Colonial Legacy, Private Property, and Rural Development in Namibia

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September 2019

Abstract

Does the legacy of direct colonial rule, through its impact on property rights security, affect rural development in Africa? Although mainstream economic theory links secure property rights to development, extant micro-level evidence from the continent remains mixed. We take advantage of a natural experiment in Namibia, exploiting as-if random application of direct colonial rule. Using a remotely sensed vegetation index to measure agricultural productivity in a regression discontinuity framework, we find evidence of more intensive agricultural cultivation in directly ruled areas. We relate this finding to differing tenure regimes. In indirectly ruled areas, where land continues to be allocated by traditional chiefs, investment, agricultural productivity, and living standards lag. Our work has direct implications for students of colonial legacies and land tenure regimes.

The authors extend their gratitude to Amanda Robinson, Jan Pierskalla, participants in the Ohio State University’s comparative politics workshop, and numerous attendees of the 2019 APSA annual meeting for insightful comments on earlier drafts of this paper. All remaining errors and omissions remain our own.
1 Introduction

A rich body of scholarship from across the social sciences has linked present socioeconomic outcomes to the enduring legacies of colonial heritage. An important strand within this literature in political science and economics has argued that colonialism’s historical imprint persists through its effect on former colonies’ institutions (Dell, 2010; Mahoney, 2010; Banerjee and Iyer, 2003; Engerman and Sokoloff, 2002; Acemoglu, Johnson, and Robinson, 2001; Engerman and Sokoloff, 1997). Acemoglu, Johnson, and Robinson (2001) famously argue that where Europeans settled for the long term, they established more secure property rights, thus engendering economic growth. This insight builds upon a long-standing thesis from economics that links privately-held control over productive resources to investment (Smith, 2010; North, 1981). While this account goes a long way in explaining macro cross-country patterns, the micro evidence from former colonies is often mixed. Importantly, extant studies examining the link between private property rights in land and investment in Africa have yielded inconclusive results (Fenske, 2011; Brasselle et al., 2002).

The goal of our article is to bridge this gap and examine the relationship between colonial-era property rights regimes, household-level investment, and local development in a well-identified framework. To do so, we exploit a natural experiment in Namibia where a specific institution associated with indirect colonial rule - communal land tenure - co-exists side by side with land owned as secure private property. Under communal land tenure, land is usually not freely bought and sold. Instead, it is allocated by traditional leaders who grant access to plots and regulate transfers. To aid causal identification, we follow Lechler and McNamee (2018) and evaluate our research question at a border created by as-if randomly assigned colonial policy. Based on the extent of an infectious cattle disease at a particular point in time in the 1890s, German colonial administrators divided Namibia in two zones separated by a veterinary border. Due to its characteristic depiction in colonial maps, the border became known as the “Red Line.” While areas south of the border were ruled directly, regions north of the border continued to be ruled by indigenous elites. In 1905, the German Reichstag instructed the colonial
administration not to extend its policing powers beyond the veterinary border. Despite subsequent changes to the exact location of the veterinary border that were overseen by the South African colonial administration, it is possible to identify areas where the location of the border did not change since it was first delineated. In these areas, the location of the border remains plausibly as-if randomly assigned. Importantly, one institutional difference between formerly indirectly and directly ruled areas remains: whereas to the north of the border, land continues to be allocated by traditional leaders, farms south of the line are bought and sold by individuals who hold private property rights over them. Thus, in terms of land rights at least, Namibia remains one country with two systems, each of which traces its origins to a different form of colonial rule.

To examine whether the institutional difference in land rights regimes induced by colonial rule impacts local development, we compare values of the enhanced vegetation index (EVI) at the Red Line. EVI is a type of remotely sensed data which captures the electro-magnetic radiation from the sun that is reflected from Earth’s surface. Different objects reflect different wavelengths. Vegetation absorbs electro-magnetic radiation in the red band and reflects wavelengths in the infra-red band. Comparing reflection originating in the two bands can be used for assessing vegetation health (Ferreira, 2018). More cultivated, greener areas are associated with higher values of EVI. As such, EVI is a powerful alternative for discerning differences in socioeconomic conditions in generally poorer agricultural regions because these areas are usually under-electrified. In these contexts, direct data on economic well-being is often limited and unrepresentative at the very local level. Popular measures such as night light intensity are likewise not suited for detecting differences in less affluent regions. Since EVI data is exceptionally fine-grained, we take advantage of the tens of thousands of observations to match on climatic conditions. This approach enables us to “layer” two distinct causal identification strategies to make more credible causal claims. Employing a host of parametric and non-parametric estimators of the geographic distribution of EVI, we find that areas where land is allocated

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1 For an extensive discussion of EVI’s potential as a measure of socioeconomic conditions, see Ferreira (2018).
by traditional leaders are consistently less likely to produce evidence of extensive agricultural activity. The results are robust to differing bandwidths, a placebo test, and the McCrary test of the density of the forcing variable. (McCrary, 2008).

To explain this outcome, we draw on an important literature in economics that highlights the importance of secure property rights for investment (North, 1981; Besley, 1995; Acemoglu et al., 2001). In areas where farmers hold secure property rights over their land, they are more likely to invest in their fields and achieve greater productivity. To illuminate the mechanism at play, we use household income and expenditure survey data to compare investment patterns in areas neighboring the arbitrary colonial border. In accordance with expectations, we find that households living on freehold land are more likely to invest in their property.

