The Legacy of Rubber: Long-Term Effects of Colonial Experience in the Democratic Republic of Congo

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Abstract

This paper studies the long-term economic consequences of colonial rubber exploitation in the Democratic Republic of Congo (DRC) during the Congo Free State (1885-1908). I digitized the exact location of colonial posts used as rubber collection points and show that proximity to these posts is associated with substantially lower night-time light intensity today, indicating persistent effects of colonial exposure. To overcome potential endogeneity concerns, I construct a novel, high-resolution measure of land suitability for wild rubber (*Landolphia Owariensis*) to capture spatial variation in colonial economic interest and show that rubber abundance strongly predicts the presence of colonial posts. The results are robust to a variety of empirical tests, including alternative measures of rubber suitability, placebo tests across Africa, and controls for pre-colonial characteristics and climatic confounders. These findings suggest that the combination of natural resource abundance and coercive colonial institutions has created enduring scars on development, consistent with a context-specific resource curse.

1 Introduction

In recent years, a large body of research has established the long-term impact of colonialism on economic development (Acemoglu, Johnson, and Robinson, 2001; Engerman and Sokoloff, 2005). In the case of African countries and sub-national regions with unequal levels of development, there have been two main focuses. The first group links development patterns to path-dependent effects of regional geographical fundamentals, such as disease environments or isolation (Alsan, 2015; Gallup and D. Sachs, 2001), while a second body of research emphasizes the legacy of colonial powers and institutions (Nunn and Wantchekon 2011, Cagè and Rueda, 2016, Michalopoulous and Papaioannou 2016). This paper combines both approaches to study the legacy of rubber exploitation during the colonial period in the Democratic Republic of Congo (DRC).

Specifically, I study the long-run impact of forced labor instituted by the Congo Free State (CFS) during its existence from 1885 to 1908. Unlike most African colonies at the time, the CFS was run as a private enterprise by King Leopold II of Belgium. This uncommon colony created a minimalist state heavily funded by the collection of in-kind taxes of wild rubber, the most valuable resource in the Congo river basin at that time.CFS authority on the ground consisted almost uniquely of a network of military and trade posts along the shores of the Congo River

and its tributaries, from where colonial officials or concessionary companies exerted power and collected rubber quotas from nearby villages.[1]

This unique setting created an incentive to open posts strategically depending on trade routes and rubber abundance, causing colonial authorities to exercise unequal presence and coercion over the territory. To capture this historical exposure, I created a suitability measure for wild grown rubber (*Landolphia Owariensis*) using the exact location of historical occurrences and relevant gridded climate variables.[2] *Landolphia Owariensis* is a rubber vine only present in Sub-Saharan Africa and was the main source of rubber during the CFS.[3]

This approach addresses key historical data limitations. First, there exists no disaggregated data for the collection of rubber during the CFS period, so I use the suitability index as a measurement of the natural resource endowment.[4] This is arguably better than rubber collection data itself, as it mitigates endogeneity concerns related to reported production. Second, the extraction of rubber for commercial use was an episode well-defined in time, as the rubber price boom coincided with the CFS regime. Although the vine was known to the indigenous population, it had no commercial value before colonization, making the suitability measure exogenous to pre-colonial characteristics.

To assess if rubber endowment effected exposure to colonial exploitation, I digitized historical records of colonial posts from 1907, the last year of the rubber period. Using a spatial grid-level logistic model, I find that rubber suitability is a strong predictor of colonial post presence. Moving from low to high rubber-endowed regions increases the presence of a post by a factor of 2.8. Extending this analysis to 1928, two decades after the end of the CFS, I find that new posts constructed in the post-rubber era are not predicted by rubber abundance. These results support the idea of a minimalist extractive state that asserted presence and coercive force depending on potential revenue from natural resources.

To study the long-term effects, I use Night-light data and the as predictor of local development. I estimate an instrumental variable (IV) model that exploits the exogenous variation in post location determined by rubber endowment. After controlling for historical and geographic characteristics, estimates reveal that proximity to a former rubber post is associated with a statistically significant reduction in night-time light intensity.

