Circular Migration, Marriage Markets, and HIV: Long-Run Evidence from Mozambique*

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Abstract

Circular migration has been a mainstay of African life for over two centuries. I study its long-run impacts on sending regions using an arbitrary border within Mozambique that, from 1893 to 1942, separated areas where authorities either promoted or prohibited young men's circular migration. Counterintuitively, but consistent with narratives and theory, living standards change smoothly across this border today while HIV prevalence is lower on the former migrant-sending side. Modern and historical data suggest that partner age gaps – which facilitate HIV's spread – have long been smaller in this region, as circular migration made younger men in bride price societies marriageable.

Keywords: Labor migration, bride price, age gap, HIV, historical determinants of health
JEL Codes: I14, J12, N37, O15

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1. Introduction

Movements of people out of Africa have received substantial academic and popular focus, as they have been watersheds for development and health on the continent and around the globe.[1] But it is arguably the case that "migration within [Africa] has been far more central to the lives of [its people] over the course of the last two centuries" (de Haas and Frankema, 2022, p. i). The authors designate the period from 1850 to 1960 as the age of intra-African migration – and as Africa's contribution to the global age of mass migration – although the movement of labor within the continent has continued apace since then.[2] Because circular migration within Africa has thus been "one of the most distinctive features of that continent's development" (Stichter, 1985, p. 1), in this paper I examine its (very) long-run effects on regions of origin.[3] My focus is on wealth and health given its historical impacts in these domains, poor outcomes across Africa today, and a relative lack of evidence despite migration's ever-growing importance globally (Lucas, 2005; Ratha, Mohapatra and Scheja, 2011; Constant, Nottmeyer and Zimmerman, 2013).

One of the most important systems of African circular migration has been that which brought hundreds of thousands of men to South Africa each year after the 1886 discovery of gold on the Witwatersrand.[4] Figure 1 shows its scale during the mid- to late twentieth century: through their network of posts across Southern Africa, the mines annually recruited up to one-third of the working-age male population in one neighboring country and as much as one-tenth in others. Nonetheless, these national-level data understate the intensity of circular migration to the Witwatersrand from areas of countries like Mozambique and South Africa, in which mine labor recruitment was sustained at high levels but was concentrated in certain regions. Indeed, for much of the colonial period, it was prohibited in all but the southernmost part of Mozambique.

Because the border that separated the migrant-sending and migrant-restricting regions of southern Mozambique was drawn arbitrarily in 1893 and erased completely in 1942, I exploit it to study the causal effects of an additional half-century of historical exposure to one of Africa's largest and longest-lasting circular migratory systems. Specifically, I estimate the main results of this paper using georeferenced data from the Demographic and Health Surveys (DHS) in a regression discontinuity (RD) design to compare present-day levels of economic development and HIV prevalence in areas along the former boundary.

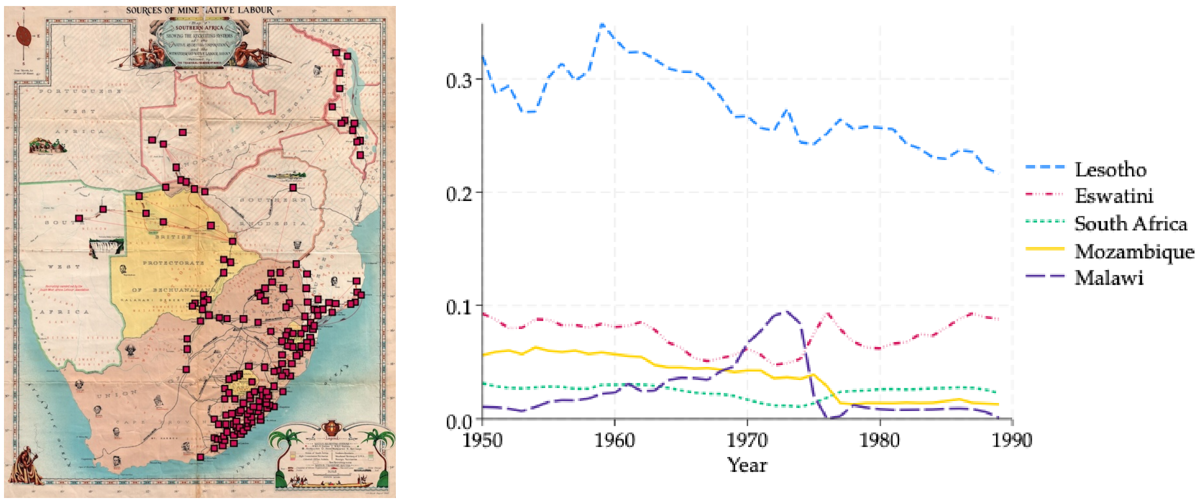
[1] For example, the slave trades had lasting ill effects on Africa (Nunn, 2008), helped Britain industrialize (Heblich, Redding and Voth, 2023), and brought virulent malaria to the Americas (Yalcindag et al., 2011).

[2] Over the last six decades, far more Africans have been labor migrants inside the continent than have left it or become refugees (Africa Center for Strategic Studies, 2021; de Haas and Frankema, 2022).

[3] It has also had important consequences for global development and health. For instance, the Bantu expansion spread new institutions across precolonial Africa (Verhoef, 2018), which are linked to economic performance today (Michalopoulos and Papaioannou, 2013), and migration to Central African cities and mining centers in the mid-twentieth century ignited the HIV pandemic (Pepin, 2011; Faria et al., 2014).

[4] Other large migrant labor flows in this period include those recruited by copper mines in Central Africa (Juif and Frankema, 2018), contract and forced labor bringing men from the West African savanna to coastal regions (Teye, 2022), and worker-initiated migration to farms in East Africa (de Haas, 2019).

Figure 1: Witwatersrand Mine Labor Recruitment across Southern Africa



(a) Recruitment Posts, 1946 **(b)** Share of Country's Men 15-64 in Witwatersrand Mines

Notes: The left map from the Transvaal Chamber of Mines (1946) shows its labor recruitment network in Southern Africa, with red squares overlaid on posts' locations. Mozambique is at the eastern edge of the center of the map and is labeled as Portuguese East Africa. The right graph shows the average annual numbers of Witwatersrand mine workers from each country (Crush, Jeeves and Yudelman, 1991) as a share of its estimated male population aged 15 to 64 (UN Population Division, 2022).

To generate hypotheses regarding contemporary differences (or lack thereof) between the sending and restricting regions, I first turn to historical accounts of southern Mozambique's history, which I summarize in Section 2. While these areas were governed by separate entities for this half-century – the former by the colonial state and the latter by a private company – historians have argued that the primary difference between them was indeed in migration policy. Specifically, one of the sending region's largest sources of revenue was extracting wealth from migrant laborers, whereas the latter's chief function became restricting men's mobility to create a low-cost labor pool – each region "was [thus] governed . . . no less exploitatively" than the other (Allina, 2012, p. 94). These scholars also noted that, rather than development, the main impacts of the migration policy border were on marriage markets, leading to effects such as young men being able to afford bride prices at earlier ages than were previously possible (Harries, 1983).

I then develop an overlapping generations model of the economy and marriage market (based on Tertilt, 2005) that produces formal predictions regarding the effects of greater historical exposure to circular migration. I give an overview of the model and these predictions in Section 3, and I present them in their entirety in Appendix A. In brief, the model contains men and women who live through young and old adulthood, and men choose in which period to pay bride prices to marry young women and have children whose survival is costly.[5] The key assumption is to match the historical context: while young women work for an endogenous wage and save for old age, young and old men must work for an exogenous wage (i.e., on behalf of foreign capital).

[5] Men's choice to marry and reproduce only in one period is a result, not an assumption.

The first result is that on the baseline balanced growth path (BGP), all marriages are between old men and young women, and positive population growth determines the rate of polygyny. However, once a subset of young men begins to earn much higher wages (i.e., circular migration becomes possible), the second result is that they enter the marriage market immediately, driving up the bride price and population growth while reducing the share of age-disparate marriages and the number of wives per man. After one period of this new wage regime, consumption per person effectively rises to the new-BGP level, which ends up being not too different from the baseline BGP's given the much higher bride price and population growth's dilution of the domestic capital stock (thus lowering young women's wages). Conversely, the third result is that the marriage market takes another generation to reach the new BGP: the first cohort of high-wage young men does not remarry when old, so the share of age-disparate unions declines again.

To map these predictions onto the southern Mozambican context, I view the 50-year existence of the border between the sending and restricting regions as implying that the former began its transition to the new BGP around two generations before the latter. By defining a generation's length as 30 years (Wang et al., 2023) and having the last one under the baseline BGP in the restricting region end in 1940, taking the model literally implies that marriage market outcomes only equalized along the border in 2000, whereas living standards converged by 1970.[6] As such, by the time HIV was first detected in Mozambique in 1986 (Audet et al., 2010), the model suggests that the share of age-disparate unions – a major risk factor for the virus – would have been lower on the former migrant-sending side due to its earlier transition to the new BGP.[7] Importantly, this prediction is *not* that circular migration lowers HIV prevalence – its first-order effect is very much the opposite (Weine and Kashuba, 2012) – but rather that *earlier historical exposure to a given rate of circular migration* should equalize risks arising through the direct channel while differentially reducing HIV transmission via its indirect effects (i.e., on marriage markets).

In Section 4, I use the RD setup described above to test the hypotheses of equal present-day living standards along the border but lower HIV prevalence on the side with an additional half-century of historical exposure to circular migration.[8] The results are very much as predicted: while I find no substantive differences in measures of development today, adult HIV prevalence decreases 8 to 11 percentage points (p.p.) just inside the former sending region (40 to 50 percent of the restricting-region mean). These results are broadly robust to a number of robustness checks (e.g., varying the bandwidth, weighting kernel, and polynomial order) and placebo tests (e.g., displacing the boundary as well as using the same RD design along a different border between colonial state and private company territory in northern Mozambique).

[6] The model omits culture, but including a utility penalty for deviating from the previous generation's marriage patterns would clearly further delay convergence in this domain but not in average consumption.

[7] The intuition for why age-disparate relationships increase HIV transmission is that older men are a high-HIV prevalence group, so large age gaps between sexual partners facilitates the virus's spread into the next generation. See de Oliveira et al. (2017) for phylogenetic evidence of this phenomenon.

[8] Given the low number of DHS survey clusters near the historical boundary, I complement the RD estimates with those from the Cattaneo, Frandsen and Titiunik (2015) randomization inference procedure.

I then show that the proximate causes of the HIV result and historical channels underlying it appear in large part to be those hypothesized above. In Section 5, I find large decreases in partner age gaps just inside the former migrant-sending region (1.8 to 2.2 years, or 25 to 40 percent of the restricting-region mean), but limited or no evidence of discontinuities in other HIV risk factors (e.g., condom use). To quantify the contribution of partner age gaps, a back-of-the-envelope approach suggests that it could generate the entire HIV effect, and causal mediation analysis (Imai, Keele and Tingley, 2010) implies that it explains over one-fifth. In Section 6, I use district-level data from the 1940 census of Mozambique to show that discontinuously higher circular migration rates just inside the sending region (20 p.p., or two to four times the rate in the restricting region) indeed coincided with higher marriage rates for young men (14 to 23 p.p., or 25 to 40 percent). Importantly, despite the fact that data from the 1960 census show that circular migration rates had converged along the former border by then, the difference in young men's marriage rates remained substantive (14 to 16 p.p., or 37 to 45 percent), as the model predicted.

Lastly, in Section 7 I study whether the theory and evidence in this paper have implications for the other Southern African countries that participated in this circular migratory system. To do so, I return to the model to examine what happens under *simultaneous historical exposure to different rates of circular migration* (i.e., areas reach the new BGP at the same time but with various high-wage shares of young men).[9] Intuitively, the prediction is that raising this share heightens the differences between the baseline and new BGPs, which implies higher living standards, lower partner age gaps, and higher rates of HIV (migration's direct effect on prevalence) that lower partner age gaps suppress (its indirect effect). I test for these correlations in georeferenced DHS survey clusters within 25 km of recruitment posts in Figure 1 and find strong support for them, providing suggestive evidence of external validity.

Taken together, these results contribute to four main literatures. First, as transportation costs fall rapidly across the globe, it is important to understand the long-run effects of labor migration on sending regions, yet evidence in this domain is scarce (e.g., Lucas, 1987; Theoharides, 2020; Khanna et al., 2022; Salem and Seck, 2023). The most closely related studies in this area are by Dinkelman and Mariotti (2016) and Dinkelman, Kumchulesi and Mariotti (2024), who examine the lasting impacts of Malawi's brief exposure to WNLA recruitment. There is also an influential literature on colonial institutions (e.g., Acemoglu, Johnson and Robinson, 2001; Banerjee and Iyer, 2005; Dell, 2010; Michalopoulos and Papaioannou, 2014), a burgeoning subset of which focuses on African labor (e.g., van Waijenburg, 2018; Lowes and Montero, 2021*a*; Archibong and Obikili, 2023). A highly relevant paper in this sense is the one by Dupas et al. (2023), who examine the fertility effects of forced migration in Burkina Faso.

Another expanding area of study that my results add to is on historical shocks as determinants of disparities in human capital, especially health (e.g., Alsan and Wanamaker, 2018; Lowes

[9] To my knowledge, aside from Mozambique, no country that sent workers to the Witwatersrand had regions in which exposure to circular migration began at different times.

and Montero, 2021*b*) and more specifically the HIV pandemic (Bertocchi and Dimico, 2019; Cagé and Rueda, 2020). The most closely related paper here is by Anderson (2018), who compares HIV prevalence along borders between countries with different legal origins. More broadly, I also contribute to the economic analysis of non-Western marriage markets (e.g., Tertilt, 2005; Ashraf et al., 2020; Corno, Hildebrandt and Voena, 2020; Reynoso, 2023), which determine how most people in the world get married. In particular, I show that they are a novel channel through which history can shape the present (Grosjean and Khattar, 2019; Nunn, 2020).

2. Historical Overview

In this section, I summarize the relevant elements of southern Mozambique's history, from the intensification of Portuguese colonization in the late nineteenth century to the end of its civil war and the explosion of its HIV epidemic in the 1990s. My focus is on the establishment and administration of the sending and restricting regions as well as the narrative evidence describing and comparing them.[10] The key elements for subsequent sections of the paper are that the border separating these regions was created arbitrarily and was erased after 50 years, the main difference between them was arguably in their policies regarding young men's labor mobility, and circular migration during the colonial period had much larger impacts on their marriage markets than on levels of economic development.

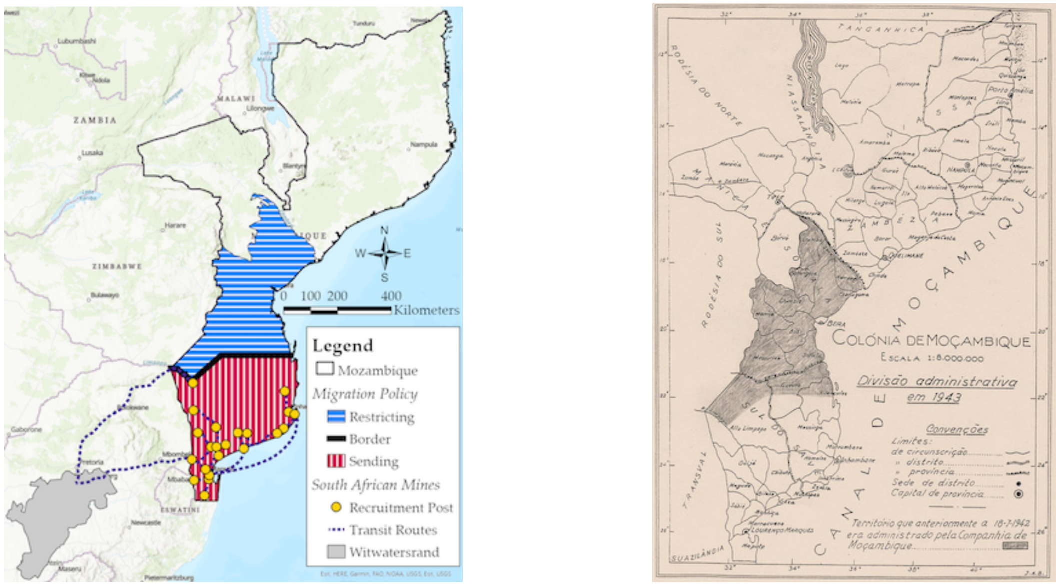
2.1. *Assignment of Territory to Government or Company Rule*

The Berlin Conference of 1884-85 established effective occupation of African territory as the organizing principle for European powers' claims to it. To meet this standard in Mozambique, Portugal pursued a two-part strategy that was common across the continent: projecting the colonial state outward from port cities established in the sixteenth century into the regions surrounding them, and granting vast, mostly unexplored areas to private companies as concessions (Smith and Smith, 1985). Leveraging its presence in Lourenço Marques (present-day Maputo), the government assigned to itself the area from the southern international border to the Sabi River. But it could not quickly establish state capacity between the Sabi River and (tributaries of) the Zambezi River, so it granted a royal charter to the Mozambique Company in 1891 to govern this area (Newitt, 1995).[11]

However, the Mozambique Company's territory was extended southward two years later. Figure 2a shows the final border separating government and company rule in southern Mozambique. A royal decree defined it almost entirely by latitude and longitude given the lack of knowledge of the area, citing the need to effectively occupy more of the colony:

[10] See Newitt (1995) for a comprehensive history of all of Mozambique, including the region of interest.
[11] It was originally supposed to be for 25 years, but shortly after being granted, its term was extended until 1942, making it the only chartered colonial concession in Africa to last beyond the 1920s (Vail, 1976).

Figure 2: Colonial Migration Policy in Southern Mozambique



(a) Regional Boundaries, 1893-1942 **(b)** Administrative Reorganization, 1943

Notes: The left map shows the migrant-restricting and migrant-sending regions in southern Mozambique and the border between them. Labor recruitment posts and transportation routes are taken from Figure 1a. The right map is from Gengenbach (2010) and shows the Mozambique Company's former concession (shaded) overlaid on administrative boundaries redrawn in 1943 after its charter ended.

> Whereas the Mozambique Company has at its disposal important means of action, and consequently it is highly expedient that [lands south of the Sabi River] should be administered by that Company, so as to insure [their] proper development and defence; ... The administration and "exploitation" of the territory bounded ... on the west by ... the Limpopo [River] ... as far as the point where it is intersected by the 32nd meridian, ... by the direct line starting from the last-named point as far as that where the 32nd meridian intersects the 22nd parallel of latitude, and [by the line] following the course of the said parallel of latitude as far as the sea ... is granted to the Mozambique Company. (Great Britain Foreign Office, 1901, pp. 601-602)

In northern Mozambique, the government also chose to administer the area around the then-capital on Mozambique Island and granted a chartered concession to the Niassa Company for the adjacent land between the Lúrio River and the border with present-day Tanzania from 1891 to 1929 (see Appendix B1). While I do not study in depth the history of this additional government-company boundary, I briefly discuss its history below to contrast it with southern Mozambique's.