We contribute to extant literature in several distinct ways. First, we inform the debate on the long-term effects of colonialism by investigating a particular institutional dichotomy that came into being due to colonial policy. Rather than treating colonialism as a bundle of treatments, we zoom in on the effects of communal land tenure in a case where the difference between individual and communal property rights is defined by a clear geographical boundary. Second, we provide new evidence in support of the hypothesis that secure, individual property rights lead to greater investment in land holdings. Although extant literature has made the theoretical case for this observation (Besley, 1995), empirical evidence remains mixed (Fenske, 2011; Bras-selle et al., 2002) due to empirical and measurement challenges associated with tests of this hypothesis. By relying on fine-grained data of agricultural activity and a natural experiment, our study alleviates many of these challenges. Furthermore, by showing that private property rights are associated with higher living standards of ordinary households, we find contrary evidence to the claim that capitalist institutions that trace their origin to European colonization lead to greater inequality (Acemoglu and Robinson, 2012). Last but not least, our main dependent variable takes advantage of a novel way of measuring agricultural activity in generally rural areas (Ferreira, 2018). We demonstrate the practical utility of remotely sensed vegetation indicators as an alternative to popular measures of development such as night light intensity in
rural, under-electrified contexts.

The rest of the paper unfolds as follows. We first briefly articulate the relationship of the present study to extant literature on colonial institutions, land rights regimes, and their effect upon investment in land productivity. Second, we introduce the natural experiment that provides the necessary quasi-random assignment of the treatment condition. Next, we introduce our empirical strategy and data in detail, focusing particularly upon our dependent variable, the enhanced vegetation index. We subsequently summarize the obtained results and the conducted robustness checks. The final section concludes with suggestions for future research.

2 Colonial Legacy, Land Tenure, and Investment

One of the lasting effects of colonial rule in Africa are its differing land tenure regimes. Colonial rulers molded these regimes in order to reach their goals and project authority over the territories they administered (Herbst 2014). In regions chosen for European settlement, European administrators crafted individual property rights regimes after models they knew from the Old Continent (Acemoglu et al. 2001), in localities meant for pure extraction, no similar frameworks emerged (Lowes and Montero 2017). Alternatively, areas ruled indirectly through traditional leaders often retained some form of communal land tenure (Mamdani 1996). This last form of social control was of particular significance for the colonizers since they did not seek direct control over much of African land, either because its relatively low levels of suitability for economic exploitation or because of the limited number of European administrators present (Cameron 1937). Relaying control over land to traditional leaders via indirect rule and communal land tenure proved an attractive form of social control over the native population (Migdal 1988). Since land was controlled by traditional chiefs who depended for their status on cooperation with the colonizers, European administrators devised a cost-effective mechanism for extending their power over rural populations (Mamdani 1996).

Considering the long-term economic impact of the differing land tenure regimes that often
emerged from colonialism, many a social scientist have argued that communal land tenure in Africa is inefficient and should be replaced with individually-held titles (Ault and Rutman, 1979; Johnson, 1972). This argument stems from a long-standing hypothesis in economics which argues that institutions securing property rights matter for development (North, 1981; Acemoglu et al., 2001) because individuals who can rely on more secure property rights are also more likely to invest in it. Writing in the *Wealth of Nations*, the father of modern economics Adam Smith was one of the first to observe that legal regulations which contribute to property security lead to greater investment and, as he saw it, contributed to England’s grandeur (Smith, 2010, Book III, ch. 2). De Soto (2000) describes property rights security as a crucial explanation for the take-off of Western capitalism, noting that formalization of property rights is a necessary condition for successful market economies. In his seminal study, Besley (1995) identified several mechanisms that link communal land tenure to reduced investment. These mechanisms center on certainty about future returns from investment, access to capital via collateralization, land tradability, and the likelihood of innovation.

**Future gains from investment**

As Adam Smith observed, one is unlikely to invest in the presence of considerable uncertainty. Since by investing, individuals essentially delay present consumption in order to consume more in the future, stronger property rights should result in greater investment due to greater certainty over future returns. In essence, the extra uncertainty over future returns associated with weak property rights serves as an additional discount rate (Pagiola, 1999). Moreover, individuals are likely to further increase investment if they can reliably predict that they will enjoy the fruits of their investment individually. In contexts where land is communal, individuals may expect that returns to investment will likewise be shared communally and the expected return on investment per individual becomes less certain.

**Collateralization**

Following Feder et al. (1988), Besley (1995) links increased investment to the ability of privately held land to serve as collateral, a fact that is also emphasized by De Soto (2000). If land
can be credibly held as collateral, lending institutions are likely to charge lower interest rates. This leads rational farmers to invest more since the comparison between the marginal return on investment and the interest rate charged by lending institutions becomes more favorable. Importantly, individuals in contexts characterized by weak property rights will find themselves in frequent and protracted conflicts over land rights. If property rights can be secured and the likelihood of similar disagreements decreased, resources saved by not engaging in protracted conflicts over land rights can also be devoted to investment instead (Deininger and Castagnini, 2006).

**Land tradability**

Secure land rights might further encourage investment because individuals are capable of selling their land and the associated investments if profitable opportunities emerge. The same logic applies to renting of improved land. Consider an individual who decides whether or not to invest in the improvement of his land. One reason to avoid such decision is the uncertainty about whether or not the said individual will want to continue to pursue the activities associated with land ownership in the future. If land rights are secured, the individual might invest in his land and later rent it to somebody else. Secure property rights also ensure that the conclusion of the rent period will come about smoothly without unnecessary transaction costs.