To address validity concerns, I perform placebo tests by estimating a reduced-form regression of rubber suitability on development outcomes in the DRC and other sub-sharaian African countries. While *Landolphia Owariensis* is autochthonous to the region, other colonies relied on different rubber sources or had non-coercive colonial regimes. The estimates show a statistically negative relationship inside the DRC but insignificant coefficients for other African countries, suggesting that the negative relationship between rubber suitability and development

[1] As Wolf and Wolf (1936) explain rubber in-kind taxes were demanded inside and outside concession areas: "These 'taxes' were exacted by the concessionaire companies just as by the government and, whether in government or concession areas, actually were limited. Officials or commercial agents decided what amount of rubber or other produce they wanted brought in every week or fortnight or month, [...]".

[2] Similar examples of suitability measures would be those used in Global Agro-Ecological Zones (GAEZ) developed by The Food and Agriculture Organization of the United Nations (FAO) to create measurement of suitability and production potentials for individual crop types under specific input and management conditions.

[3] Even though *Landolphia Owariensis* was not the only plant from which rubber could be extracted in Congo Free State, it was the only abundant plant that yield high quality rubber in the region (Harms, 1975).

[4] The rubber collection data that has survived is scarce. For example, post-level rubber production data from 1904 for ABIR concessionary company (de Ryck, Microfilm Collection 1885-1954).

is explained by the past colonial experience.

2 Historical Background

By the late 19th century, innovations in transportation and manufacturing drove a significant increase in rubber demand. At that time, neither mass plantations nor synthetic petroleum by-products were available, and rubber came exclusively from wild growing trees and vines.[5] The lack of mass production constrained supply, driving prices to unprecedented levels.[6]

In the Congo River Basin, the primary source of natural rubber was the vine *Landolphia owariensis*, which was found throughout the territory. Rubber was extracted by cutting the vine's bark to release latex, a process simple enough to make the commodity ideal for taxation and exploitation.

At the Berlin Conference of 1884-1885, the Congo Free State was established under the personal control of King Leopold II. Unlike other colonies, the CFS functioned as a corporate entity designed to maximize short-term revenue.[7] The emergence of a lucrative rubber market coincided with the CFS, making it a richly endowed colony.

To make the colony profitable, Leopold issued decrees in 1891-92 forbidding natives to sell rubber and declaring natural resources state property. Rubber was extracted through a system of in-kind taxation on the indigenous population, enforced by agents responsible for overseeing collection. Thanks to the successful navigation of the Congo River by early European explorers, there was easy access to the interior.[8] Those who failed to meet quotas faced brutal reprisals by the *Force Publique* or company militias, including imprisonment, forced labor, and hostage-taking. Agents were remunerated according to the quantity of rubber extracted, fostering an environment of coercion and violence.

To formalize control, the administration established a network of posts, serving as strategic points along transportation routes and rubber collection centers.[9] Lacking manpower and legitimacy, the administration implemented indirect rule from these posts by co-opting local leaders or replacing them with compliant figures. The collection process required workers to venture deep into forests, demanding little capital investment, which disincentivized broader infrastructure development.[10]

[5]The discovery of how to vulcanize rubber made by Charles Goodyear in 1839 created new usages and commercialization opportunities for rubber.

[6]The Amazon rubber boom is also a good example of the devastation caused by rubber production for the indigenous population (Barham and Coomes 1994).

[7]Accounts on how Leopold managed to create the Congo Free State and his intentions are extensively documented. See the popularisations by A. Hochschild, *King Leopold's Ghost: A Story of Greed, Terror and Heroism in Colonial Africa* (London: Macmillan, 1999).

[8]Henry Morton Stanley's expedition of 1876-77 was the first European expedition to navigate the upper Congo river. During the first years of the Congo Free State, Stanley was in the Congo basin where he set up treaties with the local chiefs and with native leaders in the name of Leopold.

[9]Harms (1983) offers a description of the post in the ABIR concessionary company: "When an agent established a post, he conscripted people from the nearby villages to build him a house and sheds for drying and storing rubber. Some of the nearby villages were required to provide food for the post; others received the job of cutting wood for the ABIR steamships. A typical post employed ten workmen for cutting and sorting rubber, seven houseboys to serve the agent, and about thirty canoe men."