2.2. *Choice of Policy Regarding Men's Circular Migration*

Having established effective occupation of Mozambique, "extracting wealth from African peasant society became the principal objective" of government and company officials, as they soon discovered that labor was the only resource of significance to exploit (Newitt, 1995, p. 406).

However, to accomplish this goal in their respective territories, each regime established highly distinct policies toward men's labor migration.

2.2.1. *Migrant-Sending Region*

The colonial state established a migrant-sending region to profit from pre-existing labor flows across the international border with the then-Transvaal Republic.[12] The 1886 discovery of the world's largest gold deposits on the Witwatersrand led to intense demand for African workers that men from Mozambique were vital in filling (Clarence-Smith, 1985).[13] To keep wages low, the mining companies formed the monopsonistic Witwatersrand Native Labour Association (WNLA) to recruit workers on their behalf. The colonial state signed several agreements with this group beginning in 1897 to formalize labor recruitment in its territory. It derived revenues from all parts of this process: licensing fees from recruiters, payments from WNLA for each worker, and permit fees from each worker allowing them to work abroad. In addition, Portuguese officials in Johannesburg taxed wages paid on the Witwatersrand to Mozambicans (Newitt, 1995). These agreements also regulated miners' contracts and how they were paid. Contracts were limited to one year with a possible six-month extension and a mandated rest period of six months back in Mozambique. In 1928, the colonial state and the South African government established deferred payment for miners by which they would receive half of their wages only after returning home (Wilson, 1972).[14] The Portuguese had long argued for this provision because miners spent much of their wages on the Witwatersrand – often to buy status goods – rather than in Mozambique (Harries, 1994).

In return, the colonial state granted a monopoly on labor recruitment in its territory to WNLA, which also benefited from Portugal's 1899 colonial labor code. This law pushed men aged 14 to 60 into wage labor by subjecting them "to the moral and legal obligation to seek to acquire through employment the means to subsist and improve their social condition" or face forced labor (Ministério da Marinha e Ultramar, 1900, p. 647). To capitalize on its monopoly and the masses of men seeking paid employment, WNLA established a series of stations across southern Mozambique for recruiting workers as well as transportation infrastructure to move them from there to the Witwatersrand (see Figure 2a for this network in 1946). Figure 1b shows that the magnitude of this circular migration was substantial: except for the Great Depression, from 1920 to 1942, between 75,000 and 100,000 men annually arrived at the Witwatersrand mines

[12] Men could be absent from southern Mozambique for extended periods because "the role of the male in [these ethnic groups'] agricultural life was negligible" given that the savanna required little clearing and women could cultivate the loose soil (Rita-Ferreira, 1960, p. 144). Junod (1912) and Harris (1959) also noted this phenomenon and the labor mobility it had historically permitted men.

[13] Geologists estimate that one-third of all gold ever mined is from the Witwatersrand (Frimmel, 2019).

[14] In addition, the Transvaal government agreed to send up to one-half of its rail traffic through Lourenço Marques, helping Portugal realize its ambition for the city to become a major port (Clarence-Smith, 1985). Because these migrant labor and freight flows contributed heavily to the colonial state's finances, to better manage them it moved its capital from Mozambique Island to Lourenço Marques in 1902 (Newitt, 1995).

from the migrant-sending region. For context, its male population in the 1940 census was just under 565,000, around 325,000 of whom were aged 15 to 64.

2.2.2. *Migrant-Restricting Region*

In contrast, the Mozambique Company made its territory into a migrant-restricting region with the goal of creating a captive pool of low-wage workers. It issued regulations in 1900 requiring the population under its rule to engage in six months of paid labor each year, though administrators often conscripted workers on behalf of local employers offering wages too low or working conditions too harsh. Ten years later, the company formalized this forced labor system by establishing a department that could use violence to round up the workers that employers demanded (Guthrie, 2018). This bureaucracy conscripted tens of thousands of workers each year by using its police to reinforce the efforts of traditional authorities. According to correspondence between company administrators, it was common for them to tell chiefs "that on such and such a date they had to supply a certain number of men to go work; generally, ... because [some] cannot manage to organize the number of workers requested, one or more police go to help the chiefs who fell short" (as cited in Allina, 2012, p. 50).

Another method of ensuring compliance was to punish wives of men who tried to flee the forced labor system (Guthrie, 2018). The company also dissuaded many from attempting to engage in circular migration by impressing "workers returning from abroad ... into forced labor almost immediately, such that they ... could not go home for any length of time unless they were willing to [be conscripted]" (Allina, 2012, p. 58). The company abolished this forced labor bureaucracy in 1926 as a response to a League of Nations report on labor practices in Portuguese colonies, which noted that "the blacks here [in the migrant-restricting region] tell the planters that they are the slaves of the Mozambique Company" (Ross, 1925, p. 53). However, employers soon complained that they could not find enough workers without the forced labor system. To push men into returning to these jobs, in 1927 the company doubled the annual hut tax so they would have to find wage labor and mandated that males aged 15 and above carry a pass book containing their picture, work history, tax payments, and place of residence. Officials frequently conducted sweeps to check that men had their pass books and met the six-month work requirement, and noncompliance was punished with forced labor (Allina, 2012).

2.3. *Narrative Comparisons*

2.3.1. *Sending versus Restricting Regions in Southern Mozambique*

Given the rapacious extraction of wealth from African labor in both regions, Allina (2012, p. 94) contended that "the [migrant-sending region] was governed by the Portuguese colonial state no less exploitatively than [the migrant-restricting region was] by the company itself, and under the same labor code." Similarly, Harries (1994, p. 175) argued that "Portugal was the chief recipient of the profits of [circular migration, which] ... held back the development of southern Mozambique" during the colonial period. It is thus not immediately clear that private rule necessarily would have been worse for long-run economic outcomes than direct governance, in contrast to the experience of the Congo Free State (see Lowes and Montero, 2021*a*).[15]

Nonetheless, circular migration may have led to important differences between the two regions in marriage outcomes. Historians have closely linked the two, arguing that in Southern African societies with bride price customs, "one of the primary reasons that men took up migrant labor was to obtain the money necessary for paying bridewealth. ... Since most men intended to marry in their home areas, [it also] was critical in ... persuading them to return home" (Guthrie, 2018, p. 72). Both Junod (1912) and Fuller (1955) noted that young men worked in the mines once or twice prior to marriage, implying many stopped migrating after paying a bride price. As a result, "men were able to marry at a younger age" than would have been possible without the wages from engaging in circular migration, a phenomenon that was observed in other migrant-sending regions in Southern Africa (Harries, 1983, p. 327).[16] Given their higher wages, it also led to substantial bride price inflation, likely reducing the ability to marry for older men who were less capable of grueling mine labor (Harries, 1994). Thus, holding fixed the age at which women married, an important marriage market implication of circular migration would be that newly-matched partners were closer in age.

2.3.2. Government-Company Borders in Northern versus Southern Mozambique

In contrast to its approach in southern Mozambique, the colonial state did not pursue migrant-sending policies in its northern territory. While a detailed study of the history of these two regions is beyond the scope of this paper, a very brief summary of the detailed descriptions in Vail (1976) and Neil-Tomlinson (1977) is that forced labor and violence were also common in the Niassa Company's concession. As such, I view the border between these regions as something of counterfactual to the one in southern Mozambique. Put another way, if the differences between government and company rule explained the differences between the sending and restricting regions, they should also appear in northern Mozambique; if instead they were due to circular migration, they should not arise there as well.

[15] Though it was not available to the vast majority of African children in either region, one initial development-relevant contrast between them was in their provision of schooling. Specifically, Protestant missions established village schools in the migrant-sending region and there were some state-run rudimentary schools in densely populated areas, while Catholic missions established schools in the company's territory (Allina, 2012; Morier-Genoud, 2019). However, in 1930 the colonial state closed many of its village schools due to concern over foreign and Protestant influences on the African population. The decline was drastic: Helgesson (1994) noted that between 1929 and 1930, the number of Methodist village schools fell from 200 to six and their enrollment fell from over 5,400 to under 700.

[16] For example, in the context of Lesotho, "the slight decline in ages at marriage between the mid-1960s and mid-1970s coincided with a period of rapid growth in mine earnings that would have made it easier for men in their twenties to marry" (Timaeus and Graham, 1989, p. 376).

2.4. *After Migrant-Restricting Policies Ended*

Upon coming to power in 1932, the Portuguese autocrat Salazar decided to let the Mozambique Company's charter to expire a decade later, as he believed its concession eroded national sovereignty (Newitt, 1995). In the following year, the colonial state took possession of the former migrant-restricting region and undertook an administrative reorganization of the colony. The map in Figure 2b shows the erasure of the border between the regions as the provincial boundary was moved north to the Sabi River. Nonetheless, the extraction of wealth from labor continued across the colony through the 1964-74 War of Independence and the end of Portuguese rule in 1975 (Isaacman et al., 1980; Guthrie, 2016).

After gaining its independence, the country subsequently fell into turmoil. To destabilize the country's socialist regime, apartheid-era South Africa sharply cut the number of Mozambicans allowed to work on the Witwatersrand (see Figure 1b) and its security services aided the rebels in Mozambique's destructive 1977-92 civil war (Weinstein, 2006). The country became one of the world's poorest in this period, and shortly after stability returned, its HIV epidemic began to explode (Iliffe, 2006).[17] According to UNAIDS estimates, it took less than four years from the detection of its first case in 1986 for Mozambique's adult HIV rates to exceed 1 percent and another decade and a half to reach 10 percent. However, the epidemic soon stabilized and estimated adult prevalence has remained around 12 percent for over a decade.

3. Model

To organize the subsequent empirical analysis with the historical facts above in mind, I use this section to summarize the predictions of an overlapping generations model of the economy and marriage market that I develop in Appendix A and base closely on Tertilt (2005). There are two items of interest: the transition path after a subset of young men begins to receive high wages, and how the new balanced growth path (BGP) changes as this share of high-wage young men increases. I then map these predictions onto the southern Mozambican and Southern African contexts and discuss their implications for living standards, marriage and dating, and HIV prevalence today.

3.1. *Summary of Model Setup*

As I detail in Appendix A1, there are 2 generations of adults (young and old) and 2 sexes (male and female), though old women cannot reproduce. Both men and women value consumption but men also value the number of children – who are born at the end of a period and whose survival

[17] The HIV epidemics in Mozambique and Namibia—whose decades-long civil war ended in 1990—were in the exponential growth phase in the late 1990s while those in other Southern African countries had already matured. The implication is that Mozambique's and Namibia's began substantially later, likely because internal conflict limited mobility and thus the transmission of the virus (Iliffe, 2006).

into young adulthood in the next period is costly – because they will join their lineages. As in Tertilt (2005), a key assumption is that men do not care about when they have these children, so they choose the timing based on the tradeoff between fertility and consumption. Therefore, unless young men can afford high levels of both, they will marry and reproduce only when old to delay incurring the cost of children's survival.

To match the colonial African context, I assume that men work in both periods of life for an exogenous wage, analogous to forced labor laws benefiting European capital.[18] However, young women earn an endogenous wage from the domestic representative firm and save to consume when not working in old age. In each period, men and single women enter a frictionless marriage market with bride price and polygyny. It is important to note that marriage in this model is simply a method of producing legitimate offspring, so women marry when young. Upon doing so, they receive their bride price and pay a share of the cost of their children's survival.[19]

3.2. *Summary of Model Predictions*

The key assumption in solving for the baseline BGP in Appendix A2 is that old men earn weakly more than young men. As discussed above, it implies that all marriages are between old men and young women (i.e., are age-disparate). The other main prediction is that the number of young women that an old man marries equals the rate of population growth from the previous to the current period, so all marriages are polygynous.

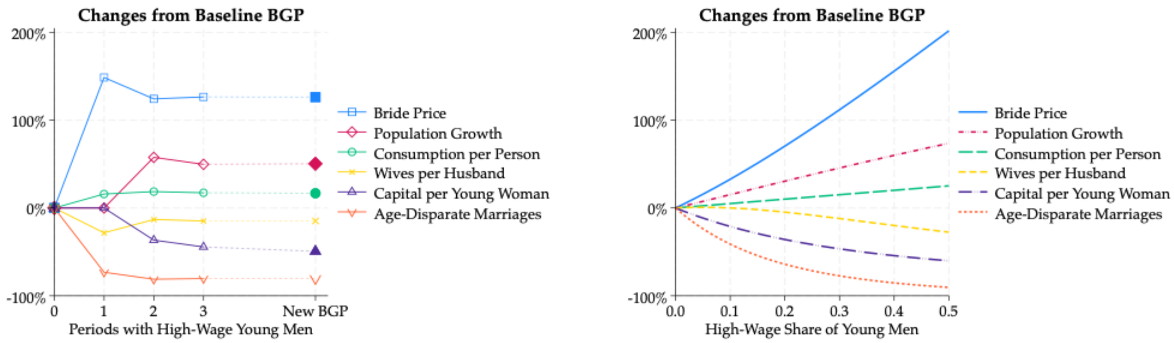
3.2.1. *Transition Path from Baseline to New BGP*

However, after a subset of young men earn begin to earn wages that are much higher than old men's, several important shifts occur, which Figure 3a presents as changes relative to the baseline BGP's values. I show in Appendix A3 that in the first period, high-wage young men enter the marriage market along with old men, causing the bride price to increase dramatically because the supply of young women was determined in the previous period. As a result, old men demand fewer wives, which sharply reduces the share of marriages that are age-disparate and lowers the number of wives per husband. Because of its high wages, consumption and fertility among this share of young men increase substantially, which has a larger relative impact on population growth into the next period than on average consumption across all individuals. The increase in fertility also substantively reduces next period's capital stock per young woman.

[18] Implicit in this assumption is that men do not save, which is important for keeping the model simple. Given the discussion of deferred pay laws in the previous section, it seems that men indeed failed to save much of the wages earned from European employers for a substantial portion of the colonial period.

[19] The assumption that women have property rights over themselves is a departure from Tertilt (2005) but is taken from an extension of an earlier version of the author's model (Tertilt, 2003). In addition to greatly simplifying the calculations, it does not change the qualitative predictions. However, it makes savings rates higher, as women can use their bride prices to pay for their children's survival and thus retain all of their labor incomes for consumption and saving.

Figure 3: Graphical Summary of Theoretical Predictions



(a) Transition from Baseline to New BGP **(b)** New BGP as High-Wage Share Varies

Notes: This figure presents predictions of the OLG model of the economy and marriage market summarized in the text and detailed in Appendix A. The model's parameters take the values listed in Appendix A6. The left graph shows changes over time relative to the baseline BGP after the wage structure shifts in Period 1 so that one-third of young men earn high wages. The smaller and hollow shapes denote values along the transition path, and the larger and solid shapes represent values on the baseline and new BGPs. The right graph shows the relative differences between the baseline and new BGP as the high-wage share of young men increases from zero to one-half.

I turn to the changes in subsequent periods along the transition path in Appendix A4. For a number of reasons, including last period's high-wage young men choosing not to reenter the marriage market in old age, the bride price, the share of age-disparate marriages, and population growth into the next period fall and remain below their levels set in the first period. However, the increase in brides' affordability raises the number of wives per husband, though it stays below the baseline-BGP value. In addition, rates of population growth above the baseline BGP's continue to dilute the capital stock, lowering young women's wages but raising the interest rate on old women's savings. Average consumption per person thus changes little after the first period.

3.2.2. New BGP as High-Wage Share of Young Men Varies

I examine in Appendix A5 the effect of changing the high-wage fraction of young men on outcomes of interest in the new BGP. Figure 3b shows these predictions. Clearly, higher shares strengthen the changes described above: there are greater increases in the bride price, population growth, and consumption per person, and there are greater decreases in the number of wives per husband, the capital stock per young woman, and the share of age-disparate marriages.

3.3. Implications for Outcomes of Interest

3.3.1. Southern Mozambique

To map these predictions onto the southern Mozambican context, I assume that the length of a generation is 30 years (Wang et al., 2023), Period 0 in the migrant-sending region corresponds to

1880, and Period 0 in the restricting region corresponds to 1940 (Period 2 in the sending region).[20] As such, if the model is taken literally, effective convergence in these regions' living standards – measured as consumption per person – should have occurred by 1970. In contrast, convergence in marriage market outcomes like the share of age-disparate marriages should have taken longer, not occurring until 2000.

However, it is important to note that the forces determining the model's transition path are entirely mechanical. If cultural factors, such as preferences for marriages emulating those of parents and grandparents, also played a role, it seems clear that convergence in marriage market outcomes would take longer but there would be little impact on the speed of convergence in living standards.[21] Indeed, Leclerc-Madlala points out when discussing marriage and dating in Southern Africa that age-disparate relationships and concurrent partnerships

> have antecedents in older practices that have long played a part in defining the nature of social life and the particular values and norms associated with sexuality. Many culturally inscribed assumptions and expectations that once legitimized these practices still prevail at present, and continue to influence the meanings that people attach to contemporary sexual relationships and the expectations that people have in relationships. (Leclerc-Madlala, 2008, pp. S22-S23)

But even if the model does not incorporate social norms, the mechanical transition path still yields clear predictions regarding HIV prevalence. One is that although circular migration promotes the virus's spread (Weine and Kashuba, 2012), convergence in rates of labor mobility (i.e., shares of high-wage young men) by 1970 would imply that this risk factor would have equalized across the former sending and restricting regions well before the first Mozambican case's detection in 1986 and the country's epidemic's explosion in the 1990s (Iliffe, 2006; Audet et al., 2010). In contrast, if the age-disparate share of marriages – another major HIV risk factor (de Oliveira et al., 2017; Schaefer et al., 2017) – remained lower in the former sending region until 2000, its effect would be to lower HIV prevalence there today.[22]

3.3.2. Southern Africa

Predictions for Southern African areas in which circular migration began at the same time but its intensity was different come from Figure 3b. Clearly, with greater labor mobility, higher-share

[20] Recall that gold was discovered on the Witwatersrand in 1886, sparking the massive demand for circular migrant labor from the sending region, and the border between it and the restricting region was erased in 1942.

[21] Specifically, suppose that there was an idiosyncratic utility penalty for deviating from the average age disparity and number of wives in the previous generation's marriages. In that case, the marriage-market changes that occur predominantly in Period 1 in Figure 3a would instead be spread out across subsequent periods, as progressively larger fractions of high-wage young men deviated from previous norms.