**Innovation**

Finally, communal land rights might not be conducive to investment because communities may worry about the negative externalities associated with innovative behavior. This is particularly relevant in contexts where one plot of land is used for multiple purposes by multiple community members. If an innovative irrigation system, for instance, reduces the ability of other community members to use parts of the plot for grazing of their animals, disagreement over innovation will arise, transaction costs increase, and investment decline as a result.

In spite of the strong theoretical reasoning that links communal land tenure to greater investment, extant empirical evidence remains far from conclusive (Brasselle et al., 2002). Fenske (2011) discusses a number of reasons why empirical evidence remains less clear than economic
theory would suggest. First, communal land regimes may in fact offer considerable security. The risk of losing access to land held under communal land tenure may in reality be too small to discourage investment (Jacoby and Minten, 2007). Furthermore, Africa’s land abundance makes the benefits derived from land expropriation rather limited (Place and Hazell, 1993). Second, insecurity of property rights might not discourage the attractiveness of investment. Individuals in communal contexts may be higher in their altruistic values and the fact that the fruits of their labor are shared with their community may be less discouraging than economic theorists are willing to assume. Third, access to credit in rural Africa is generally inadequate due to underdeveloped financial institutions and this is unlikely to change with the establishment of private property rights over rural farmland. Thus, the ability to use privately held land as collateral may in fact not lead to increased access to funds for investment. Fourth, investment may sometimes be undertaken to strengthen claims to land (Place and Migot-Adholla, 1998). Bruce (1988) discusses planting of trees as a mechanism for defining permanent ownership over a particular area, showing that investment can sometimes precede security of land rights. Fifth, focusing on land titling as a measure of property rights security of land might be inadequate in conditions where the state is weak and communal rights enjoy greater respect. In order for land titling to work, states first have to attain the capacity to enforce it (Smith, 2004). Sixth, land tenure regimes may be difficult to distinguish and measure, particularly in conditions where de jure rules do not neatly overlap with de facto practices. Using the border between Ghana and Ivory Coast, Bubb (2013) shows that property rights regimes do not differ based on the border, despite vastly different legal rules that prevail in the two countries. This suggests that informal norms dependent on local traditions matter more than official policy. Finally, studies of land rights in Africa are particularly challenging because data on investment is limited and not sufficiently detailed (Place, 2009). Sparse data can lead to lack of variation in the dependent variable which makes detecting of significant effects difficult (Fenske, 2011).

In light of the challenges discussed above, the Namibian case is particularly well suited for identifying the effects of differing land tenure regimes on investment and associated agricultural
activity. Unlike many African countries, Namibia can boast some of the most secure property rights on the continent (Amoo, 2014). The worry that land titling does not offer comparatively more secure property rights is likewise not relevant in the country as the state has repeatedly demonstrated sufficient capacity to enforce legal regulations throughout its territory. At the same time, vast areas of the country are made up of communal land and the border between communal and freehold land is very clear. This means that de jure rules and de facto practices overlap perfectly. Importantly, the boundary between communal and freehold land in Namibia goes back to an arbitrary colonial policy that depended on a historical accident which offers a rare natural experiment and a unique opportunity for causal identification. Namibia is also a country with comparatively well developed financial system which allows access to credit. Ergo, property rights over land should result in greater borrowing capacity of land owners. In other words, if there is a link between property rights security and development that runs through investment as the bulk of relevant literature posits, we should see it in the Namibian case. Accordingly, we hypothesize that areas with secure property rights enjoy greater investment and as a result, exhibit greater agricultural activity.

3 The Red Line and Land Tenure: A Historical Overview

The origins of the veterinary border which divides Namibia in two parts date back to the 1896-1897 rinderpest cordon, which was intended to stop the spreading of the rinderpest pandemic into areas farmed and inhabited by European settlers. Rinderpest is a disease that affects cloven-hoofed animals and kills over ninety percent of the infected livestock (Miescher, 2012). A major epidemic of the disease broke out in eastern Africa in the 1880s and soon thereafter spread to the banks of Zambezi river, which until then served as a natural barrier. In early 1896, the disease appeared south of the river, endangering the vast cattle herds owned by European farmers in the southernmost reaches of Africa. This alarmed the colonial authorities in German-controlled South West Africa as well as the British territories that make up today's
South Africa (Phoofolo 1993). As part of a collective effort, the Germans agreed to limit the movement of livestock in the north of their territory to prevent the spreading of rinderpest from the direction of Angola and Zambia.

This commitment presented a major challenge to the German colonial administrators, who had only several hundred soldiers at their disposal (Miescher 2012). The solution devised and implemented by the Germans was to delineate a cordon that would attempt to limit the movement of animals and thus protect European herds. The cordon itself was established relatively hastily between November 1896 and February 1897 (Miescher 2012) and consisted of German military outposts manned by Germans and local auxiliaries. The outposts were established near water holes but borders between individual outposts were connected by more or less arbitrary straight lines. Placement of outposts at waterholes was strategic because moving animals were more likely to travel to and from these points. Importantly, the precise location of the cordon reflected the limits of the European colonial administration at the moment of the rinderpest pandemic. This was the case despite the German administration’s clear interest in eventually reaching agriculturally productive areas north of the veterinary border (Lechler and McNamee 2018). The decision as to where to establish the veterinary cordon was driven chiefly by the motivation to stop the spread of rinderpest and access to agriculturally promising areas north of the cordon had to be sacrificed for the attainment of this goal. Although the cordon ultimately failed to control the spread of rinderpest, its importance as a line dividing directly policed areas from the rest of South West Africa, as Namibia was then called, persisted. Due to its singular purpose, the new border proved particularly disruptive to long-established trade routes that were used by the native population. As McNamee (2016) demonstrates, the border ignored precolonial polities and cut across precolonial homelands of several ethnic groups. This contributed to the declining economic conditions faced by Africans under German colonial rule at the time.