[10]During the Congo Free State colonial period, only the construction of the 420 kilometers railroad between port city of Matadi and the Stanley poll was constructed to bypass the series of rapids and falls which hindered access from the South Atlantic Ocean to the Congo Basin. This key infrastructure finished in 1900, gave access

The brutality of the regime sparked international outrage.[11] Estimates suggest the population may have been reduced by half between 1880 and 1920, with up to ten million deaths. By the early 1910s, global rubber prices collapsed due to British plantations in Southeast Asia, and the Belgian Parliament annexed the CFS in 1908, abolishing the rubber tax and ending the rubber exploitation in the Belgian Congo.

3 Variable Estimation and Data

3.1 Rubber Suitability Measure Estimation

I examine the long-run impact of rubber exploitation by creating a measure for wild rubber suitability, which serves as a proxy for regional natural rubber endowments during the CFS. A suitability measure is necessary because only aggregated data exists for rubber collection. Rubber was not traded before the Europeans arrived, making the presence of vines independent of precolonial institutions or urbanization. To construct the Rubber suitability, I estimate the

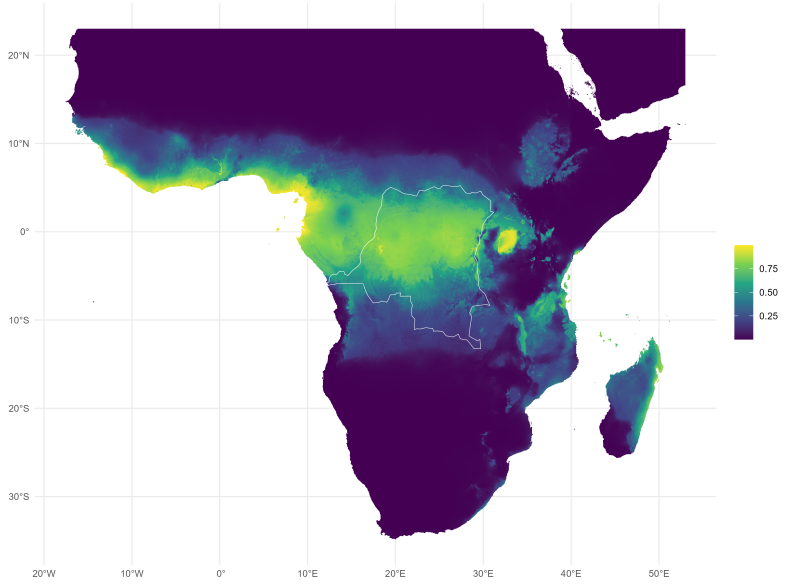

Figure 1: Rubber suitability in subsaharian Africa

distribution of the vine using historical occurrences from the Global Biodiversity Information Facility (GBIF). Ecological studies indicate that vine distribution is effectively explained by rainfall and seasonality. Therefore, I used gridded annual precipitation and temperature range from the WorldClim database as predictor variables. Using MaxEnt (Maximum Entropy Modeling), I estimate the probability of *Landolphia Owariensis* presence in Sub-Saharan Africa.[12] Table 1 reports the rubber suitability index, which ranges from 0 to 1 and measures the probability of encountering a rubber vine.

to European colonialist to the navigable Congo river and its tributaries (Wolf and Wolf, 1936, p. 89).

[11] To know more see the Casement Report of 1904: https://www.gutenberg.org/files/50573/50573-h/50573-h.htm

[12] I use Pownitha et al. (2020) as a reference for my approach, in which they estimate the suitability of two medically valuable lianas in the Indian subcontinent using MaxEnt software.

3.2 Data Construction

The final dataset consists of 6,102 regular cells (approximately 25 km^2) extending across the DRC.

