placebo lines below (see columns ..., Table ...).

Tafo-Kumasi 1923

The Eastern line, with Accra as terminus, reached Tafo in 1916, when war time restrictions on construction materials suspended all further railway projects. Tafo station was then opened in July 1917. Bauxite discoveries, midway between Tafo and Kumasi in 1917, led to the decision to extend the Accra-Tafo railway to Kumasi (Tsey (1986), p.64). Actual construction, however, only started in 1920. The line was completed in 1923.

Huni Valley-Kade 1927

The line ran parallel to the coast, about 80 km inland. It connected the diamond mines at Kade and was supposed to encourage cocoa, kola, palm oil and timber exports. By conveying more tra c to the newly developed harbor at Takoradi (Sekondi), it was hoped to make the port viable. Construction begun in 1923. Several roads already connected the area to the coast, but they were of poor quality. Railroad surveyors believed that lorry tra c could not operate pro tably beyond 50 km from the coast, but this turned out to be wrong. The short distance to the coast made lorry transport very competitive reviving the old ports of Cape Coast, Saltpond and Winneba directly in the South.

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