Disruptions associated with German colonial policies soon led the native population to rise up in a series of military conflicts, which culminated in an attempt by German troops to
exterminate the Herero and Nama ethnic groups. Partially due to the costs associated with the genocidal war, the Reichstag in Berlin passed a resolution in 1905 which mandated that police protection in the colony be restricted to the smallest possible area which was of direct interest to the Germans \cite{Lechler:2018}. In South West Africa, this meant that direct colonial rule would not spread beyond the border established by the rinderpest pandemic. Because regions north of the cordon did not receive German police protection, areas south of the veterinary cordon became known as the Police Zone. This division meant that Europeans were encouraged to settle in this zone, while settlement outside of it was expressly prohibited.

Upon the commencement of WWI hostilities in 1914, German South West Africa did not have enough German soldiers at its disposal to mount a serious defense against the invading South African troops, who joined the war on the side of the Allies. Since 1915, therefore, today’s Namibia was under South African control. South African administrators largely respected the division of the Namibian territory between the directly ruled Police Zone and indirectly ruled northern territories. However, the South Africans oversaw changes to certain parts of the veterinary border. In 1945, the South African administration convened the so-called Lardner-Burke Commission that was tasked, among other things, with considering whether more land should be secured for white settlers \cite{Botha:2000}. The commission subsequently suggested expanding the area devoted to white settlement but this move was vigorously opposed by the colonial veterinary service. Finally, a solution was found where the Police Zone was expanded in the east and west but remained the same in other areas that the Commission singled out for incorporation. After 1961, several other proposals for expanding the Police Zone were rejected by the authorities. In 1964, the policy of expanding the Police Zone was partially reversed and farms were bought back from settlers to create space for African “homelands.” For example, 222 settler families were relocated and compensated to make room for the new native homeland of Damaraland \cite[p. 162]{duPisani:1986}. The final location of the Red Line was codified by the Odendaal Commission. This commission was established by South Africa in 1962 and tasked with investigating the living conditions of South West Africa’s African population. The
commission recommended the expansion of the territory left to the African population, which entailed purchasing of European farms to make more room for African homelands along the Red Line \cite{Odendaal1964}. The final location of the Red Line as codified by the Odendaal Commission and digitized by \cite{Mendelsohn2002} is depicted in the left part of figure \ref{fig:map} below.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{red_line.png}
\caption{\textbf{The Red Line}. The map on the left delineates the exact position of the Red Line as it was codified by the Odendaal Commission in 1964. The border’s location has not changed since then. Areas south of the Line consist of freehold farms, land north of the boundary is held under communal land tenure. The map on the right depicts the northern part of the Red Line, whose location has not changed since its initial charting by the German colonial administration in response to the rinderpest pandemic. Our analysis focuses on areas divided by this, historically stable, portion of the Red Line.}
\end{figure}

The above discussion illustrates that the exact position of the Red Line underwent several changes throughout the decades following its initial charting. As we have demonstrated, the initial location of the veterinary cordon was dependent on the timing of the rinderpest pandemic. Attractive agricultural areas were ignored for the purpose of stopping the disease from spreading. Subsequently, the decision of the German Reichstag halted any attempts at the expansion of European settlements north of the cordon. Finally, the South African colonial administration oversaw both expansion and contraction of European-controlled territories, several times giving
up valuable agricultural land in order to make native homelands viable (Odendaal, 1964). Even though the historical processes that led to these changes were often orthogonal to agricultural activity, one cannot safely assume that the entirety of the Red Line provides as-if random variation in land tenure regimes. Following Lechler and McNamee (2018), we restrict our analysis to the northern part of the Red Line, whose location did not change since its initial charting during the rinderpest pandemic. This particular section of the Red Line is shown in the right part of figure 1.

With respect to land tenure, the difference between the directly ruled Police Zone and indirectly administered areas has continued after Namibia attained independence in 1990. The country’s constitution preserves the distinction between freehold and communal land, the latter of which is vested in the state (Republic of Namibia, 1990). In much of the Police Zone, land is held under freehold tenure which grants land owners the right to trade their plots and farms, as per individual property rights. North of the Red Line however, land is largely communal and therefore not tradable. The Communal Land Reform Act of 2002 formally empowers traditional authorities and so-called communal land boards to allocate the right to use land but not to sell it. Although communal land boards are designed to include other local stakeholders and officials besides traditional leaders, their decisions rarely go against the wishes of traditional authorities. Attempting to ground customary practices in modern legislation, the Namibian government had after the passing of the Communal Land Reform Act in 2002 started a campaign of customary land registration. This campaign seeks to register customary land rights with the Ministry of Land Reform. The pace of registration has however been very slow, with 4,000 applications approved and certificates issued in the first five years of the program. The total number of communal land properties in Namibia is estimated at 230,000 (Mendelsohn, 2008, p. 18).