- **Colonial Post:** I digitized the *Carte Politique de L'État Indépendent du Congo* from 1907 to record post locations. This map illustrates the maximum reach of colonial authority, showing 322 posts at the peak of the regime.
- **Development Outcomes:** I employ night-light density as measurement of economic development. Remote-sensed nighttime luminosity data from the 2015 VIIRS product acts as a proxy for electrification and local economic activity. VIIRS data is a strong predictor of local development in data-scarce regions like the DRC.
- **Confounders:** I include geographic and historical controls such as distance to Kinshasa, distance to the Congo River, terrain ruggedness, elevation, Malaria Ecology Index, caloric agricultural suitability, and pre-colonial population density (1880). Additionally, I control for ethnic group, as defined in the Murdock Ethnographic Atlas, and for the concessionary company to which each grid cell belongs.

4 Empirical Analysis and Main Results

4.1 Assessing Congo Free State Presence

To test if the Rubber suitability captures the presence and coercion of the colonial force, I implement a logit model where the probability of a post existing in a grid cell is a function of the Rubber suitability, historical and geographic controls, and concessionary company and ethnic group fixed effects. In order to account for potential spatial autocorrelation I show the Conley standard errors. Results are in Table 1, and show that three factors determined the presence of colonial post: rubber suitability, population density in 1880 and Malaria presence.

This result show that colonial authorities, directly under the CFS or through concessionary companies, decided to open colonial post in areas with high labor abundance and rich in rubber. For example, using the coefficients in column 3, the odds of a post being present are approximately 2.8 times greater in rich rubber cells (0.80) compared to poor ones (0.20).[13] These results are robust to spatial autocorrelation and alternative definitions of post presence.

To support the hypothesis that post locations were determined by resource endowments, I replicate the analysis using post locations from 1928. By this time, the rubber tax had been abolished, and the economy had shifted to cash crops and minerals. I find that rubber suitability does not predict the presence of posts in 1928, nor does it explain the location of new posts established after 1907. However, posts that disappeared between 1907 and 1928 were concentrated in high rubber suitability areas, suggesting they were discontinued once their extractive function became obsolete.

[13]There were also other colonial related settlement not controlled directly by CFS that did not follow this placement strategy. For example, christian missions stationed their health facilities on places with high sleep sickness presence (Lyons, 2002).

	(1)	(2)	(3)
	Rubber collection center (10km)		
Rubber suit.	1.550***	2.327**	1.744*
	(0.600)	(1.021)	(1.047)
Elevation	−0.0004	−0.0004	−0.0004
	(0.001)	(0.001)	(0.001)
Ruggedness	−0.023	0.004	−0.024
	(0.016)	(0.014)	(0.017)
Pop. Denisty 1880	0.092***	0.054**	0.089***
	(0.033)	(0.023)	(0.031)
Caloric suitability	−0.0005	0.001	−0.0004
	(0.001)	(0.001)	(0.001)
Malaria suit.	0.114***	0.082**	0.125***
	(0.041)	(0.037)	(0.041)
Dist. river	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Dist. Capital	0.0000*	−0.0000	0.0000*
	(0.0000)	(0.0000)	(0.0000)
Ethnic Group FE	Yes	No	No
Concession FE	No	Yes	No
Ethnic Group × Concession FE	No	No	Yes
Observations	6,099	6,102	6,099

Conley Standard errors with 100km cutoff are reported in parentheses.
* p<0.1, ** p<0.05, *** p<0.01

4.2 Instrumental Variable Approach

After the estimation of post location in Table 1, I study the effect of colonial rubber exploitation on the long-run development within the DRC. A simple OLS approach might suffer from endogeneity bias, as post locations were influenced by favorable characteristics like trade routes. To overcome this, I use an Instrumental Variable (IV) approach, employing the Rubber suitability as the instrument for colonial post presence. The distribution of *Landolphia Owariensis* is arguably orthogonal to pre-colonial characteristics, as rubber was not traded prior to the CFS.

The OLS models predict a positive and weakly significant association between historical posts and development. However, the IV estimates reveal a negative and highly significant relationship in all different specifications. Proximity to a former rubber post is associated with a substantial reduction in night-time light intensity, showing the persistent effects of the colonial exploitation experience in the DRC.