[22] The implications regarding polygyny are more ambiguous for two reasons. First, there is often a negative ecological association between polygyny and HIV (Reniers and Tfaily, 2008, 2012), and the number of lifetime sexual partners may matter more than whether they are concurrent or sequential (Tanser et al., 2011). Second, the number of wives per husband marrying in a period does not change monotonically.

regions should have higher living standards and fewer age-disparate relationships. In terms of HIV, assuming that circular migration dominates all other risk factors implies that such areas should have higher prevalence. However, the second-order effects from the marriage market prediction suggests that HIV prevalence should be lower than would be expected due to circular migration's direct effect. In other words, labor mobility's impact on marriage markets should suppress the migration-HIV link across Southern Africa.

4. Present-Day Effects

In this section, I test the present-day implications for southern Mozambique discussed above. Table 2 reports RD and randomization inference estimates for HIV and economic development outcomes, and Figure 5 presents graphical evidence on seroprevalence. Consistent with these predictions, HIV prevalence is indeed much lower just inside the former migrant-sending region and there are no substantive differences in measures of living standards today.

4.1. Data

I use georeferenced individual-level data from the 2009, 2011, 2015, and 2018 waves of the Demographic and Health Surveys (DHS) in Mozambique. Figure 4a shows the reported locations of the survey clusters within 150 km of the historical border. These locations are slightly displaced for respondents' anonymity and privacy.[23] As such, four urban clusters along the coast may have been displaced into the wrong region, so I remove them from the sample. Below, I discuss the implications for the analysis of not knowing the remaining clusters' exact locations.

As a complement to these data, I also use the IPUMS 10-percent sample of the 2007 Mozambican census, which groups respondents into third-level administrative units (administrative posts). Figure 4b shows those with centroids within 150 km of the former border. Because the number of observations is much greater but administrative posts do not respect the former border, using the census data addresses some issues with the DHS but suffers from others that it does not. I also discuss these considerations below.

4.2. Empirical Strategy

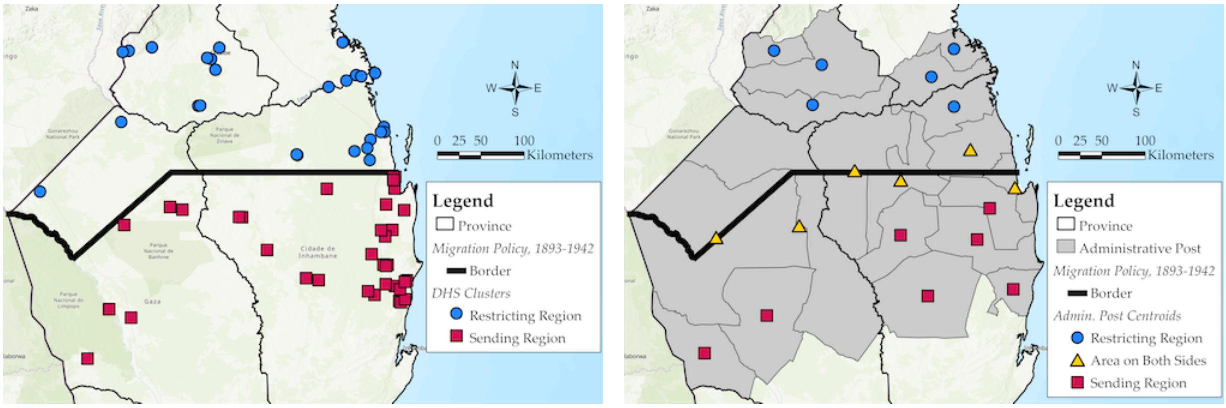
I use an RD design to compare the long-run impact of historical assignment to the migrant-sending region relative to the restricting region. The baseline estimating equation is

$$y_{i,u} = \alpha + \tau \text{MigrantSending}_u + f(\text{Distance}_u) + \text{Lon}_u + \mathbf{X}_i\beta + \delta_t + \epsilon_{i,u} \quad \text{for } u \in B^*_{\text{MSE}} \qquad (1)$$

where $y_{i,u}$ is an outcome for individual i in geographic unit u (i.e., DHS survey cluster or administrative post). The first three explanatory variables are MigrantSending_u, an indicator for

[23] Urban clusters are displaced by up to 2 km, 99 percent of rural clusters by up to 5 km, and 1 percent of rural clusters by up to 10 km.

Figure 4: Georeferenced Survey Units within 150 Kilometers of Historical Border



(a) DHS Clusters **(b)** Administrative Post Centroids

Notes: The left map shows the reported locations of survey clusters within 150 km of the historical border in the 2009, 2011, 2015, and 2018 DHS waves in Mozambique. The right map shows administrative posts (3rd-level administrative units) with centroids within 150 km of the historical border.

whether u (or its centroid) is in that region; $f(\text{Distance}_u)$, the RD polynomial controlling for smooth functions of distance to the historical border; and Lon_u, a unit's longitude coordinate, which is important to include in RD designs to capture east-west trends (Kelly, 2021).[24] I also include the vector $\mathbf{X}_i$ containing individual-level controls (age, age squared, and a female indicator) and the survey-year fixed effect δ_t.

The coefficient τ identifies the effect of historical assignment to the migrant-sending region instead of the restricting one. The motivating idea is that because the border between them was arbitrary, Portuguese colonial officials quasi-randomly allocated the territory around it to one of the two migration policies. In the main text, I estimate this effect using a local linear specification estimated separately on each side of the border with a triangular kernel (Gelman and Imbens, 2019). I define the set B^*_{MSE} containing the units in the sample using the Calonico, Cattaneo and Titiunik (2014) mean-squared error (MSE) optimal bandwidth. Because these lengths vary across outcomes, I also estimate results using a constant bandwidth of 125 km, which is approximately the average across all in the main text. For inference, I cluster standard errors by u and also use the wild cluster bootstrap to ensure the small number of units does not overstate the results' precision (Cameron, Gelbach and Miller, 2008). In addition, I calculate Conley standard errors allowing for arbitrary spatial correlation between observations within 100 km of each other using a Bartlett kernel (Conley, 1999; Colella et al., 2019).

To address the low density of clusters near the border, I complement the RD results with the Cattaneo, Frandsen and Titiunik (2015) randomization inference procedure, the motivation for which is precisely this scenario. Specifically, I permute the MigrantSending_u values of up to the 5 closest units on each side of the border for which balance on the share female cannot be

[24] Distance_u has a near-perfect correlation with latitude ($\rho > 0.99$), so it accounts for north-south trends.

rejected ($p \geq 0.15$), regress the outcome on the permuted treatment indicator, and calculate sharp p-values as the share of t-statistics that are greater in absolute value than the observed one. The basic estimating equation is

$$y_{i,u} = \alpha + \tau \text{MigrantSending}_u + \epsilon_{i,u} \quad \text{for } u \in B_{\text{RI}}, \tag{2}$$

where B_{RI} denotes the set of up to 5 units on each side.

4.2.1. *Biases in Estimation*

Because the displacement of DHS clusters mentioned above is random, it induces classical measurement error in the running variable. As such, it biases the RD coefficients toward zero. Additionally, in the census data, there are administrative posts that combine observations from both regions. Because the centroids of units entirely within one region are too far from the border to allow the calculation of MSE-optimal bandwidths on their own, I keep those with area on both sides in the sample. The likely result of their inclusion is a bias toward results of smaller magnitudes when using the census data, as combining treatment and control observations should mask their differences.

4.3. *Balance on Precolonial and Geographic Traits and Disease Suitability*

The assumption underlying the RD design is that all other relevant factors changed smoothly at the migration policy border. To help rule out discontinuities in precolonial characteristics, Appendix B2 shows that the border is entirely within one Murdock (1959) ethnic homeland. Additionally, the neighboring ethnicities are in the broader Shona-Thonga cultural group, suggesting that important behaviors and characteristics were not substantially different across neighboring ethnic homelands at the time that the border was created. To test whether aspects of the geographic and disease environments changed along the border, I divide Mozambique into 0.25×0.25 degree cells – approximately 25 km $\times$ 25 km in the study area (see Appendix B3) – and estimate a version of equation (1) without individual-level variables and clustering standard errors by administrative post. In addition, I modify the randomization inference procedure to include up to the 25 closest cells on each side of the border for which balance on longitude cannot be rejected ($p \geq 0.15$). Consistent with the border being arbitrary, Table 1 shows that changes in these variables just inside the migrant-sending region are small relative to restricting region means.[25]

[25] The one exception is the positive and significant coefficient for rainfall in Panel A Column (2). However, the estimates in Panels B and C and the RD plots in Appendix C1 show that the estimate is an artifact of very high values at the end of the RD bandwidth in the restricting region.

Table 1: Geographic Traits and Disease Suitability

	Geographic Traits				Disease Suitability	
	Elevation (1)	Rainfall (2)	Slope (3)	Soil Index (4)	Malaria (5)	TseTse (6)
Panel A. Optimal Bandwidth						
Sending Region	9.92	25.27	0.018	3.80	-0.212	0.001
	(29.81)	(10.59)	(0.084)	(6.14)	(0.349)	(0.007)
	[26.89]	[11.11]	[0.050]	[3.86]	[0.252]	[0.005]
Observations	248	206	192	151	151	133
Clusters	53	38	36	27	27	23
Bandwidth	208.6	176.7	161.2	121.4	120.2	96.9
Wild Cluster Bootstrap p-value	0.74	0.03	0.79	0.33	0.62	0.86
Restricting Region Mean	190.8	94.24	0.197	50.54	10.70	1.254
Restricting Region SD	153.0	99.81	0.158	15.29	2.18	0.082
Panel B. Constant Bandwidth						
Sending Region	-0.426	6.63	0.013	3.93	-0.230	-0.001
	(31.10)	(7.62)	(0.099)	(6.15)	(0.355)	(0.008)
	[22.03]	[6.42]	[0.054]	[3.89]	[0.260]	[0.006]
Observations	168	168	161	168	168	166
Clusters	29	29	28	29	29	28
Bandwidth	125	125	125	125	125	125
Wild Cluster Bootstrap p-value	0.99	0.43	0.86	0.29	0.57	0.95
Restricting Region Mean	172.7	72.11	0.180	51.36	10.83	1.260
Restricting Region SD	108.2	80.29	0.129	15.12	2.13	0.079
Panel C. Randomization Inference						
Sending Region	7.68	-9.44	0.035	-0.600	-0.242	-0.011
	{0.80}	{0.34}	{0.61}	{0.90}	{0.34}	{0.77}
Observations	50	50	46	50	50	48
Window	-42, 35	-42, 35	-42, 35	-42, 35	-42, 35	-42, 35
Restricting Region Mean	172.5	36.69	0.191	44.24	11.10	1.232
Restricting Region SD	108.2	80.29	0.129	15.12	2.13	0.079

Notes: Observations are 0.25×0.25 degree cells. In Panels A and B, standard errors clustered by administrative post are in parentheses and Conley standard errors using a 100-km bandwidth and a Bartlett kernel are in brackets. Regressions estimate a local linear RD specification on each side of the border using a triangular kernel and include longitude as a control. RD bandwidths in Panel A are MSE-optimal. In Panel C, sharp p-values are in curly braces, and the samples include up to the 25 closest cells on each side of the border for which balance on longitude cannot be rejected ($p \geq 0.15$). Means and standard deviations are calculated using observations within the RD bandwidth or randomization inference window. Outcomes are averages within a cell of elevation in meters (Danielson and Gesch, 2011), rainfall in mm (Schneider et al., 2020), slope in degrees (World Bank, 2020), an index of soil suitability for 16 food and energy crops from 1981 to 2010 (Zabel, Putzenlechner and Mauser, 2014), an index of malaria transmission stability Kiszewski et al. (2004), and an index of tsetse fly suitability (Alsan, 2015).

4.4. HIV Prevalence

I then turn to the main outcomes of interest in this paper. The first is the present-day spatial distribution of HIV among adults along the former migration policy border, measured as the

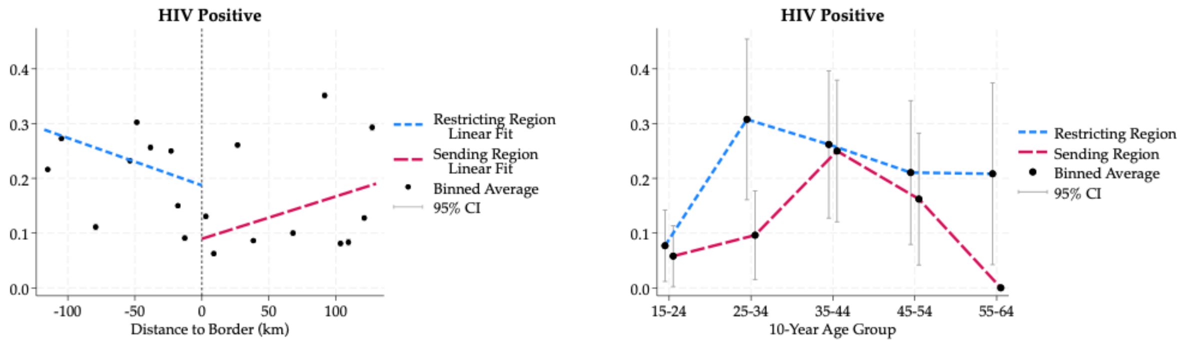
Table 2: HIV and Development Outcomes

	HIV Positive			Assets	Schooling	
	Pooled	Women	Men	Pooled	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Optimal Bandwidth						
Sending Region	-0.110	-0.097	-0.137	0.129	0.341	-0.078
	(0.045)	(0.053)	(0.089)	(0.158)	(0.273)	(0.580)
	[0.032]	[0.040]	[0.098]	[0.192]	[0.258]	[0.653]
Observations	918	610	224	2,102	1,264	1,039
Clusters	23	23	15	19	27	28
Bandwidth	139.7	136.0	99.5	48.8	91.2	96.5
Wild Cluster Bootstrap p-value	0.05	0.13	0.31	0.74	0.25	0.91
Restricting Region Mean	0.215	0.214	0.198	-0.351	2.49	3.23
Restricting Region SD				0.465	2.66	3.05
Panel B. Constant Bandwidth						
Sending Region	-0.103	-0.087	-0.126	-0.210	-0.003	-0.445
	(0.050)	(0.055)	(0.065)	(0.119)	(0.253)	(0.497)
	[0.037]	[0.042]	[0.063]	[0.117]	[0.249]	[0.533]
Observations	860	563	297	5,076	1,899	1,478
Clusters	21	21	21	45	40	40
Bandwidth	125	125	125	125	125	125
Wild Cluster Bootstrap p-value	0.07	0.16	0.17	0.13	1.00	0.49
Restricting Region Mean	0.215	0.214	0.217	-0.341	2.45	3.16
Restricting Region SD				0.576	2.60	2.94
Panel C. Randomization Inference						
Sending Region	-0.078	-0.067	-0.100	-0.069	-0.253	-0.366
	{0.03}	{0.19}	{0.13}	{0.04}	{0.29}	{0.18}
Observations	427	278	149	609	455	371
Clusters	10	10	10	6	10	10
Window	-38, 66	-38, 66	-38, 66	-21, 9	-28, 18	-28, 18
Restricting Region Mean	0.197	0.188	0.214	-0.402	2.30	3.04
Restricting Region SD				0.385	2.40	2.56

Notes: In Panels A and B, standard errors clustered by DHS survey cluster are in parentheses and Conley standard errors using a 100-km bandwidth and a Bartlett kernel are in brackets. Regressions estimate a local linear RD specification on each side of the border using a triangular weighting kernel and include age, age squared, a female indicator, longitude, and year fixed effects as controls. RD bandwidths in Panel A are MSE-optimal. In Panel C, sharp p-values are in curly braces, and the samples include up to the 5 closest clusters on each side of the border for which balance on the share female cannot be rejected ($p \geq 0.15$). Means and standard deviations are calculated using observations within the RD bandwidth or randomization inference window.

results of blood tests for the virus taken by a randomly selected subset of DHS respondents in 2009 and 2015. I focus on adults aged 15 to 64 because, given the historical treatment, my interest is in the effects on anyone who was ever sexually active, not just those who were at the time of

Figure 5: HIV Prevalence RD Plot and Age Profile within RI Window



(a) RD Plot **(b)** Prevalence in RI Window by Age

Notes: The left graph shows the average share of HIV-positive blood tests in each bin after adjusting for age, age squared, longitude, and fixed effects for sex and year. The running variable is a DHS survey cluster's distance to the historical border. The linear fits on each side are estimated using a triangular kernel and the RD bandwidth is MSE-optimal. The right graph shows HIV prevalence within the randomization inference window by 10-year age group on each side of the border. The graphs use the same y-axis scale to facilitate comparisons across them.

the survey. Table 2 Panel A Column (1) pools both sexes and shows that adult HIV prevalence drops 11 p.p. just inside the former sending region, and Figure 5a shows this discontinuity visually. This point estimate is large relative to 22 percent prevalence in the restricting region.[26] In addition, the wild cluster bootstrap p-value suggests that its statistical significance is not due to false precision. I also split the sample by sex in Columns (2) and (3) and find similar effects, but the low number of clusters for the male estimate make those standard errors artificially small.

The magnitudes and significance of the results are effectively unchanged when using the constant bandwidth in Panel B, though the additional clusters make the standard errors for men more accurate. In Panel C, the randomization inference estimates are slightly smaller in absolute and relative terms – a 7.8-p.p. decrease in HIV at the border, or 40 percent of the restricting region's mean – while having similar p-values. To complement these results, Figure 5b shows HIV prevalence within the randomization inference window by 10-year age group, each of which has lower rates in the former sending region. It is most apparent for ages 25 to 34, when HIV prevalence peaks in the former restricting region. As such, these age profiles are consistent with the HIV transmission cycle driven by age-disparate relationships (de Oliveira et al., 2017): prevalence should peak at a lower level and in an older group if partner age gaps (and thus transmission from high-prevalence men to young women) are lower. In the next section, I examine this and other potential channels and discuss whether they could generate the HIV effects above.

[26] However, note that prevalence is a stock, not a flow, and even small differences in transmission rates can lead to large differences in the size of an epidemic (e.g., Viboud, Simonsen and Chowell, 2016).

4.5. *Economic Development*

Next, I examine economic development along the border. The outcomes of interest are an asset ownership score (measured in 2009, 2011, 2015, and 2018) and years of schooling (2009, 2011, and 2015).[27] Table 2 Panel A Columns (4) through (6) present these results.[28] They show that the asset score and female schooling are slightly higher while male schooling is slightly lower just inside the former migrant-sending region, but these differences are mostly small and indistinguishable from zero. However, when using the wider constant bandwidth in Panel B, the first two results flip signs and the decrease at the border in the asset score approaches statistical significance. Taken alongside the smaller but significant negative point estimate in Panel C as well as the null schooling effects across the panels, these results provide little convincing evidence of discontinuous changes in living standards at the border today. Indeed, if anything, they weakly suggest that development outcomes are worse just inside the former migrant-sending region.