Because the Communal Land Reform Act proscribes trading of communal land, any economic activity that might result from land tradability is likewise not permitted on communal plots (Mendelsohn and Nghitevelekwa, 2017). The intention is ostensibly to protect communal land holders and to secure income for traditional authorities, who receive fees for land alloca-
The typical land allocation fee depends on the region and local custom but amounts to roughly one head of cattle for a small, one-family plot. The perceived wealth of the “buyer” likewise matters, as richer individuals will be asked to pay higher amounts, sometimes substantially so (Mendelsohn and Nghiteveleka, 2017, p. 10). Traditional authorities rely on a diverse set of criteria when deciding whether to allocate land to a particular applicant (Mendelsohn, 2008). A common criterion is whether or not the applicant is known to his neighbors. Family members generally enjoy relatively easy access to land whereas newcomers may face additional scrutiny. A newcomer from a different area from within the same traditional authority will in turn face less scrutiny than migrants from an entirely different traditional polity. Such applicants might have to introduce themselves to the local chief and perhaps even undergo interviews by the traditional council. Another criterion is the probability with which a new resident will engage in social disputes. An applicant known for amicable relationships with his neighbors is more welcome than someone known for quarrels. Some traditional authorities also consider the availability of water and grazing space before allocating land, others place a limit on the number of livestock that can be kept by residents (Mendelsohn, 2008). Upon the death of the man to whom land was allocated, the surviving widow will often, but not always, inherit the right to continue to use it. In some communities, the widow’s character and degree of assimilation are assessed by the traditional authority in order to decide whether inheritance is appropriate. In other cases, the widow herself may be treated as part of the estate which may be inherited by the deceased landholder’s brother (Mendelsohn, 2008).

4 Data and Empirical Strategy

To compare agricultural productivity in areas under communal land tenure to regions where land is held under private property rights, we test for evidence of a discontinuity in EVI at the border of the two land tenure regimes. Specifically, we compare areas surrounding the northern part of the Red Line, whose location has remained stable since the era of German colonialism.
We use the position of the boundary as it was codified by the Odendaal Commission (Odendaal, 1964). We initially focus our analysis on areas within 5 kilometers of the border and subsequently conduct a bandwidth sensitivity test where we expand to areas up to fifteen kilometers from the Red Line. The main dependent variable is the enhanced vegetation index (EVI) which is a type of remotely sensed data. This type of data is captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) which is an imaging sensor launched by NASA in the late 1990s and early 2000s. It provides detailed information on the electro-magnetic radiation that originates in the sun and is reflected back to space by terrestrial surface. The logic of vegetation indices rests on the comparison of electro-magnetic radiation in the red band to that in the infra-red band. These ratios can be used to assess the health of surface vegetation since trees and plants absorb radiation in the red band and reflect wavelengths in the infra-red portion of the spectrum (Ferreira, 2018). In comparison to measures such as the Normalized Difference Vegetation Index (NDVI), EVI seeks to correct for variation in the angle under which solar rays hit the Earth as well as general atmospheric conditions capable of inducing measurement error (Weier and Herring, 2000). Whereas NDVI values depend on the time of day when vegetation signal is sensed, EVI remains relatively stable throughout the day. EVI ranges between -1 and 1 and healthy vegetation usually falls on the positive side of the spectrum. The version of the index we downloaded comes from NASA’s MOD13A1: MODIS/Terra Vegetation Indices (version 6) product and provides a single datapoint for each 500-by-500-meter square (NASA Land Data Products and Services, 2018). The data capture the highest EVI value detected within a sixteen-day period from March 6th to March 21st, 2018. These dates were chosen because the typical harvest period of millet, Namibia’s most abundant crop, is between April and May annually (Food and Agriculture Organization of the United Nations, 2019). This means that the crop will typically achieve its highest EVI values in mid-March. To show that EVI is a reasonable proxy for local development, we draw on an existing survey of household income and expenditure patterns. We demonstrate that EVI is correlated with the natural log of total annual household expenditure as well as adjusted per capita income. This validation exercise and its results are
discussed in the online appendix.

To control for the effects of local natural conditions, we compile a number of indicators from the digitized version of the Atlas of Namibia [Mendelsohn et al., 2002], including average annual rainfall, average annual temperature, elevation, malaria prevalence, and average crop suitability. See the online appendix for a detailed description of these covariates. Since agricultural activity is inextricably linked to natural and climatic conditions that can exhibit extensive local variation, the natural experiment created by the northern part of the Red Line may not be sufficient in creating comparable “matches” of observations similar in key covariates. Furthermore, we cannot exclude the possibility that natural conditions affected the degree to which different areas were exposed to rinderpest. Because the colonial administrators’ desire to stop rinderpest from spreading further determined the Red Line’s specific location, naively ignoring features of the local landscape could lead to biased estimates. Since we work with tens of thousands of individual observations, we subset our data to further increase our confidence that differences in EVI are due to different land tenure regimes and not to the underlying natural conditions. Specifically, we subset our data to observations that represent the 45%-55% quantile of the included covariates. We consider these observations to be most representative of the “average” levels of the assessed covariates. This approach also allows us to exclude observations with extreme weather conditions. As a result, we obtain 4,690 geographic granules which are identical in their covariate values and thus attain perfect balance\textsuperscript{2}. We assume that any remaining differences in EVI are due to the institutional differences that prevail to the north and south of the Red Line.