4.3 Robustness Tests

A primary threat to validity is that rubber suitability might capture other climatic factors influencing development unrelated to colonial exploitation, particularly the location of tropical rainforests. To address this, I include a rainforest fixed effect, finding that the results remain similar to the baseline. I also perform several robustness checks: transforming the instrument into a categorical instrument using quartiles yields similar second-stage results; adding Popula-

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			IV	
Dependent Var.			Nightlight density			
Colonial Post presence	0.0097	0.0084	0.0102	-0.4432	-0.4611	-0.6052
Robust SE	(0.0024)***	(0.0024)***	(0.0024)***	(0.1388)***	(0.0933)***	(0.2629)**
Conley SE (50km)	(0.0037)***	(0.0039)***	(0.0037)***	(0.2331)*	(0.1948)**	(0.4138)
Conley SE (100km)	(0.0038)**	(0.0042)**	(0.0038)***	(0.2510)*	(0.2232)**	(0.3792)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Ethnic Group FE	Yes	No	No	Yes	No	No
Concession FE	No	Yes	No	No	Yes	No
Ethnic Group × Concession FE	No	No	Yes	No	No	Yes
Observations	6,099	6,102	6,099	6,099	6,102	6,099
R-squared	0.23	0.14	0.24	0.24	0.15	0.24
F-statistic first-stage				12.46	29.67	5.99

Heteroskedastic and Conley standard errors are reported in parentheses.
* p<0.1, ** p<0.05, *** p<0.01

tion Controls via log population density (an endogenous variable) does not alter the results while the F-statistic remains strong; and using an Alternative Rubber suitability constructed with all possible climatic variables (rather than just the two key ones) produces similar results, though with lower first-stage power.

4.4 Placebo Test

To further ensure rubber suitability does not affect development through unobservables, I implement a placebo test. While *Landolphia Owariensis* is autochthonous to the region, the specific coercive post system was unique to the CFS. Other colonies, such as British territories, relied on laissez-faire trade,[14] while French colonies utilized different rubber sources (*Funtumia elastica*) or failed to implement concessionary systems as successfully.[15]

Table 1: The *Landolphia Suitability Index* on Night-light outside Democratic Republic of Congo.

			Nightlight density	
	DRC	Full sample	British Colonies	Bordering states
	(1)	(2)	(3)	(4)
Rubber suitability	-0.154***	0.128	0.238**	0.004
	(0.042)	(0.085)	(0.098)	(0.026)
Country FE				
Ethnic Group FE				
Controls				
Observations	6,099	21,195	9,451	8,093
R^2	0.236	0.07	0.12	0.06

Notes: Conley Standard errors with 100km cutoff are reported in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

I estimate the reduced-form relationship between Rubber suitability and night-lights for the

[14]For example, the Gold Coast, known today as Ghana, had a positive experience with rubber extraction at the end of the 19th century. Dumett (1977) claims that profits saved by natives from rubber tapping became an important source of indigenous capital investment in future cocoa farming after the price bust, having a positive effect on the country's development

[15]Due to less abundance of rubber, fewer population and expensive transportation cost, concessionary companies failed to make a profit in French Congo. On the French West African colonies a combination of administrative officers and trading firms blocked attempts to implement concessionary regimes (Wolf and Wolf, 1936).

DRC and other African countries. As expected, the results show a negative effect of rubber suitability on development within the DRC. In contrast, the coefficient is insignificant for the full sample of other countries and for neighboring countries. In former British colonies, Rubber suitability is positively correlated with night-lights, suggesting that resource abundance might aid development under different institutional settings. These results support the hypothesis that Rubber suitability negatively influenced development only when interacted with the extractive institutions of the CFS.

5 Conclusion

This research documents how natural resource endowment in colonial Congo influences contemporary economic development through historical exposure to colonial extractive practices. I exploit the location decisions of colonial posts—determined largely by rubber endowment—as a source of exogenous variation. I estimate long-run negative effects on night-light density and the Relative Wealth Index.

My strategy relies on two key features: the rubber boom was well-defined in time and coincided with the initial colonial occupation, and the minimalist nature of the CFS allowed post locations to serve as a proxy for exposure to coercion. The results suggest that a significant portion of the correlation between geography and development in the DRC is related to the specific colonial history experienced by different areas, consistent with a context-specific resource curse.

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