4.6. *Robustness and Credibility*

Given the low density of clusters along the border, I view randomization inference as the best robustness test for these results. Nonetheless, for the HIV results, I also show point estimates and confidence intervals for a range of bandwidths when using linear (Appendix C2) and quadratic RD polynomials (Appendix C3) and when varying the weighting kernel, polynomial, and bandwidth selection method (Appendix C4). The results are unstable when using shorter bandwidths due to the low number of clusters, but for the most part they converge to the results above.[29] I also collapse the data into cluster-level means and perform the same estimation in Appendix C5 and find similar patterns as when using the individual-level data. In addition, I vary the number of clusters that are included in the randomization inference window in Appendix C6. Generally, it takes about 5 survey clusters on each side for sharp p-values to approach or achieve statistical significance, though the estimates usually reach comparable magnitudes before that point.

To enhance the credibility of the results, I also conduct a series of placebo tests. In Appendix C7, I move the border 5 clusters into each region and switch the observed treatment status of those closest to the true cutoff. Especially for the pooled and male samples, the placebo effects for HIV are of smaller magnitudes and no sharp p-value reaches statistical significance, whereas those for development outcomes are mostly larger and sometimes have smaller sharp p-values than those in Table 2. And to help rule out that these results are driven by the effect of colonial concessions more generally rather than features unique to this border, in Appendix C8 I replicate

[27] The score is the first principal component of a principal component analysis of household assets.

[28] As these measures were recorded for almost all DHS respondents within a survey-year – not just a randomly selected subset – and in more survey-years, the numbers of observations are much greater and the bandwidths are generally much shorter than for the HIV results.

[29] The main exceptions are when using a quadratic RD polynomial and the coverage error rate optimal bandwidth: the former leads to very wide confidence intervals (especially below 100 km) and the latter leads to bandwidths around 100 km (only 15 clusters).

Table 2 for the Niassa Company border. Consistent with the latter interpretation, a very different pattern arises in these results, all but one of them are statistically insignificant (female schooling).

Lastly, I study whether respondent refusal to participate, differential HIV treatment, or choices of outcome can explain the results above. I examine in Appendix C9 if refusing blood tests (as in Lowes and Montero, 2021*b*) or detecting blood-based biomarkers for antiretroviral (ARV) drugs are more common on one side of the border. For both, there is no evidence of substantive differences, and refusal rates are negligible in the study area. I also use other sources of development-relevant data to test whether they yield the same null results as outcomes from the DHS. I find that it is indeed the case for nighttime lights and population density in Appendix C10 (see Appendix B4 for maps) as well as human capital and migration outcomes in Appendix C11 (literacy, having any schooling, and residing in one's district of birth).

5. Proximate Causes

I now examine what explains the decrease in HIV prevalence just inside the former sending region, focusing first on factors related to the history of southern Mozambique and the model discussed previously. Table 3 reports RD and randomization inference estimates for age-disparate relationships, Figure 6 presents the corresponding graphical evidence, and Table E7 contains the results of a mediation analysis. In brief, these partner age gaps are substantially smaller on the former migrant-sending side, and they mediate over one-fifth of the discontinuous change in HIV rates at the border.

5.1. *Age-Disparate Relationships*

To examine present-day age disparities between spouses and sexual partners, I again use the DHS and 2007 census datasets. The outcome of interest in the former is the age gap between a respondent of reproductive age (15 to 49) and their most recent sexual partner, measured as the man's age minus the woman's.[30] I winsorize this outcome at 90 percent due to extreme outliers at both ends of the distribution.[31] In the census data, I examine age gaps between women of any age and their husbands, which makes a closer link between the model and present-day outcomes but at the cost of a likely downward bias (see Section 4.2.1). For the same reason as above, I also winsorize this outcome at 90 percent.

Table 3 Panel A reports the results for age-disparate relationships using the MSE-optimal RD bandwidths. Columns (1) through (4) show a consistent 2-year decrease in these partner age gaps just inside the former sending region for all adults in the DHS data as well as only those who are married. These effect sizes are again quite large, ranging from one-fifth to two-fifths of the mean

[30] Ninety-six percent of women and 89 percent of men in the DHS reported their most recent sexual partner was a spouse or boyfriend/girlfriend, implying that respondents would know this person's age.

[31] This winsorization increases the precision of the RD estimate without changing its magnitude.

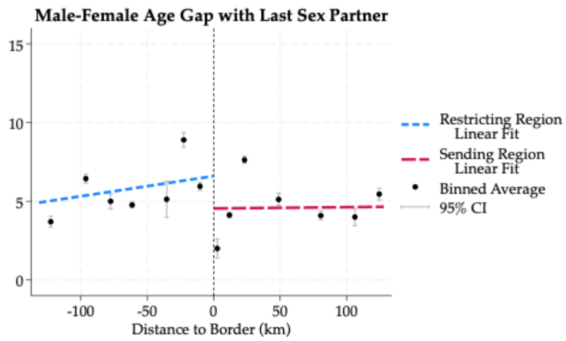
Table 3: Age-Disparate Relationships

Male-Female Age Gap with:	Last Sexual Partner				Spouse
	Women 15-49		Men 15-49		Women
	All	Married	All	Married	
	(1)	(2)	(3)	(4)	(5)
Panel A. Optimal Bandwidth					
Sending Region	-2.20	-1.84	-2.22	-2.23	-0.82
	(0.82)	(0.78)	(0.87)	(1.16)	(0.29)
	[0.63]	[0.71]	[0.96]	[1.41]	[0.22]
Observations	218	281	221	150	11,134
Clusters	14	22	41	35	18
Bandwidth	65.4	94.1	133.1	132.6	144.5
Wild Cluster Bootstrap p-value	0.12	0.05	0.10	0.21	0.05
Restricting Region Mean	7.34	6.91	5.58	7.02	8.36
Restricting Region SD	5.45	4.99	4.71	5.03	6.49
Panel B. Constant Bandwidth					
Sending Region	-1.39	-1.40	-2.25	-2.34	-0.76
	(0.72)	(0.82)	(0.92)	(1.22)	(0.30)
	[0.68]	[0.83]	[1.00]	[1.44]	[0.24]
Observations	480	391	208	144	7,361
Clusters	30	30	38	32	14
Bandwidth	125	125	125	125	125
Wild Cluster Bootstrap p-value	0.13	0.13	0.08	0.19	0.09
Restricting Region Mean	6.84	6.95	5.74	7.00	8.38
Restricting Region SD	5.00	5.03	4.69	4.95	6.59
Panel C. Randomization Inference					
Sending Region	-1.95	-1.93	-1.68	-1.71	-1.02
	{0.03}	{0.10}	{0.14}	{0.14}	{0.00}
Observations	120	104	85	86	5,245
Window	-28, 18	-28, 18	-28, 28	-46, 39	-77, 77
Restricting Region Mean	7.66	7.61	6.76	7.10	8.34
Restricting Region SD	5.60	5.86	5.00	5.39	6.71

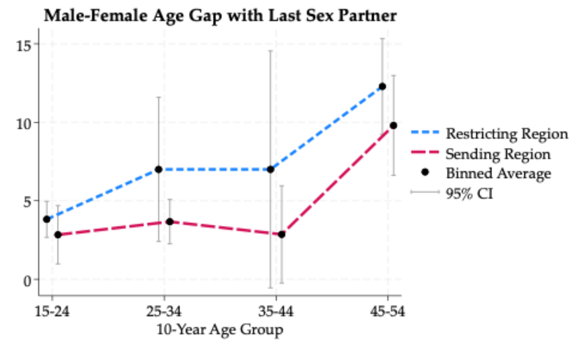
Notes: In Panels A and B, standard errors clustered by DHS survey cluster or administrative post are in parentheses and Conley standard errors using a 100-km bandwidth and a Bartlett kernel are in brackets. Regressions estimate a local linear RD specification on each side of the border using a triangular weighting kernel and include age, age squared, a female indicator, longitude, and year fixed effects as controls. RD bandwidths in Panel A are MSE-optimal. In Panel C, sharp p-values are in curly braces, and the samples include up to the 5 closest clusters or administrative posts on each side of the border for which balance on the share female cannot be rejected ($p \geq 0.15$). Means and standard deviations are calculated using observations within the RD bandwidth or randomization inference window.

in the former restricting region, and their statistical significance does not appear to result from a small number of clusters. As expected, the estimate when using the census data in Column (5) is smaller – 0.8 years, or 10 percent of the restricting region mean – but it remains distinguishable

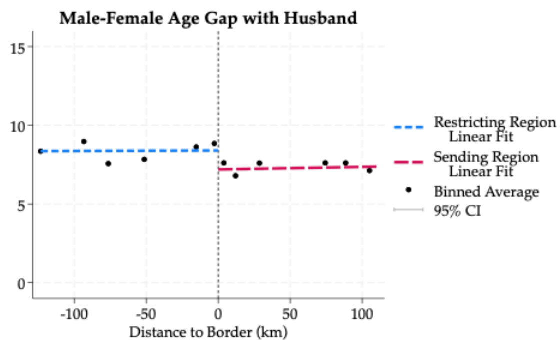
Figure 6: Partner Age Gap RD Plots and Age Profiles within RI Window



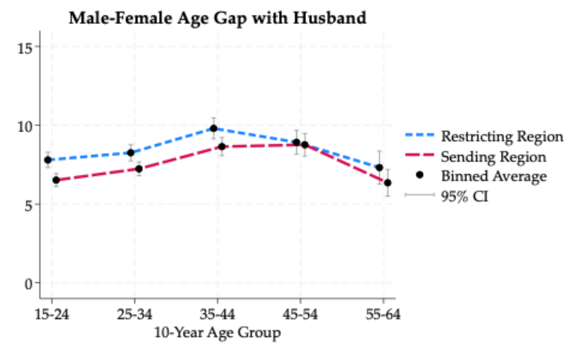
(a) RD Plot: Age Gap with Last Sexual Partner (Men)



(b) RI Window by Age: Age Gap with Last Sexual Partner (Men)



(c) RD Plot: Age Gap with Husband



(d) RI Window by Age: Age Gap with Husband

Notes: The left graphs show the average of the respective partner age gaps in each bin after adjusting for age, age squared, longitude, and year fixed effects. The running variable is a DHS survey cluster's or administrative post's distance to the historical border. The linear fits on each side are estimated using a triangular kernel and the RD bandwidth is MSE-optimal. The right graphs show the average partner age gap within the randomization inference window by 10-year age group on each side of the border. The graphs use the same y-axis scale to facilitate comparisons across them.

from zero. Figures 6a and 6c show the RD plots for corresponding to Columns (3) and (5).

When using the constant bandwidth in Panel B, the estimates for women in Columns (1) and (2) decrease but remain mostly precise while the other results remain unchanged. However, the results in Panel C using the 5 closest survey clusters or administrative posts on each side of the border are more in line with those in Panel A. Figures 6b and 6d show the age profiles of age gaps within the randomization inference windows among all men in the DHS (with last sexual partners) and married women in the census (with husbands). As with HIV, these major risk factors for the virus are much lower across the age distribution in the former sending region.

5.1.1. *Robustness and Credibility*

As in the previous section, I view the randomization inference results as the best robustness check because of the small number of clusters near the border. However, I also conduct the same robustness checks as before. For the RD estimates, I use a range of bandwidths with a linear (Appendix D1) and quadratic (Appendix D2) RD polynomial, vary the weighting kernel, polynomial, and bandwidth selection method (Appendix D3), and collapse the data into survey clusters or administrative posts (Appendix D4). Additionally, I vary the number of survey clusters or administrative posts within the randomization inference window (Appendix D5). While unstable and noisy with narrow bandwidths (50 to 100 km), the RD estimates are statistically significant with wider bandwidths and consistently negative regardless of length. For the randomization inference, the point estimates are also consistently negative but statistical significance is more common with 12 or fewer units in the window. Nevertheless, I take these results as broadly supporting the robustness of the estimates above. I also conduct the same placebo tests to enhance these results' credibility. In Appendix D6, I shift the true border 5 clusters or administrative posts in each direction and do not find similar results. I also replicate Table 3 along the Niassa Company's former border to rule out a general effect of colonial concessions on these outcomes. Once again, the same consistent patterns do not arise in Appendix D7.

5.2. Risk Factors Associated with Age-Disparate Relationships

While age gaps in relationships can be HIV risk factors on their own, they are also associated with behaviors that promote HIV transmission. These risks include male partners who are in concurrent relationships (possibly formalized through polygyny), an earlier sexual debut for women and girls, not using condoms, and having been forced to have sex, all of which relate to low bargaining power (UNAIDS, UNIFEM and UNFPA, 2004; Schaefer et al., 2017; Evans et al., 2019; Mabaso et al., 2021). In Appendix E1, I compare these outcomes among reproductive-age individuals in the DHS along the former border. In each case, the result suggests that women in the former migrant-sending region face fewer of these associated risks, though some of the magnitudes are quite small and no estimate is statistically significant. As such, age-disparate relationships' indirect effects seem less important than their direct impacts on HIV transmission.

5.3. Other Risk Factors Related to Southern Mozambican History

There are many other ways that the regions' histories might have affected HIV prevalence today. For example, although I did not find any accounts consistent with this hypothesis, it could be that the migrant-sending region has received more investment in its health infrastructure. I test this proposition in Appendix E2 using data from Maina et al. (2019) on the count of public health facilities in each gridcell around the border (see Appendix B5 for a map). However, I find no evidence to support it. Similarly, it is possible that landmines from or violence during the 1977-92 civil war (see Appendix B6 for maps) affected mobility, which can affect the spread of HIV (Iliffe, 2006; Oster, 2012). However, again consistent with the lack of narrative evidence suggesting a link between them and the former border, there are null results for landmines in

Appendix E3 as well as violent events and deaths in Appendices E4 and E5.

5.4. *Risk Factors Unrelated to Southern Mozambican History*

In addition, I examine other important HIV risk factors in Sub-Saharan Africa that, to my knowledge, are not credibly related to the histories of the sending and restricting regions. In particular, I draw from the literature on the virus' spread across the continent and create indicator variables in the DHS data for having a genital ulcer in the past 12 months (Chen et al., 2000), a man having ever paid for sex (Dunkle et al., 2004), and a man having been medically circumcised (Maffioli, 2017). The results in Appendix E6 show that none of these outcomes point in the direction of lower HIV prevalence in the former migrant-sending region. Indeed, the only statistically significant result is for genital ulcers, but it implies a greater likelihood of contracting the virus in this area. Therefore, it is unlikely that these factors contribute to the HIV results above.

5.5. *Quantifying Channels' Contributions*

I first take the simplest approach to assessing the extent to which the HIV effects above could arise from the discontinuity in age-disparate relationships. Specifically, I multiply the size of the change at the border in partner age gaps (1 to 2 years) by the cross-sectional estimate of how much an additional year of male-female age difference raises a young women's risk of contracting HIV in a Southern African country (7 to 10 p.p., according to Evans et al., 2019). With the caveat that the authors' estimates are likely larger than the true causal effects due to selection into such relationships, this back-of-the-envelope exercise implies a discontinuity in HIV rates of 7 to 20 p.p., suggesting a very important role in generating the estimates in Table 2.

A more rigorous approach is to use the mediation analysis framework developed by Imai, Keele and Tingley (2010). In brief, this approach decomposes the total effect of a treatment into its direct effect on the outcome and its effect via mediating variables such as the factors examined above. In the RD framework, the first estimating equation is

$$m_{i,u} = \alpha + \tau_1 \text{SendingRegion}_u + f(\text{Distance}_u) + \text{Lon}_u + \mathbf{X}_i\beta + \delta_t + \epsilon_{i,u} \quad \text{for } u \in B^*_{\text{MSE}}, \qquad (3)$$

where $m_{i,u}$ is the mediating variable and all else is as in equation (1), and the second equation is

$$y_{i,u} = \alpha + \tau_2 \text{SendingRegion}_u + \gamma m_{i,u} + f(\text{Distance}_u) + \text{Lon}_u + \mathbf{X}_i\beta + \delta_t + \epsilon_{i,u} \quad \text{for } u \in B^*_{\text{MSE}}. \quad (4)$$

Substituting equation (3) into equation (4) shows that the total effect on the outcome of being just inside the former migrant-sending region is $\tau_2 + \gamma\tau_1$, or the sum of the direct impact (τ_2) and that which arises through the mediating variable ($\gamma\tau_1$). I calculate these point estimates and the share of the effect mediated by a variable as well as bootstrapped 90-percent confidence intervals.

In Appendix E7, I examine the contributions of 5 mediating variables for all adults: the asset ownership score, years of schooling, age gap with last sexual partner, having had multiple sexual partners, and having used a condom at last sex.[32] Specifically, I use the MSE-optimal bandwidth for equation (4) using observations with non-missing values of the mediating variable of interest (Panel A), the constant bandwidth (Panel B), and the optimal bandwidth using observations with non-missing values of all mediators (Panel C). Across these specifications, the only consistent finding is that partner age gaps contribute 3.2 to 3.3 p.p. (20 to 22 percent) to the HIV discontinuity. Additionally, in Appendices E8 and E9 I show the constant magnitudes of the age disparity results in Panels A and C across a range of RD bandwidths.

6. Historical Channels

Next, I compare the sending and restricting regions during the colonial era with a particular focus on the outcomes discussed in Section 3. Table 4 reports RD and randomization inference estimates using district-level data from the 1940 and 1960 censuses of colonial Mozambique, and Figure 8 presents selected RD plots. The main result is that, as predicted by the model, marriage market outcomes remained substantively different along the border between these regions even two decades after it had been erased. An important implication is that the present-day discontinuity in age-disparate relationships appears to have its roots in the colonial period.

6.1. Data

I digitized district-level summaries of the 1940 and 1960 censuses of colonial Mozambique (Repartição Nacional de Estatística, 1942; Direcção Provincial dos Serviços de Estatística, 1966) and used administrative maps from around these years (Saldanha, 1940; Ministério do Ultramar, 1959) to georeference them. Figures 7a and 7b show maps of these districts in 1940 and 1960 and highlight their centroids. I restrict my focus to the provinces immediately adjacent to the border and exclude their capital cities or the districts containing them.