Subsequently, we run both standard parametric polynomial estimator and non-parametric kernel estimator in our regression-discontinuity design. The advantage of a kernel estimator is that it chooses its own optimal bandwidth and does not require manual adjustment. We create a continuous forcing variable to measure the great-circle distance of units of analysis to the border, with a negative sign for southern units. We assume that the latent treatment variable

\textsuperscript{2}See descriptive statistics of both raw and matched data in the online appendix.
- communal land tenure - is a deterministic function of this distance-based forcing variable, where all units with positive values are assigned to the “control condition”, whereas all units with negative forcing variable values are assigned to the “treatment condition” under communal land rights regime. Therefore, we consider the border where the forcing variable equals 0 as the cutpoint and fit both parametric and non-parametric regressions on each side to capture the relationship between the forcing variable, the latent “treatment”, and EVI. The parametric linear regression estimates the treatment as follows:

\[ Y = \alpha + \eta D + \beta_1 X + \beta_2 DX + \epsilon \]

where \( Y \) stands for EVI, \( D \) is the latent treatment variable, \( X \) is the distance-based forcing variable, and \( \eta \) identifies the treatment effect of interest. Note that the non-parametric kernel regression allows for higher-order terms and a more flexible model specification for the forcing variable \( X \). The kernel regression works with an optimal bandwidth chosen by the MSE-RDD bandwidth procedure [Imbens and Kalyanaraman, 2012]. In both cases, we assume that the potential value of EVI is continuous around the cutpoint and estimate the local average treatment effect (LATE). LATE (\( \eta \)) captures the discontinuity of the regression line or curve at the border.

To test the robustness of our discontinuity estimates, we conduct several falsification checks. First, we examine bandwidth sensitivity by varying the size of our bandwidth between 2 and 15 kilometers to eliminate the possibility that our finding is simply the result of an arbitrary choice of bandwidth. We carry out placebo tests by hypothetically moving the border to the south and north by 1-4 kilometers to see if the discontinuity only occurs at the geographic border. In light of McCrary [2008], we also check the density of the forcing variable around the Red Line to exclude the possibility of manipulation.

Furthermore, we use two additional estimators to cross-validate our findings from the initial

\(^3\)Substantively, this assumption means that we can reasonably extrapolate the regression pattern to the other side of the border. This extrapolation allows us to attribute the observed discontinuity at the cutpoint to the average treatment effect.
discontinuity design. The first is the standard OLS estimator which relies on a dummy indicator to denote different sides of the Red Line. If, as we expect, the presence of the treatment effect is not model-dependent, the dummy variable should have a coefficient similar to that of the LATE yielded by the discontinuity. The final estimation strategy is a combination of standard parametric regression discontinuity and a spatial error model (SEM) that uses spatial weights to account for autocorrelative nuisance between geographic neighbors. As [Kelly (2019)] warns us, analysts of historical persistence who employ spatial designs run the risk of making invalid conclusions by leaving potential spatial autocorrelation unaccounted for. To avoid this trap, we use a contiguity-based weight matrix that captures neighbors within 1 kilometer in the stochastic component of the parametric regression model.

To investigate the mechanisms at play, we obtained geocoded data from the 2015/2016 Namibia Household Income and Expenditure Survey (NHIES). The survey randomly samples 10,368 households from 864 primary sampling units from across Namibia to capture recent expenditure and income patterns at the household level [Namibia Statistics Agency 2018]. Using ArcGIS, we ascertain whether a primary sampling unit is located to the north or south of the Red Line and create a dummy variable South, which takes on the value of 1 whenever a primary sampling unit is located south of the line. We use a binary variable indicating whether households made any investments in the past twelve months to assess the validity of the investment mechanism.

The NHIES dataset further allows us to examine whether differences in EVI are accompanied by differences in education that would signal the possibility that colonial policies have generated differential human capital endowments [Glaeser et al. 2004]. It is reasonable to assume that individuals living in formerly directly ruled areas are better educated and this head start gives the localities in which they reside an advantage regardless of whether land is bought and sold freely or allocated by traditional dignitaries. Were this the case, education would be a crucial confounder. Hence, we use an ordinal measure of educational attainment of the household head from NHIES to investigate this possibility.
To examine whether agricultural activity trickles down to the people who live on the land and enhances their standards of living, we obtained the 2011 de-identified census data for all Namibian citizens from the Namibia Statistics Agency [Namibia Statistics Agency, 2011]. In comparison to the NHIES, the census data naturally comprises of many more observations but also lacks in variable diversity. For the purpose of examining living standards in close proximity to the Red Line, we use three dichotomous variables indicating whether the respondent has access to a toilet facility, whether the energy source for heating is powered by electricity, and whether the floor is made of sand, earth, mud, or clay. We also code a binary measure that indicates whether or not respondents engaged in agriculture in the past year. Although this information is not available for every single citizen, it constitutes a large, nationwide sample nevertheless. The census data is tied to specific enumeration areas (EAs) which were defined by the Namibia Statistics Agency for the purpose of the 2011 census [Namibia Statistics Agency, 2011]. The entire country was divided in 5,475 EAs, each of which consists of several hundred inhabitants. As with the NHIES primary sampling units, we first plotted all EAs in ArcGIS to determine their location with respect to the Red Line. Our a priori expectation is that individuals residing in southern EAs should, due to their advantage in agricultural productivity, exhibit higher living standards. When it comes to involvement in agricultural activities, we have no strong priors although more advanced agricultural practices associated with larger farms under property rights regimes are likely to lead to higher productivity even when a smaller proportion of the population engages in them.