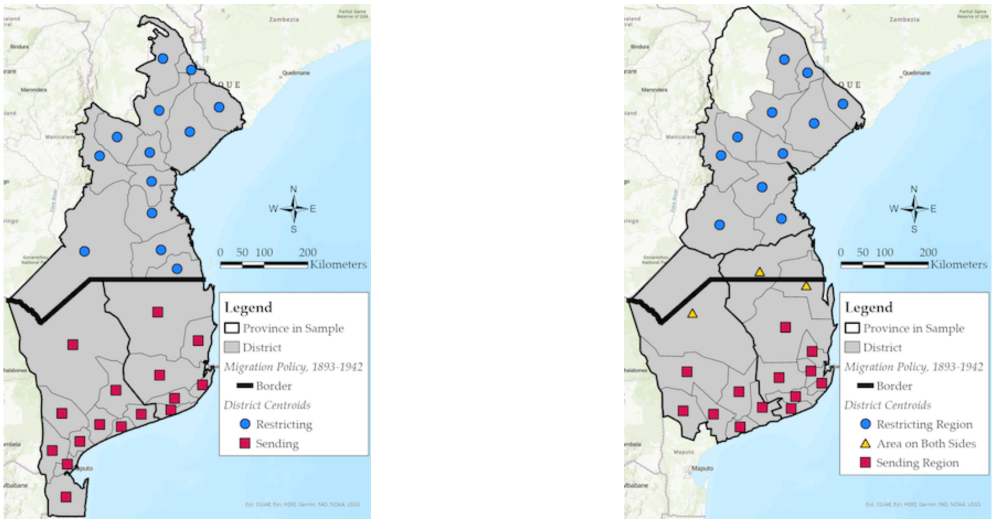
Data from the 1940 census are the best available regarding the populations living in the sending and restricting regions while the border between them still existed, as it was the first in the colony's history that met basic standards for accuracy (Darch, 1983; Harrison, 1998; Havik, 2013). Nonetheless, the preface to the published summaries notes that insufficient funding and inadequate staffing impacted the data collection process, although there is no mention of the effects being more severe in one region. To address concerns regarding poor coverage in some districts, I exclude those that appear to be extreme outliers (i.e., have values highly distinct from neighboring districts in the same region), likely due to systematic issues with data collection.[33]

In a similar vein, the 1960 data allow for the most reliable and longest-run comparison of the two regions during the colonial period. This census took place 18 years after the Mozambique

[32] Respondents must be in the random subset that took HIV blood tests, making sample sizes smaller.

[33] For transparency, the appendices contain RD plots showing each district (rather than binned averages) and highlighting any excluded outliers.

Figure 7: Historical Districts in Southern Mozambique



(a) 1940 **(b)** 1960

Notes: The maps show districts in each region from the respective years that are included in the sample. The shapes denote centroids for districts in the restricting region (blue circles), sending region (red squares), and with area on both sides of the former border in 1960 (yellow triangles).

Company's charter ended and it was the last one before the Mozambican War of Independence (1964-74). It thus should not suffer from the kinds of problems that can arise when governments attempt to collect data while participating in internal conflicts (e.g., Barakat et al., 2002). Nonetheless, I take the same approach to extreme outliers as with the 1940 data given the continued potential for inadequate coverage two decades later. Another concern is that, as with administrative posts in 2007 (see Section 4.1), the 1960 district boundaries did not respect the former border between the regions. Therefore, for the three with area on both sides in 1960 – the only ones whose centroids were within 100 km of the border – I assign them to the institution containing their centroids and discuss the effects on the estimation below.

6.2. *Empirical Strategy*

To examine historical differences between the regions, I estimate the RD specification

$$y_d = \alpha + \tau \text{MigrantSending}_d + f(\text{Distance}_d) + \text{Lon}_d + \epsilon_d \quad \text{for } d \in B, \tag{5}$$

where observations are at the level of district d and are weighted by population, the set B is defined by the sample restrictions above – as there are too few centroids near the border to estimate MSE-optimal bandwidths – and all else is as in equation (1). To address the shortcomings of this approach, I again complement the RD results with the randomization inference procedure that estimates the equation

$$y_d = \alpha + \tau \text{MigrantSending}_d + \epsilon_d \quad \text{for } d \in B_{\text{RI}}, \tag{6}$$

where B_{RI} uses up to the 5 closest districts on each side of the border for which balance on longitude cannot be rejected ($p \geq 0.15$). Additionally, as mentioned above, the 3 closest districts to the former border in 1960 have area on both sides of it; to the extent that they combine characteristics of each region, their effect is to mask differences between the two and thus bias point estimates toward zero.[34]

6.3. *Differences between Regions while Border Existed (1940)*

6.3.1. *Men's Circular Migration and Women's Agricultural Labor*

I first test whether men's circular migration rates were in fact different while the border between the regions existed. The outcome of interest is the share of males aged 15 to 64 ("prime-aged men") who were circular migrants, which I define as those listed in the census as working abroad. Table 4 Panel A Column (1) shows that this measure increased by 20 p.p. just inside the migrant-sending region in 1940. This estimate is precise and over four times greater than the circular migration rate in the restricting region. Additionally, the randomization inference estimate in Panel B is of a similar magnitude, highly significant, and just under twice as large the restricting-region mean within this narrower window.

Figure 8a shows this discontinuity visually. To verify that young men were the primary drivers of this effect, in Appendix F1 I present RD plots by 10-year age group. As expected, rates declined monotonically with age: while over one-third of men aged 15 to 34 and one quarter of those aged 35 to 44 engaged in circular migration, only 10 percent of men aged 45 to 54 and almost no men aged 55 to 64 did so. As such, these data are consistent with historical accounts and a key assumption of the model in Section 3.

I then examine how men's absences may have affected women's labor. The outcome of interest is the share of prime-aged women who worked "on the land," which most likely corresponded to subsistence agriculture. In Panels A and B, the estimates in Column (2) are negligible in absolute terms and especially so when compared to the near-universal share of women in the restricting region who were in this occupational category. Indeed, as the narrative evidence reference in Section 2 suggested, it may have been women's historical responsibility for food production that enabled men's circular migration in the first place.

6.3.2. *Marriage and Fertility*

Next, I compare marriage market outcomes along the border, focusing on ages 15 to 34 because men in this range were most heavily involved in circular migration. Specifically, I calculate the share of men and women in this age group who were ever married. While the estimates for men in Column (3) are large and statistically significant in Panels A (23 p.p., or 40 percent of the restricting-region mean) and B (14 p.p., or 24 percent), the analogous estimates for women

[34] I also highlight these districts in the RD plots in the appendices so their influence is clear.

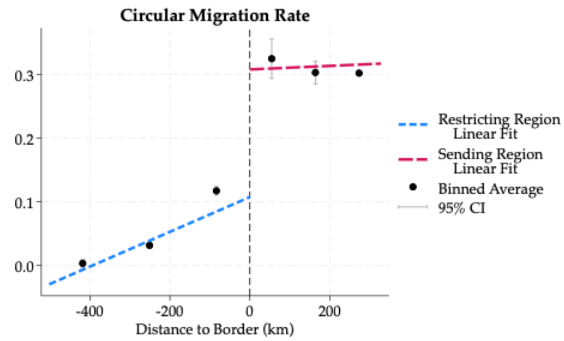
Table 4: Historical Differences between Regions

	Men Migrants (1)	Women Farming (2)	Men Married (3)	Women Married (4)	Children per Woman (5)	Boys in School (6)	Girls in School (7)
Panel A. 1940: RD Estimates Using All Districts in Sample							
Sending Region	0.200	0.016	0.234	0.039	0.157	-0.035	-0.004
	(0.090)	(0.018)	(0.067)	(0.032)	(0.082)	(0.016)	(0.006)
	[0.087]	[0.016]	[0.073]	[0.038]	[0.074]	[0.014]	[0.005]
Observations	28	28	27	27	27	28	28
Bandwidth	-503, 329	-503, 329	-503, 329	-503, 329	-503, 329	-503, 329	-503, 329
Restricting Region Mean	0.047	0.958	0.583	0.846	0.848	0.050	0.006
Restricting Region SD					0.144		
Panel B. 1940: Randomization Inference							
Sending Region	0.195	-0.008	0.138	0.004	0.182	-0.014	0.009
	{0.01}	{0.55}	{0.11}	{0.94}	{0.13}	{0.55}	{0.71}
Observations	10	10	10	10	10	10	10
Bandwidth	-223, 218	-223, 218	-223, 218	-223, 218	-223, 218	-223, 218	-223, 218
Restricting Region Mean	0.117	0.960	0.574	0.891	0.757	0.038	0.002
Restricting Region SD					0.093		
Panel C. 1960: RD Estimates Using All Districts in Sample							
Sending Region	-0.025	0.006	0.138	0.042	-0.058	-0.014	-0.034
	(0.049)	(0.004)	(0.043)	(0.070)	(0.085)	(0.033)	(0.026)
	[0.050]	[0.004]	[0.043]	[0.065]	[0.076]	[0.029]	[0.025]
Observations	27	28	27	27	27	28	27
Bandwidth	-500, 294	-500, 294	-500, 294	-500, 294	-500, 294	-500, 294	-500, 294
Restricting Region Mean	0.163	0.997	0.374	0.678	0.820	0.089	0.041
Restricting Region SD					0.121		
Panel D. 1960: Randomization Inference							
Sending Region	-0.061	-0.000	0.161	0.094	-0.080	0.022	0.017
	{0.33}	{1.00}	{0.04}	{0.12}	{0.28}	{0.79}	{0.74}
Observations	10	10	10	10	10	10	10
Bandwidth	-282, 163	-282, 163	-282, 163	-282, 163	-282, 163	-282, 163	-282, 163
Restricting Region Mean	0.238	0.995	0.358	0.713	0.827	0.085	0.055
Restricting Region SD					0.108		

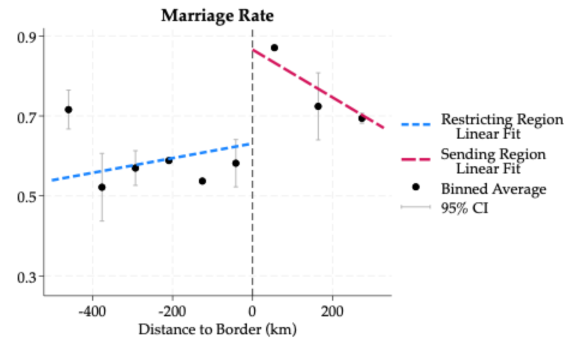
Notes: Observations are districts. In Panels A and C, robust standard errors are in parentheses and Conley standard errors using a 100-km bandwidth and a Bartlett kernel are in brackets. Regressions estimate a local linear RD specification on each side of the border using a triangular kernel and include longitude as a control. The left (negative) and right (positive) ends of the RD bandwidth used in each regression are in kilometers. In Panels B and D, sharp p-values are in curly braces, and the samples include up to the 5 closest districts on each side of the border for which balance on longitude cannot be rejected ($p \geq 0.15$). Means and standard deviations are calculated using observations within the RD bandwidth or randomization inference window.

in Column (4) are very much not. These results suggest that circular migration in fact enabled young men to marry, and under the assumption of women only marrying men of equal or

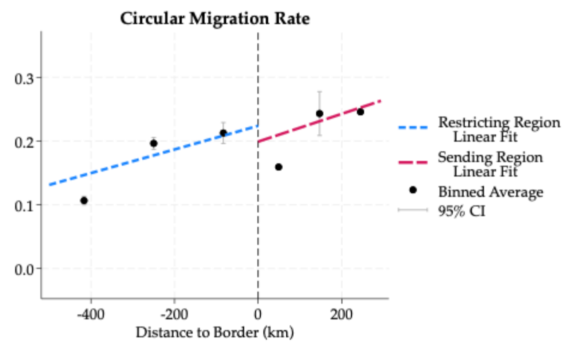
Figure 8: RD Plots for Historical Differences between Regions



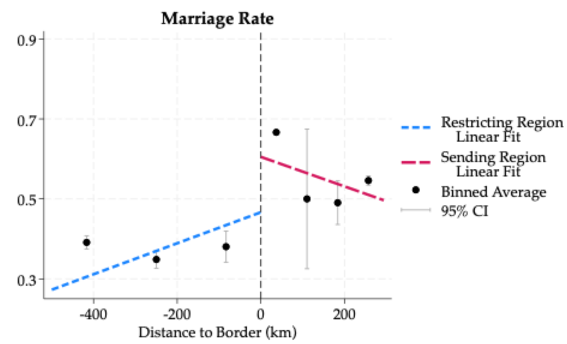
(a) Circular Migration in 1940: Men 15-64



(b) Marriage in 1940: Men 15-34



(c) Circular Migration in 1960: Men 15-64



(d) Marriage in 1960: Men 15-34

Notes: The graphs show the average of the respective outcomes in each bin after adjusting for longitude. The running variable is a district's distance to the historical border and the linear fits on each side are estimated using a triangular kernel.

greater age, that the marriage market absorbed these additional young men by matching more similarly-aged couples and reducing the rate of polygyny. While these implications cannot be tested directly, they are in line with the predictions in Section 3.

Figure 8b presents the RD plot for men's marriage rates. As with the migration results, in Appendix F2 I test whether young men drove this effect by splitting the data into the ages most involved in circular migration (15 to 34) and those less so (aged 35 to 54). Once again, the discontinuity is only visible among younger men. However, the lack of a difference at the border among older men is due in part to ceiling effects, as marriage was almost universal by these ages.

I also examine the ratio of children aged 0 to 4 to women aged 15 to 44, which is the only available measure of fertility in the colonial censuses. The estimates in Column (5) are again of large and statistically significant increases at the border: 0.16 additional children per woman (19 percent of the restricting-region mean) in Panel A and 0.18 (24 percent) in Panel B. As with marriage, these results are in line with the model's prediction of greater population growth in the sending region before the border with the restricting region was erased.

6.3.3. Boys' and Girls' Schooling

Finally, I examine the rates at which children aged 5 to 14 were listed in the census as being enrolled in school at the time of enumeration. For boys, Panel A Column (6) shows a precisely estimated 3.5-p.p. decrease (70 percent of the restricting-region mean) just inside the migrant-sending region. However, the randomization inference estimate in Panel B is smaller and statistically insignificant (a decrease of 1.4 p.p., or 37 percent). For girls, there are null effects in Column (7) of Panels A and B, which is not surprising given rates of enrollment well below 1 percent. However, as noted in Section 2, an important caveat when interpreting these effects is that the provision of education differed between these regions through 1942, so these mostly negative but insignificant estimates should be attributed to the combination of supply- and demand-side factors. But taken alongside the results above, this picture of colonial southern Mozambique is consistent with the gains from circular migration being used for marriage and fertility rather than investment in children's human capital (i.e., quantity over quality).

6.4. Differences between Regions after Border Erased (1960)

I then turn to comparing the 1940 results to those from 1960, nearly two decades after the border between the regions had been erased. The first major difference is that in both Panels C and D, the circular migration estimates in Column (1) have become small and insignificant.[35] Figure 8c shows that this change was due to rates having risen sharply in the former restricting region after men's labor mobility was permitted. But despite this convergence in migration, the estimates for men's marriage in Column (3) remained large and distinguishable from zero in 1960. Figure 8d shows this continued discontinuity visually, and in Appendix F2 I verify that it still arose from more young men (aged 15 to 34) marrying in the former sending region. This combination of migration and marriage results is once again consistent with the predictions in Section 3. The same is true for the other notable difference between the 1940 and 1960 results: namely, that the signs of the estimates in Column (5) change in Panels C and D. While they are no longer statistically significant, the higher rates of fertility just inside the former restricting region are in line with the large predicted increase in population growth after the first generation in which circular migration became possible.

6.5. Robustness and Credibility

For transparency regarding the exclusion of certain observations, Appendix F3 contains 1940 RD plots showing individual districts rather than binned averages and highlighting those near the border that I considered extreme outliers. While these choices are subjective, I view these

[35] The 1960 census summary tables grouped circular migrants into a category with all men who worked in a mine, regardless of location. However, given the small number of mines in southern Mozambique, I consider it an effective measure of working on the Witwatersrand (i.e., circular migration).

districts as having values substantively different from its immediate neighbors in the same region, plausibly arising from issues with data collection in the colonial period (see Section 6.1). I do the same for the 1960 results in Appendix F4 and also highlight districts with area on both sides of the former border. To test the robustness of the results above, I focus on the randomization inference estimates given the wide RD bandwidths and very few districts near the border. In Appendices F5 and F6, I show the main results in 1940 and 1960 over a range of windows. For those that are distinguishable from zero in Table 4, the estimated magnitudes remain consistent across window sizes but statistical significance becomes more common once they contain 4 districts on each side of the border. In Appendices F7 and F8, I also examine the credibility of these results by moving the border 5 districts into each region. With the exception of men's circular migration rates, which varied with distance from South Africa, no pattern above is apparent or statistically significant in these tests. I also rule out differential missionary investments in Appendix B7.

7. Effects across Southern Africa

Although the RD setup provides internal validity in estimating the causal effects of greater historical exposure to circular migration, it is not immediately clear that the findings above should generalize beyond the area around the former border. Indeed, at first glance, migration's well-established links to better development outcomes (e.g., Dinkelman, Kumchulesi and Mariotti, 2024) and higher HIV prevalence (e.g., Weine and Kashuba, 2012) across Sub-Saharan Africa appear to cast doubt on any claims of external validity. However, there are important differences between the histories of circular migration in southern Mozambique and Southern Africa that lead the model to generate distinct predictions for these two contexts. As discussed in Section 3.3, the former corresponds to adjacent regions having migration rates of the same magnitude that started in different periods, while the latter maps onto them having rates of different magnitudes that started in the same period. I now examine whether the expected effects on Southern Africa are visible in correlations within migrant-sending areas across the region, which would provide suggestive evidence that the relationships studied in this paper generalize more broadly.

7.1. Data and Empirical Strategy

I use georeferenced DHS data from the five Southern African countries most heavily exposed to WNLA mine labor recruitment in Figure 1: Eswatini (2006), Lesotho (2004, 2009, 2014), Malawi (2004, 2010, 2012, 2015), Mozambique (2009, 2011, 2015), and South Africa (2016). Appendix B8 shows a map of survey clusters in these countries within 25 km of a historical recruitment post. Because Malawi had a much shorter experience with young men's circular migration to the Witwatersrand gold mines (see the discussion in Dinkelman and Mariotti, 2016), I consider it separately from the other four countries as a form of placebo test. In other words, I expect any relationships present to be much weaker in Malawi.

The key assumption in the analysis that follows is that within an area around a historical recruitment post, greater distance from it implies greater costs to engage in circular migration. I thus use this distance as a proxy for migration rates and estimate

$$y_{i,c,t} = \tau \text{Distance}_c + \mathbf{X}_i \beta + \alpha_{u(c)} \times \mathbf{Z}_c + \gamma_{p(c)} + \delta_t + \epsilon_{i,c,t} \quad \text{for Distance}_c < 25 \text{ km}, \tag{7}$$

where $y_{i,c,t}$ is the outcome of interest for individual i in survey cluster c observed in year t, Distance$_c$ is c's distance from the nearest recruitment post $p(c)$, $\mathbf{X}_i$ is a vector of individual-level characteristics (age, age squared, female indicator), $\alpha_{u(c)}$ is a fixed effect for c's first-level administrative unit $u(c)$ interacted with a vector of c's characteristics (urban indicator, elevation, quadratic polynomial in latitude and longitude), and $\gamma_{p(c)}$ and δ_t are fixed effects for $p(c)$ and t. I restrict the sample to clusters within 25 km of a recruitment post. The coefficient of interest is τ, which measures the association of an additional kilometer of distance from a post with the outcome examined. Importantly, comparisons are made only between observations within a 25-km area around a recruitment post and after accounting for a rich set of geographic characteristics within each state or province. For inference, I cluster standard errors by DHS survey cluster.

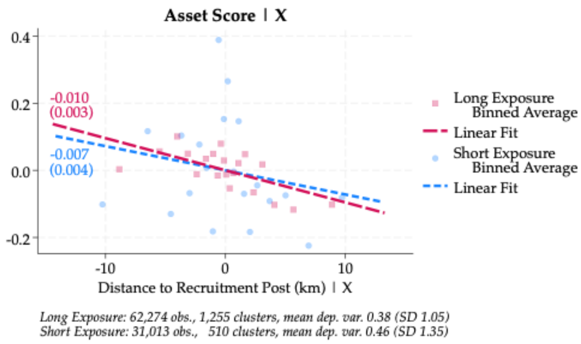
7.2. Asset Ownership and Age-Disparate Relationships

The first outcome of interest is the asset ownership score. Figure 9a shows an added-variable plot of its partial relationship with distance to a recruitment post. While both groups have precisely estimated relationships, as expected it is weaker for Malawi. From the post to the edge of its 25-km catchment in long-exposure countries, the asset score decreases by 0.25 (two-thirds of the mean, or nearly a quarter of a standard deviation), whereas in the short-exposure country it only decreases by 0.18 (38 percent of the mean, or 0.13 standard deviations). Next, I examine the male-female age gap between respondents and their last sexual partners, and Figure 9b presents this added-variable plot. Once again, the estimated magnitude is larger for long-exposure countries: over the 25 km, partner age gaps in this group increase by a precisely estimated 0.68 years (13 percent of the mean, or 0.14 standard deviations), but in Malawi, they only increase by an imprecise 0.40 years (7 percent of the mean, or 0.08 standard deviations).

7.3. Suppression of HIV-Migration Link by Age-Disparate Relationships

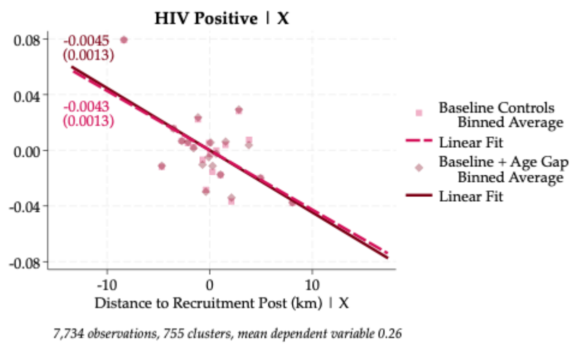
I then turn to the results of HIV blood tests. In addition to estimating equation (7) with the baseline set of controls listed above, I also estimate a specification in which I add the partner age gap as a control. My aim is to study how its inclusion changes the distance-HIV partial relationship. Figure 9c presents the added-variable plot for the long-exposure countries showing both estimates. With only the baseline controls, HIV prevalence decreases by a precisely estimated 10.8 p.p. (41 percent of the mean) across the 25 km. However, when controlling for partner age gaps, the magnitude increases to 11.3 p.p. (43 percent of the mean). The implication is that while the direct effect of migration strongly increases HIV prevalence, its magnitude is 0.5 p.p. (5 percent)

Figure 9: Effects of Circular Migration across Southern Africa

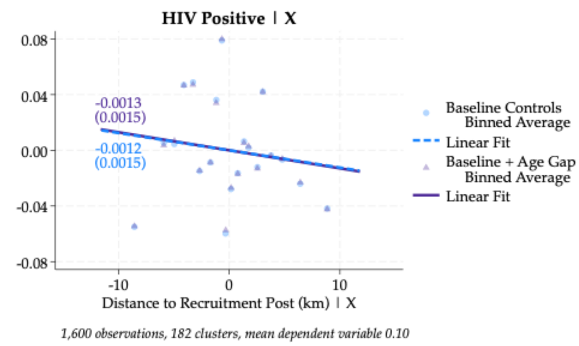


(a) Asset Index

(b) Age Gap with Last Sexual Partner (Pooled)



(c) Long-Exposure Countries: HIV (Pooled)



(d) Short-Exposure Country: HIV (Pooled)

Notes: The top graphs are added-variable plots showing the partial effect of distance to a post on the outcome of interest, estimated separately for short- and long-exposure countries. Coefficients are displayed next to the regression lines with standard errors clustered by DHS cluster in parentheses. Regressions control for age, age squared, female sex, fixed effects for year and closest recruitment post, and state- or province-specific effects of urban status, elevation, and a quadratic polynomial in latitude and longitude. The bottom graphs are added-variable plots showing the partial effects of distance to a mine labor recruitment post in a group of countries on HIV prevalence before (dashed lines) and after (solid lines) adding male-female age gaps with last sexual partners to the controls above. In all graphs, bin widths are set by ventiles of the residualized distance variable for each group within a graph.

less than it would have been without its marriage market effects. A similar but smaller pattern arises in the added-variable plot for Malawi in Figure 9d – decreases of 3.0 p.p. versus 3.3 p.p. (30 percent of the mean versus 33 percent), or a 0.3-p.p. (8-percent) suppression – but the effects are not distinguishable from zero.

7.4. *Robustness*

To test the robustness of these associations, I vary the radii of the catchments around recruitment posts and also log-transform the distance measure. I show in Appendix G1 that the estimated slopes of the regression lines for the asset score and partner age gaps remain almost universally larger in magnitude in the long-exposure countries than in Malawi across these specifications.

Additionally, in Appendix G2, I show that partner age gaps continue to suppress the migration-HIV relationship in both long- and short-exposure countries irrespective of the radius length and whether distance is in levels or logs.

8. Conclusion

In this paper, I study the very long-run effects of circular migration in Africa on regions of origin. Using predictions derived from an overlapping generations model of the economy and marriage market that experiences a shock to young men's wages, I examine wealth and health outcomes along a former arbitrary border within Mozambique that separated a migrant-sending region from one in which mobility was heavily restricted for a half-century. Consistent with the model, I find no changes in development outcomes along the border but large decreases in HIV prevalence just inside the former sending region. Examining proximate causes, I find strong evidence for the predicted channel: partner age gaps, which are a major HIV risk factor in Sub-Saharan Africa, decrease substantially on this side of the former border. Looking in the colonial period, I show that these marriage market differences have their roots in the histories of these regions. Lastly, I find correlational evidence from across Southern Africa of the relationships predicted by the model, which is suggestive of their external validity.

As such, these results highlight a novel channel through which circular migration affects a range of outcomes across time, which is important to understand as this phenomenon becomes even more widespread due to transportation costs that are falling across the world. In particular, they show how historical labor market shocks can reverberate into the present day through their effects on marriage markets, especially the non-Western ones with asset transfers that determine how most of the world marries. These findings also shed light on circular migration's role in shaping one of the modern world's deadliest pandemics in the region that has been the hardest hit. In this sense, they also contribute to our understanding of disparities in the spatial distribution of HIV and our knowledge of history as a fundamental determinant of health.

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Online Appendix for:

Circular Migration, Marriage Markets, and HIV: Long-Run Evidence from Mozambique

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Contents

Appendix A. OLG Model of the Economy and Marriage Market

A1. Model Setup

The model takes place over infinite discrete time. Individuals are either male (M) or female (F) and the sex ratio at birth is 1. After they are born, surviving childhood depends on their parents' choices, which I discuss below. If they do, they live for two periods, young and old ($A \in \{Y, O\}$). Men are fecund for both periods while women can only reproduce when young. The discount factor is $\beta \in (0, 1)$.

A1.1. Preferences

Men value consumption and, in this patrilineal society, the continuation of their lineages. Their preferences are represented by the utility function $\log(c_t^{Y,M}) + \beta \log(c_{t+1}^{O,M}) + \gamma \log(f_t^Y + f_{t+1}^O)$, where f^A in a given period is the number of surviving children they have at age A and $\gamma \in (0, 1)$ is the importance placed on continuing a lineage. The preference for fertility implies that men must have children but are indifferent as to when they have them. Therefore, this assumption plays a major role in the model: the timing of children is determined entirely by the tradeoff between (discounted) utility from additional consumption and utility from additional surviving children.

In contrast (and in a minor departure from Tertilt, 2005), women only value consumption because children do not join their lineages. Their preferences are represented as $\log(c_t^{Y,F}) + \beta \log(c_{t+1}^{O,F})$. I also assume that if there is no difference between her consumption when single versus when married, she chooses to marry.[36]

A1.2. Income and Women's Savings

One of the two major deviations I make from the author's model is that both young and old men work for an exogenously set wage y^A, analogous to forced labor laws compelling them to work on behalf of European capital. This feature implies that they do not need to save to consume in old age. In contrast, I maintain the setup of young women working for an endogenously determined wage w_t while old women do not, instead consuming from what they saved and invested in the representative firm when young, s_{t-1}^F. Their investment earns the interest rate $r_t = R_t - \delta$, where R_t is the return to domestic capital and δ is depreciation.

A1.3. Marriage and Fertility

In every period, men and single women enter a frictionless marriage market in which the former demand $n_t^A \geq 0$ wives that each cost the bride price p_t. It is important to note that marriage in this model is solely a method of producing (legitimate) children – there is no intrahousehold bargaining and individuals consume only from their own budgets. To further simplify the model, the second major departure I make from Tertilt (2005) is

[36] I do so to ensure that women enter the marriage market and are indifferent between potential husbands who can pay the bride price.

to give women property rights over themselves – i.e., they decide whether to marry and are paid their bride prices – which is consistent with the assumption that they also save and invest.[37]

However, I preserve the assumption that men make fertility decisions alone by choosing to have $f_t^A \geq 0$ children spread equally across their wives, so each bears $\frac{f_t^A}{n_t^A}$. The cost for all of her offspring to survive childhood is $2\epsilon\big(\frac{f_t^A}{n_t^A}\big)^2$, which is split evenly between her and her husband. As a result, the cost to him of having f_t^A children is $\frac{\epsilon(f_t^A)^2}{n_t^A}$.

A1.4. Men's Choice Problem

Unless young men's wages are sufficiently greater than old men's, they will only marry and have children when old. To see why, note that because of discounting, they need to be able to have a good deal more children when young to justify forgoing present consumption to pay for wives and their offspring's survival. However, if young men's wages exceed this threshold, they will only marry and have children when young.[38] Therefore, if the optimal age for marriage and children is A, the problem for men of that age in period t is represented as

$$\max_{n_t^A, f_t^A \geq 0} \log\left(y^A - p_t n_t^A - \frac{\epsilon(f_t^A)^2}{n_t^A}\right) + \gamma \log(f_t^A), \tag{A1}$$

where the utility from consumption in the other period of their lives drops out because they simply consume their entire budgets.

A1.5. Marriage Market Clearing and Population Dynamics

The size of the young population of a given sex in t is M_t. Assuming that young women choose to marry, equating supply and demand in the marriage market yields

$$\frac{f_{t-1}^Y}{2} + \frac{f_{t-1}^O}{2\eta_{t-1}} = \eta_t n_t^Y + n_t^O, \tag{A2}$$

where $\eta_t = \frac{M_t}{M_{t-1}}$ is the growth rate of the young population from $t-1$ to t. Its law of motion is

$$\eta_{t+1} = \frac{f_t^Y}{2} + \frac{f_t^O}{2\eta_t}. \tag{A3}$$

[37] I base this assumption on an earlier alternative version of the author's model (Tertilt, 2003, sec. 7). Importantly, the qualitative results are the same but it leads to higher aggregate savings rates than when parents marry off daughters and receive their bride prices. In that case, young women must pay their share of the cost of children without the addition of the bride price to their budgets, which reduces what they can save.

[38] These statements will be formalized as conditions on parameters below.

A1.6. Women's Choice Problem

As the entire value of marriage to men is the ability to have children, men will only demand young women as wives. Therefore, whether a young woman enters the marriage market depends on the difference between the bride price and the cost of her fertility given a potential husband's demand for wives and children (denoted as $\tilde{n}_t$ and $\tilde{f}_t$). If $p_t \geq \frac{\epsilon \tilde{f}_t^2}{\tilde{n}_t^2}$, then she chooses to marry and her problem can be represented as

$$\max_{s_t^F \geq 0} \log\left(w_t + p_t - \frac{\epsilon \tilde{f}_t^2}{\tilde{n}_t^2} - s_t^F\right) + \beta \log\left(r_{t+1} s_t^F\right). \tag{A4}$$

Under this condition on the bride price (i.e., marriage weakly increases her consumption), it is important to note that if population growth is positive and men's wages are such that only old men marry, then each old man has more than one wife. But if the structure of men's wages implies that only young men marry, then all marriages are monogamous. Alternatively, if marriage reduced her consumption, then women would not marry and the middle two terms in her young-age budget would drop out of her problem, but the fact that men would experience infinitely negative utility from failing to continue their lineages implies that this scenario will not occur.

This logic allows for straightforward expressions for two marriage market quantities of interest. The first is the share of marriages that are age-disparate (i.e., young women marrying old men), $D_t = \frac{n_t^O}{\eta_t}$. The other is the average number of brides per man marrying in that period (henceforth "brides per married man"), $B_t = \frac{\eta_t n_t^Y + n_t^O}{\eta_t + 1}$.

A1.7. Production and Domestic Capital Market Clearing

Within the model, output is produced by a representative firm that employs young women. It has the production function $Y_t = AK_t^\alpha L_t^{1-\alpha}$, where A is the level of technology, K_t is domestic capital, L_t is labor, and α is capital's share of income. Profit maximization implies that the return to capital and the wage are

$$R_t = \alpha A k_t^{\alpha-1},\ w_t = (1-\alpha) A k_t^\alpha, \tag{A5}$$

where k_t is capital per worker. Its law of motion is

$$k_{t+1} = \frac{s_t^F}{\eta_{t+1}}. \tag{A6}$$

A1.8. Definition of Equilibrium

Definition 1. *The equilibrium of this economy is defined by the optimal choices for men in (A1) taking prices as given, the marriage market clearing as in (A2), population evolving as in (A3), the optimal choices for women in (A4) taking prices and men's demand as given, the representative firm maximizing profits as in (A5), and the domestic capital stock per worker evolving as in (A6).*

A2. Baseline Wage Regime: Balanced Growth Path

The first object of interest is the balanced growth path (BGP) – an equilibrium that satisfies Definition 1 with constant population growth η_1 and domestic capital per worker k_1 – under a baseline wage regime that only allows old men to marry. This scenario maps onto the periods prior to the start of circular migration. The predictions below regarding marriage and fertility closely match those for the polygynous BGP in Tertilt (2005), but they diverge for capital accumulation given the differences in men's production.[39]

Assumption A1. *Young men's wages do not exceed old men's, which are above a certain level:*

i. $y^O \geq y^Y$.[40]

ii. $y^O > \frac{8\epsilon(1+\gamma)}{\gamma}$.

Proposition A1. *In the BGP of this economy under Assumption A1:*

i. All marriages are age-disparate, as each old man marries $\eta_1 > 1$ young wives.

ii. The domestic capital stock per worker falls as old men's wages – and thus population growth – rise, which lowers young women's consumption by reducing their wages but raises old women's consumption by increasing the interest rate.

Proof. For part (i), the first-order conditions for (A1) are $n_t^A = \frac{f_t^A\sqrt{\epsilon}}{\sqrt{p_t^A}}$ and $f_t^A = \frac{\sqrt{\gamma n_t^A}\sqrt{y^A - p_t^A n_t^A}}{\sqrt{\epsilon}\sqrt{2+\gamma}}$. Before solving for the quantities of wives and children demanded, note that rearranging the first of these equations gives $p_t^A = \frac{\epsilon(f_t^A)^2}{(n_t^A)^2}$, so all young women will enter the marriage market. These conditions also yield a man's choices as functions of the bride price,

$$n_t^A = \frac{\gamma y^A}{2p_t(1+\gamma)},\ f_t^A = \frac{\gamma y^A}{2\sqrt{\epsilon p_t}(1+\gamma)}. \tag{A7}$$

Substituting (A7) into (A2) gives the market-clearing bride price as a function of population growth on the BGP,

$$p_0 = 4\epsilon(\eta_1^A)^2, \tag{A8}$$

[39] An interesting nuance is that if the structure of men's wages was such that young men married and old men did not (i.e., if monogamy arose endogenously), capital per worker would be lower in the monogamous BGP than under polygyny, though average consumption would still be higher. The intuition, as discussed when setting up men's choice problem, is that young men would only give up present consumption if they could afford many more children, diluting the capital stock with faster population growth. However, though it is beyond the scope of this paper to study formally, it seems likely that in this model, imposing monogamy (by constraining $n_t^Y + n_{t+1}^O \leq 1$) and adding a penalty for women remaining unmarried would reduce fertility and thus increase capital per worker, as the author finds.

[40] This assumption is sufficient for part (i) of the proposition below to hold. However, it greatly simplifies the presentation and is far more intuitive than the version that is necessary and sufficient, under which wages could strictly decrease with age.

which increases as the cost of children's survival and population growth increase. These relationships arise because wives must be compensated for raising the costs of their fertility due to having more children or their survival becoming more expensive.

Given that men will marry and have children in just one period of adulthood, population growth depends on which age it is. Substituting their demands for children in (A7) and the bride price in (A8) into the expression for population growth in (A3) yields

$$\eta_1^Y = \left(\frac{\gamma y^Y}{8\epsilon(1+\gamma)}\right)^{\frac{1}{2}}, \; \eta_1^O = \left(\frac{\gamma y^O}{8\epsilon(1+\gamma)}\right)^{\frac{1}{3}}. \tag{A9}$$

Intuitively, population growth increases as children's survival becomes relatively more affordable, either by increasing old men's wages or decreasing the cost of keeping them alive, and as the importance placed on fertility increases. Nonetheless, at first it seems counterintuitive that the population growth rate would be higher under monogamy (i.e., only young men marrying). But it is important to recall that men will marry when young only if their wages are sufficiently high to have enough children to compensate for reducing their present consumption, leading to faster population growth.

Writing the optimal choices and prices if men marry at a given age (denoted as $A_0 = A$) as functions of population growth gives

$$n_0^Y = \begin{cases} 1 & \text{if } A_0 = Y \\ 0 & \text{if } A_0 = O \end{cases}, \quad f_0^Y = \begin{cases} 2\eta_1^Y & \text{if } A_0 = Y \\ 0 & \text{if } A_0 = O \end{cases},$$
$$n_0^O = \begin{cases} 0 & \text{if } A_0 = Y \\ \eta_1^O & \text{if } A_0 = O \end{cases}, \quad f_0^Y = \begin{cases} 0 & \text{if } A_0 = Y \\ 2(\eta_1^O)^2 & \text{if } A_0 = O \end{cases}. \tag{A10}$$

With expressions (A8) through (A10), when men marry and have children can be determined by comparing their utilities in each case. To simplify the problem, note that log utility implies a constant share $\frac{1}{1+\gamma}$ of income will be spent on consumption in that period.