5 Results

We find that observations south of the Red Line are consistently characterized by higher values of the enhanced vegetation index. This difference becomes even more obvious when we focus on observations with similar natural conditions. Figure 2 demonstrates how the local mean of EVI varies as it moves northward, in both the raw data and its matched subset, each with a
95% confidence interval. Health of vegetation suddenly drops at the border between areas where land is held under private property and regions administered under customary land tenure.

Figure 2: Regression Discontinuity. This plot demonstrates the change in the values of the enhanced vegetation index when crossing the Red Line. The upper plot demonstrates this phenomenon in the raw data, the lower plot is based on observations which are perfectly balanced on geographical and climatic covariates. Curves on both sides are drawn by locally estimated scatterplot smoothing (LOESS).

This finding is robust to the different estimator strategies introduced above, whether parametric or non-parametric in nature. Importantly, our results are also robust to autocorrelative nuisance between geographic neighbors. As for the magnitude of the estimated causal effect, the observed LATE coefficient, which for all of our estimators but OLS revolves around -0.02,
corresponds to about 0.5 standard deviations of EVI in the matched dataset. In other words, holding all geographic and climatic covariates constant while crossing the Red Line from the south to the north results in about one half of a standard deviation drop in EVI.

![Graph showing estimated coefficients for different estimators.](image)

**Figure 3: Regression Discontinuity Estimates.** The plot displays the estimated effect of communal land tenure upon agricultural productivity. We display different model estimates with and without distance to the nearest road as a control for differences in infrastructural endowment. The observations are matched on geographical and climatic covariates.

Aside from differences in land tenure regimes, one can imagine that other aspects of direct colonial administration have led to conditions which engender asymmetries in local development. Specifically, the two sides of the veterinary border could differ in long-term infrastructural investment, which could partially explain differences in agricultural productivity. In this scenario, higher economic activity would not be explained by individuals’ willingness to invest in their land alone, it would also be affected by their ability to, for instance, transport their harvest to the market, obtain the requisite fertilizer, and so on. Although our data does not allow us to
investigate this possibility fully, we test for the importance of distance to the nearest trunk road as a proxy for infrastructural endowment. Regardless of whether or not we include this control covariate, we find that the local average treatment effect is consistently negative, evidencing that agricultural productivity as measured via vegetation health decreases rapidly once freehold land tenure meets its alternative.

This result is also robust to different choices of bandwidth used by local regressions on each side of the border. As figure 4 demonstrates, LATE remains statistically significant and negative when bandwidth ranges anywhere from 2 to 15 kilometers. Accordingly, the area considered in the bandwidth sensitivity test encompasses all matched observations within 15 km of the border. We choose this distance as the upper limit of the bandwidth sensitivity test because the plausibility of the regression discontinuity design assumptions arguably decreases with larger bandwidths. Setting this consideration aside, we find that larger bandwidths tend to produce larger LATEs.

Figure 4: **Bandwidth Sensitivity.** This plot shows how the local average treatment effect size estimated with a non-parametric kernel estimator changes with the size of the bandwidth.

In addition, the placebo test whose results we show in the online appendix demonstrates that
the observed robust discontinuity occurs only around the actual Red Line. The McCrary test finds no evidence of a discontinuity in the density of the forcing variable around the cutpoint. In other words, we find no sign of forcing variable manipulation. In sum, the statistical evidence implies higher agricultural productivity in areas south of the Red Line. We attribute this effect to private property rights that trace their origins to the arbitrary extension of European settler colonialism.

In table [1], we examine the NHIES data to assess patterns of household-level investment on both sides of the Red Line. The variable “investment” is a binary indicator taking on the value 1 if a household reports to have made any investments in the past twelve months. Because the household survey was not conducted with the ambition to make inferential statements around the Red Line, there is a relatively small number of observations in close proximity to the border. Still, we find the specificity of the questions asked extremely valuable. As a result, we examine households that live within 15 and 50 kilometers of the Red Line. The smaller sample yields 128 households, the larger one 389 homes. In both cases, we find that households residing on freehold land are consistently more likely to report that they made investments in the past twelve months. This aligns with the hypothesis that agricultural productivity is partially a result of investment decisions made by individuals with secure property rights. Next, we examine educational attainment of household heads to see if differing colonial institutions resulted in persistent differences in human capital. The variable “education” is an ordinal measure taking on values from 1 to 4 where 1 indicates least and 4 most education. Again, we are constrained by a limited sample but we find no evidence of a gap in human capital.
Although we can only speculate about the effects of higher agricultural productivity upon citizens’ livelihoods, our examination of several variables from the 2011 census leads us to suggestive evidence that citizens living just south of the Red Line are on average doing better than individuals residing just north of the line. Using a logistic regression framework, we regress three self-reported binary measures of individual’s living conditions on a dummy variable indicating whether or not a respondent resides south of the Red Line. We use four distinct variables. “toilet” equals 1 if a household has access to a toilet facility and “floor” takes on the value of 1 if a respondent’s floor is made of durable materials such as tiles and concrete as opposed to sand, earth, mud, or clay. Similarly, “heat” equals 1 when the respondent’s electricity for heating comes from mains as opposed to more rudimentary sources of heat such as wood or charcoal. Finally, “agriculture” takes on the value of 1 if a respondent reports to have engaged in agriculture in the past year. As table 2 indicates, individuals south of the border are more likely to report that their house’s floor is made of durable materials as opposed to sand, earth, mud, or clay. Furthermore, southern households are more likely to use electricity from mains for heating. We find no statistically reliable relationship between location of residence and access to a toilet facility in respondents’ households. Given the statistically significant relationships we find between selected measures of living standards and residence in freehold areas, we reason
that the benefits associated with secure property rights are enjoyed by the broad population. If, on the other hand, these benefits accrued to a select few individuals, it is unlikely that they would be picked up by our logistic regressions. Finally, we find that individuals living in areas with freehold tenure just south of the Red Line are less likely to report to have engaged in agricultural activities in the past year. This is consistent with the theory that private property rights over productive land will lead to more investment, trading, and potentially also accumulation of land by individuals specialized in agriculture. As a result, the proportion of individuals involved in farming decreases even if the overall productivity of the agricultural sector grows rapidly.

Table 2: Living Standards within 15 km of the Red Line

<table>
<thead>
<tr>
<th></th>
<th>toilet</th>
<th>floor</th>
<th>heat</th>
<th>agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(l)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>South</td>
<td>−0.014</td>
<td>0.605</td>
<td>0.975</td>
<td>−2.759***</td>
</tr>
<tr>
<td></td>
<td>(0.111)</td>
<td>(0.104)</td>
<td>(0.138)</td>
<td>(0.136)</td>
</tr>
<tr>
<td>Constant</td>
<td>−0.762</td>
<td>0.653</td>
<td>2.300</td>
<td>1.147***</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.046)</td>
<td>(0.076)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Observations</td>
<td>2,531</td>
<td>2,531</td>
<td>2,531</td>
<td>2,531</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>−1,582.104</td>
<td>−1,649.329</td>
<td>−867.779</td>
<td>−1,351.153</td>
</tr>
<tr>
<td>Akaike Inf. Crit.</td>
<td>3,168.208</td>
<td>3,302.657</td>
<td>1,739.558</td>
<td>2,706.306</td>
</tr>
</tbody>
</table>

*p<0.1; **p<0.05; ***p<0.01

6 Conclusion

In this paper, we ask whether the legacy of direct colonial rule, as manifested through differing land tenure regimes, leads to greater agricultural productivity, household-level investment, and higher living standards of those living on land held under secure property rights. We use the enhanced vegetation index to compare areas where land is allocated by traditional elites as per customary law to regions where farms and smaller landholdings are freely bought and sold by individuals who face comparatively greater incentives to invest in their property. To alleviate the concern that colonial authorities specifically selected areas with greater agricultural potential for
direct rule, we exploit a natural experiment in the Namibian context. We find that areas that fell outside of the veterinary cordon established by German colonial authorities for the sole purpose of combating the pandemic of a lethal cattle disease exhibit lesser amounts of healthy vegetation as measured by the enhanced vegetation index. Households living on freehold land are more likely to report that they have made investments in their property in the last twelve months. On the other hand, there appear to be no differences in human capital, suggesting that secure property rights are the main channel through which the colonial legacy of direct rule operates. We also identify a suggestive relationship between residence in formerly directly ruled areas and several measures of living standards, concluding that individuals living on agriculturally productive land with property rights are relatively better off.

Although the implications of one study that centers on one country cannot be overstated, our results shed light on long-standing debates which consider the long-term effects of colonialism as well as the importance of private property regimes specifically. With respect to the former literature, we show that seemingly arbitrary decisions made by colonial administrators can have long-lasting impact that continues to affect livelihoods decades after the end of colonial bondage. With respect to the latter strand of scholarship, we contribute by providing evidence consistent with the hypothesis that private property rights lead to greater investment, agricultural productivity, and likely also to greater economic efficiency. We show this in a country where private property rights are generally well protected, the state has the capacity to enforce them, and *de facto* practices strongly overlap with *de jure* rules. Thus, the Namibian case and our data are particularly well suited to test the variation implied by extant theory. Naturally, this also puts an important scope condition on our findings. In countries where legal rules clash with cultural practices, the state generally lacks sufficient capacity, and availability of credit for small-holder farmers remains a distant dream, we would expect the importance of formal property rights regimes to decrease precipitously.

An important shortcoming of the present article is the necessity to rely on a relatively sparse household survey sample. Since the data we use in this article was not produced with an eye
towards causal identification around the former colonial border, the survey evidence is strongly suggestive but not entirely conclusive. Future researchers could further investigate our conclusions with detailed survey designs aimed at corroborating the patterns we find. Such surveys could also yield greater insights into differing living standards around the former colonial border and carefully examine their origins. Although we believe that the census data we use to measure differences in living standards is sufficient to provide suggestive evidence, more detailed information on households’ well-being in connection with ingenious causal identification strategies could sharpen the likely connection between systems of land control and standards of living. Finally, the ways in which traditional authorities govern their communities and allocate land remain an active research agenda, particularly because the conditions traditional polities and their leaders navigate continue to change rapidly. As they do, so do customary practices, creating rich opportunities for studying and evaluating the alternatives to regimes based in private property.
References