It is then straightforward to use properties of logs to show that the first part of Assumption A1 is sufficient for $A_0 = O$. As all old men and all young women marry in this BGP, every marriage is age-disparate ($D_0 = 1$). The second part of Assumption A1 implies that population growth is positive, so the number of wives per married (old) man is $B_0 = \eta_1 > 1$.

For part (ii), $p_0 = \frac{\epsilon \tilde{f}_0^2}{\tilde{n}_0^2}$ as shown above, so young women marry and these terms drop out of their problem in (A4). Therefore, the optimal amount for them to save is $s_0^F = \frac{\beta w_0}{1+\beta}$. Substituting it and the profit-maximizing wage in (A5) into the expression for capital accumulation in (A6) yields a stock of capital per young woman of

$$k_1 = \frac{\beta w_0}{(1+\beta)\eta_1} = \left(\frac{\beta(1-\alpha)A}{(1+\beta)\eta_1}\right)^{\frac{1}{1-\alpha}}, \tag{A11}$$

which decreases with population growth. Put another way, raising men's wages from working for the outside employer lowers the amount of capital per young woman by increasing the size of the generation the representative firm employs.

In terms of consumption, for young men it is their entire budgets ($c_0^{Y,M} = y^Y$) while for old men it is a constant share $c_0^{O,M} = \frac{y^O}{1+\gamma}$ given log utility. Similarly, young women consume a constant share $c_0^{Y,F} = \frac{w_0}{1+\beta}$, and old women consume what they saved in the previous period plus interest: $c_0^{O,F} = \left(\frac{\beta}{1+\beta}\right) r_1 w_0$. These expressions make it clear that young women's consumption moves in the same direction as the capital stock – and thus in the opposite direction of population growth and old men's wages. However, the opposite is true for old women: it is straightforward to show that $\frac{\partial c_0^{O,F}}{\partial k_1} < 0$, so $\frac{dc_0^{O,F}}{dy^O} = \frac{\partial c_0^{O,F}}{\partial k_1} \cdot \frac{\partial k_1}{\partial \eta_1} \cdot \frac{\partial \eta_1}{\partial y^O} > 0$ given the description of the other partial derivatives above. The implication is that the increase in the interest rate from a smaller capital stock per worker in this period outweighs the decrease in the wages they earned as young women. $\square$

A3. New Wage Regime: First Period

The next proposition characterizes what happens to an economy on the baseline BGP after a share μ of young men start to earn much higher wages $\hat{y}^Y$, which is analogous to the first period in which circular migration became possible.[41] As I describe below, substantial differences with the baseline BGP emerge in marriage, fertility, and domestic capital accumulation as high-wage young men enter the marriage market, though only this group's average consumption changes in this period.

Assumption A2. *Young men's high wages are large enough relative to old men's wages: $\hat{y}^Y > (1+\gamma)y^O$.*[42]

Proposition A2. *Suppose that the marriage market is in the baseline BGP when a share μ of young men begin to earn wages $\hat{y}^Y$ satisfying Assumption A2. Then in the equilibrium for the first period under this wage regime:*

i. Each high-wage young man and old man marries, raising the bride price and the growth of the population into the next period.

ii. The share of age-disparate marriages, the number of brides per married man, and next period's domestic capital stock per worker decrease.

iii. Young men's average consumption rises.

Proof. For part (i), determining whether young men with high wages marry requires comparing utilities across the cases. If they do not, they consume $\hat{y}^Y$ when young and

[41] This subset could be determined by migration costs that decline with idiosyncratic ability and increase strongly with age, yielding a threshold ability level that only some young men exceed. However, as this paper's focus is on the long-run consequences of circular migration rather than the decision to engage in it, for simplicity I take this share as exogenous.

[42] Once again, for simplicity and ease of presentation, this assumption is sufficient but not necessary.

follow the old-age choices in the baseline BGP. If they do, their young-age choices are defined by replacing y^A in (A7) with $\hat{y}^Y$, and in old age they consume y^O. In this scenario, the marriage market-clearing condition is $\eta_1 = \mu\eta_1\hat{n}_1^Y + n_1^O$, making the bride price

$$p_1 = p_0\left(\frac{\mu\eta_1\hat{y}^Y + y^O}{y^O}\right), \tag{A12}$$

which is more than p_0 in (A8).

It is instructive to examine the above expression. The bride price now equals the cost to a woman of having her husband's baseline optimal number of children (p_0) scaled by the ratio of the total earnings of men in the marriage market in this period versus in the baseline BGP (the term in parentheses). This scaling factor adjusts the original bride price to account for the increase in the buying power of men demanding wives.

The reason for the bride price increase is that the population growth rate increases, which means that wives must contribute to the survival of more children (and thus must be compensated accordingly). To see why, note that the population law of motion is now $\eta_2 = \frac{\mu\hat{f}_1^Y}{2} + \frac{f_1^O}{2\eta_1}$, which yields

$$\eta_2 = \eta_1\left(\frac{\mu\eta_1\hat{y}^Y + y^O}{y^O}\right)^{\frac{1}{2}} = \frac{\sqrt{p_1}}{2\sqrt{\epsilon}}, \tag{A13}$$

which is larger than η_1. In addition, the second equality implies that (A12) can be rewritten as $p_1 = 4\epsilon\eta_2^2 = p_0\left(\frac{\eta_2}{\eta_1}\right)^2$, which is the same pattern as in (A8) for the baseline BGP.

A young man in this scenario would have $\hat{f}_1^Y = 2\eta_1^2\left(\frac{\hat{y}^Y}{\sqrt{y^O}\sqrt{\mu\eta_1\hat{y}^Y + y^O}}\right)$ children. Using the constant share of income spent on consumption in the period of marriage along with the properties of logs to compare lifetime utility in each case, it is straightforward to show that Assumption A2 is necessary and sufficient for high-wage men to choose to marry and have children only when young.

For part (ii), with a subset of young men entering the marriage market for the first time, the share of age-disparate marriages will clearly decrease. In particular, it falls from 1 in the baseline BGP to

$$D_1 = \frac{\eta_1^2}{\eta_2^2} = \frac{y^O}{\mu\eta_1\hat{y}^Y + y^O}, \tag{A14}$$

which equals the proportion of husbands' total buying power that is due to old men. Additionally, the average number of wives per married man decreases from η_1 to

$$B_1 = \frac{\eta_1}{\mu\eta_1 + 1}. \tag{A15}$$

There are no changes to the setup of the woman's problem, firm profit maximization, or capital accumulation. Therefore, $s_1^F = \frac{\beta w_1}{1+\beta}$ and the next period's capital stock per worker is

$$k_2 = \frac{\beta(1-\alpha)Ak_1^{\alpha}}{(1+\beta)\eta_2} = k_1\left(\frac{\eta_1}{\eta_2}\right) = k_1\left(\frac{y^O}{\mu\eta_1\hat{y}^Y + y^O}\right)^{\frac{1}{2}}, \tag{A16}$$

which is less than k_1 in (A11). Intuitively, it will shrink by exactly the factor by which the population growth rate increases.

For part (iii), given these changes, the average level of consumption among young men increases to $\bar{c}_1^{Y,M} = \frac{\mu\hat{y}^Y}{1+\gamma} + (1-\mu)y^Y$, which is greater than $c_0^{Y,M}$ due to the first part of Assumption A1 and Assumption A2. In contrast, old men's consumption in this period does not change ($c_1^{O,M} = c_0^{O,M}$) because all of them continue to marry and spend a constant share of their wages on consumption. Additionally, next period's capital stock has no effect on women's consumption in this period, so $c_1^{A,F} = c_0^{A,F}$, $A \in \{Y, O\}$.

□

A4. New Wage Regime: Subsequent Transition Periods

I now examine the economy's continued adjustment to the new wage regime across subsequent periods. It turns out that there are substantive differences between these periods' equilibria and the one in the first period after the shock to young men's wages, which are driven by last period's high-wage young men refraining from entering the marriage market in old age.

Assumption A3. *High wages for young men are not too large relative to old men's wages, and domestic capital's share of income is above a certain level but below one-half:*

i. $\hat{y}^Y < y^O\left(\frac{1}{\mu\eta_1}\right)\left(\frac{(1-\mu)^2}{(1-\mu\eta_1)^2} - 1\right)$.

ii. $\frac{\log\left(\mu\eta_1\hat{y}^Y + y^O\right) - \log\left(\mu\eta_1\hat{y}^Y + (1-\mu)\left(\frac{\eta_1}{\eta_2}\right)y^O\right)}{\log\left(\mu\eta_1\hat{y}^Y + y^O\right) - \log(y^O)} < \alpha < \frac{1}{2}$.[43]

Proposition A3. *Suppose that the economy in $t \geq 2$ has proceeded $t-1$ periods since the μ share of young men began to earn high wages ("the first period"). If Assumption A3 holds, then in the equilibrium for t:*

i. For even-numbered periods $t = 2m$ and odd-numbered periods $t = 2m+1$ (where $m \in \mathbb{Z}^+$), this period's bride price and population growth into next period follow the patterns

- $p_0 < p_{2m} \leq p_{2m+2} \leq p_{2m+3} \leq p_{2m+1} < p_1$
- $\eta_1 < \eta_{2m+1} \leq \eta_{2m+3} \leq \eta_{2m+4} \leq \eta_{2m+2} < \eta_2$.

[43] Intuitively, this restriction on the lower bound of capital's share of income is quite weak, as the numerator is far smaller than the denominator. For example, under the parameter values in Appendix A6, this threshold is 0.195.

ii. *The age-disparate marriage share is lower than in the first period, while the number of brides per married man is above the first period's level but remains below the baseline BGP's.*

iii. *Next period's capital per young woman is less than the level set in the first period (k_2), and the current period's is related to population growth into the next period by*

- $\frac{k_1}{k_m} < \left(\frac{\eta_{m+1}}{\eta_1}\right)^{\frac{1-\alpha}{\alpha^2}}$.[44]

iv. *Average consumption for young men does not change from the first period, while old men's and old women's are greater. In contrast, young women's is below the first-period level.*

Proof. I proceed by induction.

A4.1. Base Step

For part (i), the first-order conditions in period $t = 2$ for the $1 - \mu$ share of old men who begin the period unmarried and the μ share of high-wage young men are as before. The market-clearing condition is thus $\mu\eta_2\hat{n}_2^Y + (1-\mu)n_2^O = \eta_2$. It yields a bride price of

$$p_2 = p_0\left(\frac{\mu\eta_1\hat{y}^Y + (1-\mu)\left(\frac{\eta_1}{\eta_2}\right)y^O}{y^O}\right) = p_0\left(\frac{\mu\eta_2\hat{y}^Y + (1-\mu)y^O}{y^O}\right)\left(\frac{\eta_1}{\eta_2}\right), \tag{A17}$$

where the first equality shows that it is greater than p_0 in (A8) but less than p_1 in (A12).

The right-hand side of the second equality in (A17) helps to explain why the bride price falls in this period. The first two terms have the same interpretation as before: the cost of a wife's children in the baseline BGP and the ratio of husbands' total buying power now versus then. The third term multiplies this product by the ratio of young women in the baseline BGP versus in this period. Thus, even though there are more high-wage young husbands (due to population growth), its effect on the bride price is more than offset by last period's high-wage young men not remarrying in old age and the increase in the supply of wives.

The decreasing bride price implies that young women will bear fewer children. Substituting it into the law of motion for the population gives the growth rate as

$$\eta_3 = \frac{\sqrt{p_2}}{2\sqrt{\epsilon}}. \tag{A18}$$

Therefore, it is also higher than η_1 in (A9) and lower than η_2 in (A13). Iterating the bride price and population growth rate forward one period – as the marriage market-clearing condition and population law of motion do not change after $t = 2$ – show that these expressions take the same form as in (A17) and (A18), so $p_3 \in (p_2, p_1)$ and $\eta_4 \in (\eta_2, \eta_3)$. Following the same steps for subsequent periods yields $p_0 < p_2 < p_4 < p_5 < p_3 < p_1$ and $\eta_1 < \eta_3 < \eta_5 < \eta_6 < \eta_4 < \eta_2$.

For part (ii), the share of age-disparate marriages in $t = 2$ takes the form of the fraction of husbands' total buying power that is due to old men,

[44] This inequality does not have an intuitive explanation but is necessary for showing part (iv).

$$D_2 = \frac{(1-\mu)y^O}{\mu\eta_2\hat{y}^Y + (1-\mu)y^O}, \tag{A19}$$

as in (A14). It can be shown that $D_2 < D_1$ if and only if $(1-\mu)\eta_1 < \eta_2$, which is clearly true from part (i). In contrast, the average number of wives per married man increases from the previous period in (A15), though it remains below the baseline BGP level of η_1. To see the former, note that this period's value is

$$B_2 = \frac{\eta_2}{\mu\eta_2 + 1 - \mu}, \tag{A20}$$

so it is greater than in the first period because $\eta_2 > (1-\mu)\eta_1$. For the latter, it is straightforward to show that $B_2 < B_0$ if and only if the first part of Assumption A3 holds. Intuitively, the gap in wages cannot exceed a function of the number of high-wage young men in the previous period, which determines both the supply of brides and how many old men enter the marriage market in this period.

For part (iii), the period-3 stock of capital per worker will be

$$k_3 = k_1\left(\frac{\eta_1}{\eta_2}\right)^{\alpha}\left(\frac{\eta_1}{\eta_3}\right) = k_1^{1-\alpha}k_2^{\alpha}\left(\frac{\eta_1}{\eta_3}\right), \tag{A21}$$

which is less than k_2 in (A16) if and only if $\frac{\eta_1}{\eta_3} < \left(\frac{\eta_1}{\eta_2}\right)^{1-\alpha}$. It can be shown that the first inequality in the second part of Assumption A3 is necessary and sufficient for this condition to be true. An implication is that $\frac{k_1}{k_2} < \left(\frac{\eta_3}{\eta_1}\right)^{\frac{1-\alpha}{\alpha^2}}$: this base-step version of the second statement in part (iii) holds if and only if $\frac{\eta_1}{\eta_3} < \left(\frac{\eta_1}{\eta_2}\right)^{\frac{\alpha^2}{1-\alpha}}$, which is true because $\alpha < \frac{1}{2}$ in the second part of Assumption A3 gives $\frac{\alpha^2}{1-\alpha} < 1-\alpha$.

For part (iv), young men's average consumption does not change from the first period because their decisions remain the same, so $\bar{c}_2^{Y,M} = \bar{c}_1^{Y,M}$. However, now that old men who earned high wages in the previous period refrain from entering the marriage market, this segment of the population consumes their entire budgets. Thus, old men's average consumption increases to $\bar{c}_2^{O,M} = \left(\frac{y^O}{1+\gamma}\right)(1+\gamma\mu) > c_1^{O,M}$. The decrease in the capital stock per worker lowers consumption for young women because $w_2 < w_1$. However, for old women, consumption increases from the first period to period 2 because $r_2 > r_1$ but their wage in the previous period was still w_1.

A4.2. Inductive Step

Suppose that the hypothesis is true for $t = j$. I show that the proposition holds for $t = j+1$ as well. For part (i), the bride price in the next period takes the same form as in (A17) but with η_{j+1} replacing η_2. This expression is clearly larger than p_0 but smaller than p_1, as $\eta_{j+1} < \eta_2$ in the inductive hypothesis. Because population growth into the next period can be represented in the same format as in (A18), it is clear that $\eta_{j+2} \in$

(η_1, η_2). In addition, supposing without loss of generality that $j+1$ is odd, continuing to iterate (A17) and (A18) forward, and using the inductive hypothesis on the population growth and bride price inequalities in part (i) yields $p_{j+2} \leq p_{j+4} \leq p_{j+5} \leq p_{j+3}$ and $\eta_{j+1} \leq \eta_{j+3} \leq \eta_{j+4} \leq \eta_{j+2}$.

Similarly, for part (ii), the share of age-disparate marriages in $j+1$ takes the same form as in (A19) but with η_{j+1} replacing η_2. Therefore, $D_{j+1} < D_1$ because $(1-\mu)\eta_1 < \eta_{j+1}$ is given by part (i). This condition along with the first part of Assumption A3 imply that B_{j+1}, which is analogous to the period-2 expression in (A20), also falls between B_1 and B_0.

For part (iii), the inductive hypothesis $k_{j+1} < k_2$ and rewriting k_{j+1} as in the right-hand side of the second equality in (A21) imply that $k_j^{\alpha}\left(\frac{\eta_1}{\eta_{j+1}}\right) < k_1^{\alpha}\left(\frac{\eta_1}{\eta_2}\right)$. Expressing k_{j+2} in the same manner yields

$$k_{j+2} = k_1^{1-\alpha^2}\left(k_j^{\alpha}\left[\frac{\eta_1}{\eta_{j+1}}\right]\right)^{\alpha}\left(\frac{\eta_1}{\eta_{j+2}}\right) < k_1\left(\frac{\eta_1}{\eta_2}\right)^{\alpha}\left(\frac{\eta_1}{\eta_{j+2}}\right) = k_2\left(\frac{\eta_2}{\eta_1}\right)^{1-\alpha}\left(\frac{\eta_1}{\eta_{j+2}}\right). \quad \text{(A22)}$$

The last term in (A22) is less than k_2 if and only if $\frac{\eta_1}{\eta_{j+2}} < \left(\frac{\eta_1}{\eta_2}\right)^{1-\alpha}$, which is true regardless of whether $j+2$ is even or odd because $\frac{\eta_1}{\eta_3} < \left(\frac{\eta_1}{\eta_2}\right)^{1-\alpha}$ and the second statement in part (i) gives that η_3 is less than all other rates of population growth except η_1.

To show that the second statement in part (iii) holds, note that the inductive hypothesis implies

$$\frac{k_1}{k_{j+1}} = \left(\frac{k_1}{k_j}\right)^{\alpha}\left(\frac{\eta_{j+1}}{\eta_1}\right) < \frac{\eta_{j+1}}{\eta_1}. \quad \text{(A23)}$$

As the second part of Assumption A3 gives $\alpha < \frac{1}{2}$, it is sufficient to show that the final term in (A23) is less than $\left(\frac{\eta_{j+2}}{\eta_1}\right)^2$. If $j+1$ is odd, this statement is true because of the second statement in part (i). If $j+1$ is even, it is straightforward to use (A17) and (A18) to show that it also holds in this case.

For part (iv), young and old men's decisions remain unchanged, so $\bar{c}_{j+1}^{A,M} = \bar{c}_2^{A,M}$, $A \in \{Y, M\}$. On the female side, the fact that young women's consumption changes with the capital stock means $c_{j+1}^{Y,F} < c_1^{Y,F}$. With respect to old women's consumption, $c_{j+1}^{O,F} > c_1^{O,F}$ if and only if $\frac{\delta}{\alpha A}\left(k_1^{\alpha} - k_j^{\alpha}\right) > \left(\frac{1}{k_1^{1-2\alpha}} - \frac{k_j^{\alpha}}{k_{j+1}^{1-\alpha}}\right)$. This statement is true because the left-hand side of the inequality is positive while the right-hand side can be shown to be negative due to the second statement in part (iii).

□

A5. New Wage Regime: Balanced Growth Path

Lastly, I characterize the new BGP of this economy and marriage market. In contrast to the propositions above, which are helpful for comparing regions with the same shares of high-wage young men μ but different periods in which the new wage regime began, my interest now is in where regions that entered the new wage regime at the same time but with different values of μ end up. These predictions are most relevant for studying relationships between circular migration and outcomes of interest across Southern Africa. In summary, greater shares of high-wage young men accentuate the changes described in the previous propositions.

Assumption A4. *Domestic capital's share of income is above a certain level:* $\alpha > \frac{\delta\beta}{1+(1+\delta)\beta}$.[45]

Proposition A4. *On the BPG under the new wage regime, as the share of high-wage young men increases:*

i. The bride price and population growth rate increase while the share of age-disparate marriages, the number of wives per man, and the domestic capital stock decrease.

ii. Average consumption increases for men and old women, but it decreases for young women.

Proof. The proof consists of taking derivates of the expressions of interest with respect to μ. For part (i), following the logic in the previous section and denoting values on the new BGP with ∞ subscripts, p_∞ can be written in the same way as in (A17):

$$p_\infty = p_0 \left(\frac{\mu \eta_\infty \hat{y}^Y + (1-\mu) y^O}{y^O} \right) \left(\frac{\eta_1}{\eta_\infty} \right). \tag{A24}$$

However, the constant rate of population growth η_∞ can only be defined by the function

$$F \equiv \eta_\infty^3 - \eta_1^3 \left(\frac{\mu \eta_\infty \hat{y}^Y + (1-\mu) y^O}{y^O} \right) = 0.$$

It is straightforward to use the Implicit Function Theorem to show that $\frac{d\eta_\infty}{d\mu} > 0$, and after substituting it into the total derivative of (A24) with respect to μ, it can be shown that this expression is positive as well.

Similarly, D_∞ and B_∞ take the same forms as in (A19) and (A20). As a result, $\frac{\partial D_\infty}{\partial \mu}$ and $\frac{\partial D_\infty}{\partial \eta}$ are both negative, so D_∞ clearly decreases with μ. The sign of $\frac{dB_\infty}{d\mu}$ is not immediately apparent, as $\frac{\partial B_\infty}{\partial \mu} < 0$ but $\frac{\partial B_\infty}{\partial \eta_\infty} > 0$, but it can be shown that the former is larger in absolute value than the latter, so B_∞ also decreases with μ. In addition, the expression for the capital stock is analogous to (A11), which clearly decreases with μ because it moves in the opposite direction of population growth.

For part (ii), young men's average consumption $\bar{c}_\infty^{Y,M} = \frac{\mu \hat{y}^Y}{1+\gamma} + (1-\mu) y^Y$ increases with μ if and only if $\hat{y}^Y > (1+\gamma) y^Y$, which is given by the first part of Assumption A1 and Assumption A2. The same is clearly true of old men's average consumption,

[45] This restriction on the lower bound of capital's share of income is more strict than in Assumption A3 but still relatively weak, as the numerator is below 1 but the denominator is well above it – under the parameter values in Appendix A6, this threshold is 0.276. This condition is well beyond necessary for old women's consumption to increase with the share of high-wage young men, but it is the simplest closed-form and parameter-only version of the assumption that achieves sufficiency.

$\bar{c}_{\infty}^{O,M} = \left(\frac{y^O}{1+\gamma}\right)(1+\gamma\mu)$, whereas young women's decreases because it moves with the capital stock. Lastly, for old women's consumption $c_{\infty}^{O,F} = \frac{\beta}{1+\beta} r_{\infty} w_{\infty}$, it can be shown that Assumption A4 is sufficient for $\frac{dc_{\infty}^{O,F}}{d\mu} = \frac{\partial c_{\infty}^{O,F}}{\partial \eta_{\infty}} \frac{\partial \eta_{\infty}}{\partial \mu} + \frac{\partial c_{\infty}^{O,F}}{\partial k_{\infty}} \frac{\partial k_{\infty}}{\partial \eta_{\infty}} \frac{\partial \eta_{\infty}}{\partial \mu} > 0$ because $\eta_{\infty} > \eta_1 > 1$. □

A6. Parameter Choices

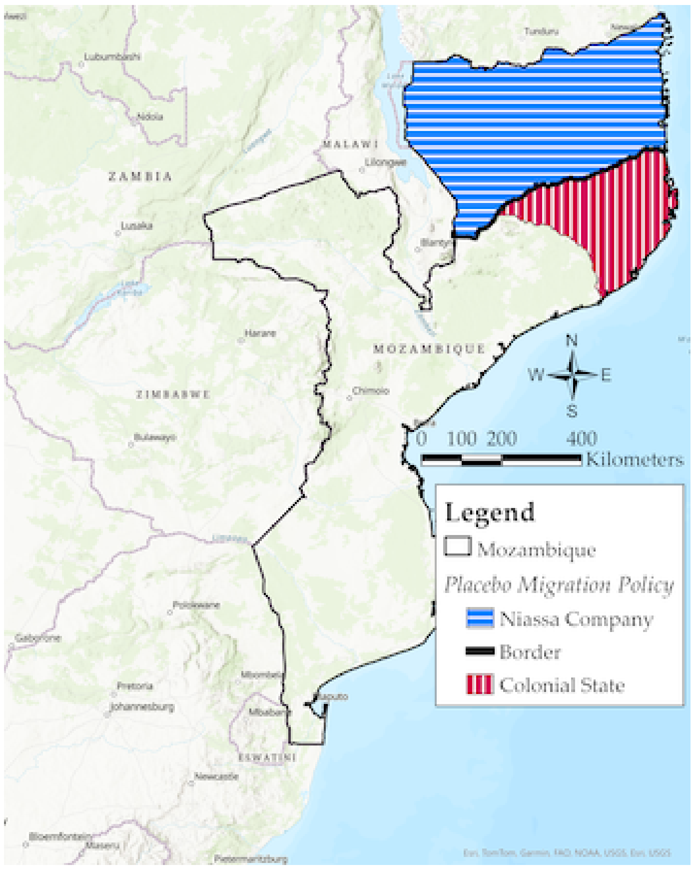
Table A1: Choices of Parameter Values [11, 55, 58]

Parameter	Interpretation	Value	Justification
Period length	How long a generation lasts	30 years	Wang et al. (2023)
γ	Preference for fertility	0.58	Tertilt (2005)
β	Discount rate	$0.95^{30} = 0.215$	Tertilt (2005)
ϵ	Cost of children's survival	44	Tertilt (2005)
A	Level of technology	433	Tertilt (2005)
α	Capital's share of income	0.4	Tertilt (2005)
δ	Depreciation	$1-(1-0.07)^{30} = 0.887$	Tertilt (2005)
μ	Share of high-wage young men	0.333	Figure 8
y^O	Old men's wages	10,000	Assumption A1, baseline BGP has annual 2.7% pop. growth and 6.9% interest
y^Y	Young men's low wages	10,000	Assumption A1, simplicity
$\hat{y}^Y$	Young men's high wages	25,000	Assumptions A2 and A3, new BGP has annual 4.0% pop. growth and 8.5% int.

Appendix B. Additional Maps

B1. Niassa Company and Colonial State Territories in Northern Mozambique

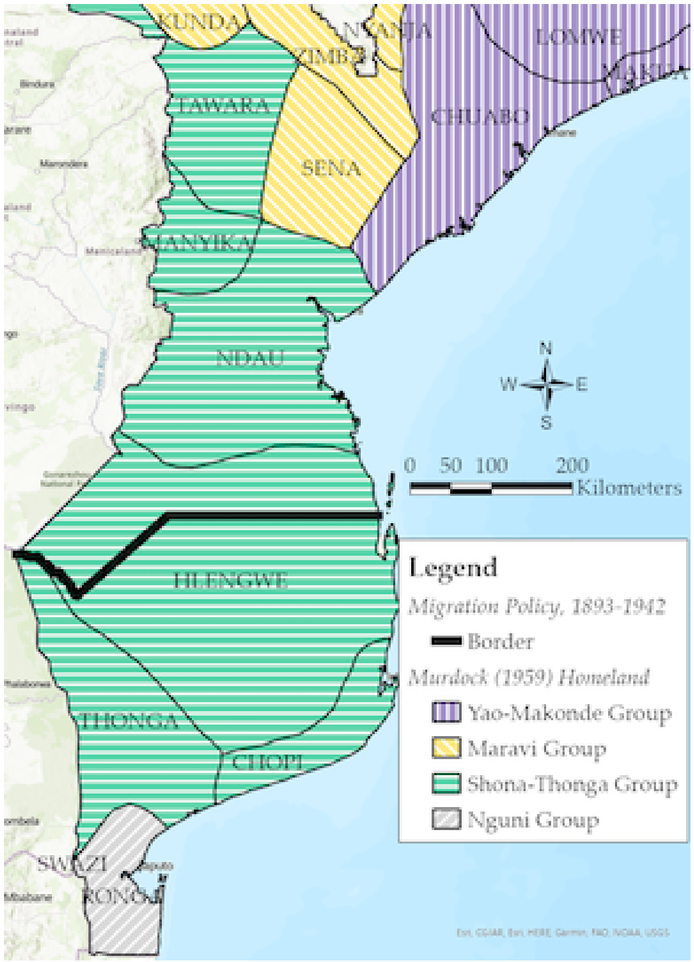
Figure B1: Government-Company Border in Northern Mozambique, 1891-1929 [5]



Notes: The map shows the border between the Niassa Company's chartered concession and territory administered by the colonial state.

B2. Ethnic and Cultural Groups

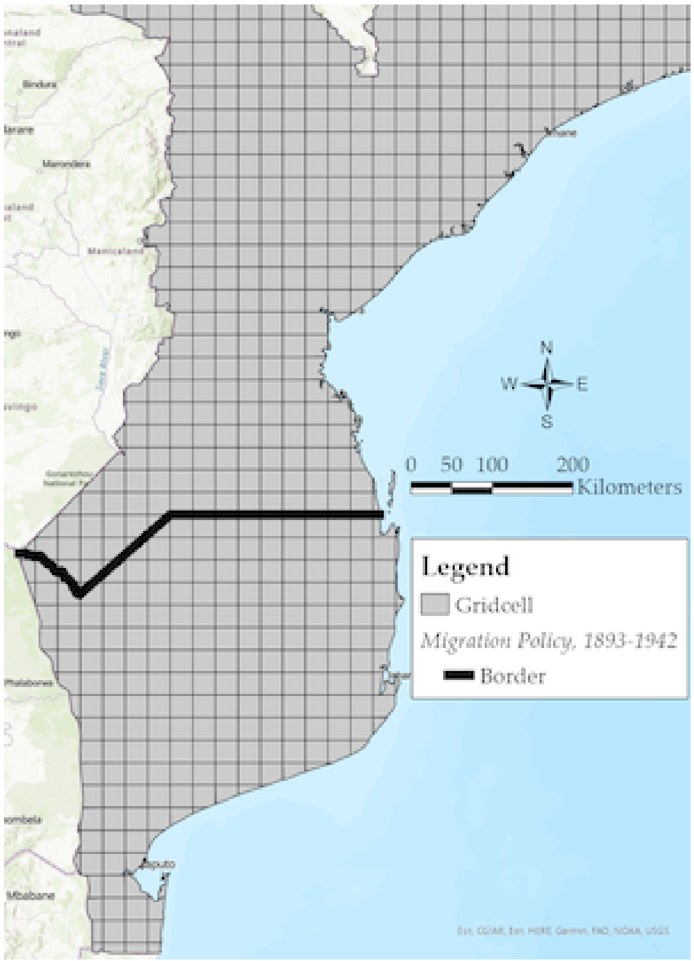
Figure B2: Ethnic Homelands and Cultural Groups in Southern Mozambique [16]



Notes: The map shows Murdock (1959) ethnic homelands and their broader cultural groups.

B3. Dividing Area into Gridcells

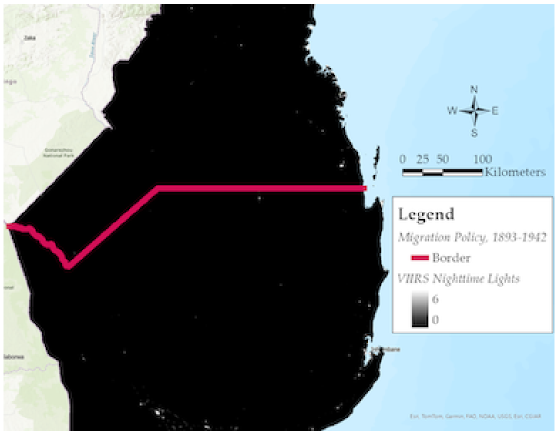
Figure B3: 0.25-Degree × 0.25-Degree Gridcells [16]



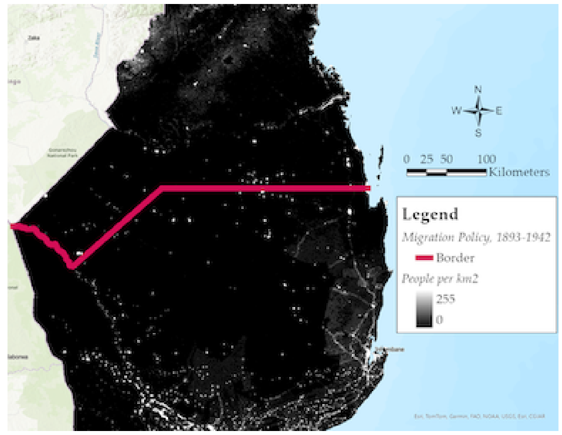
Notes: The map shows the division of southern Mozambique into 0.25 × 0.25-degree gridcells used for the analysis of geospatial data.

B4. *Geospatial Measures of Development*

Figure B4: Maps of Geospatial Measures of Development [20]



(a) VIIRS Nighttime Lights, 2019

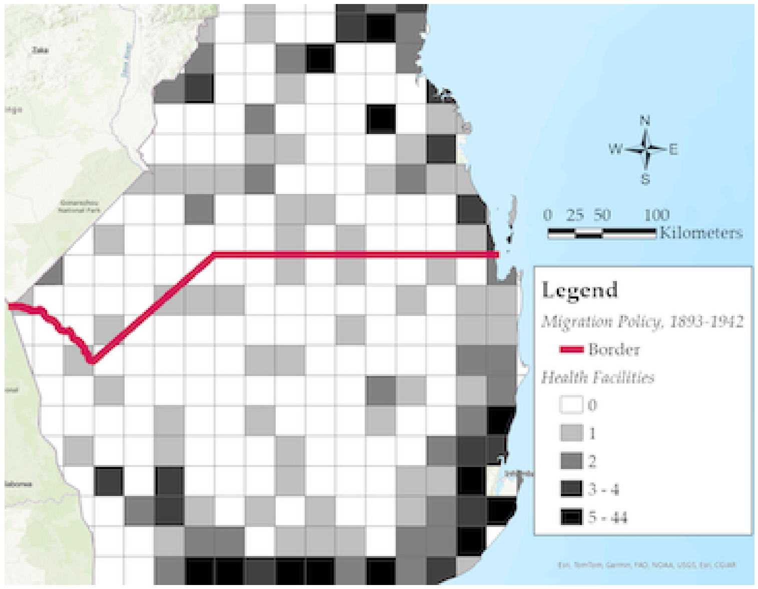


(b) Landscan Population Density, 2019

Notes: The left map shows 2019 nighttime lights from Román et al. (2018) and the right map shows estimated 2019 population density from Rose et al. (2020).

B5. Public-Sector Health Infrastructure

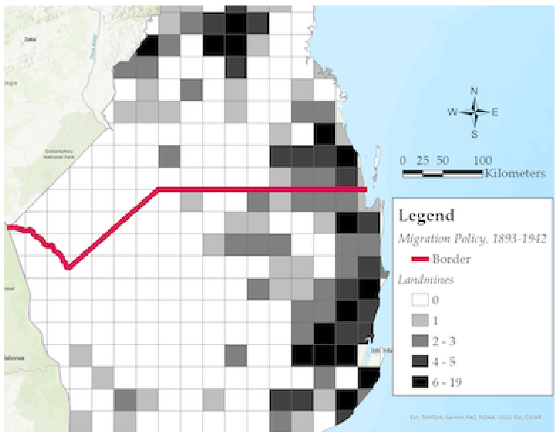
Figure B5: Public-Sector Health Facilities, 2018 [24]



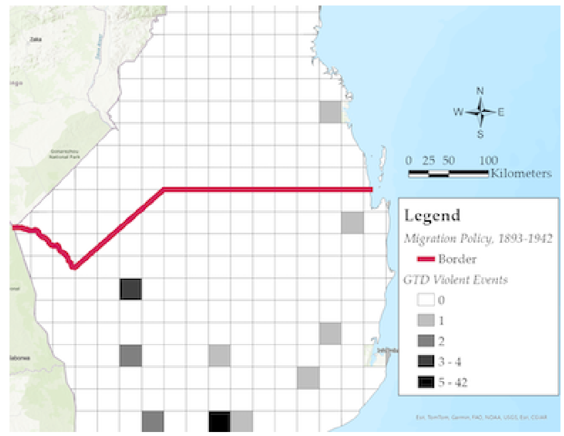
Notes: The map shows counts of public-sector health facilities in each gridcell from Maina et al. (2019).

B6. Civil War Violence and Landmines

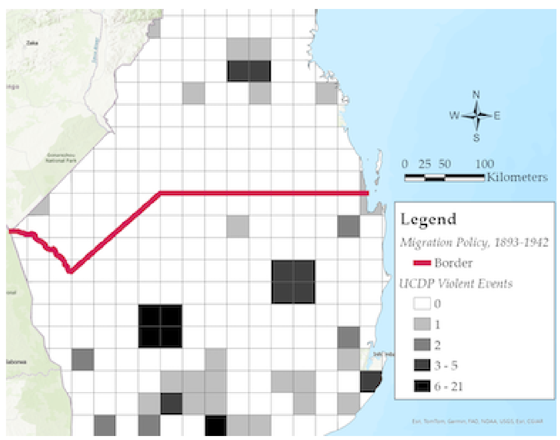
Figure B6: Maps of Civil War Violent Events and Landmines by Gridcell [24]



(a) Known and Suspected Landmines, 2007



(b) Global Terrorism Database, 1978-92

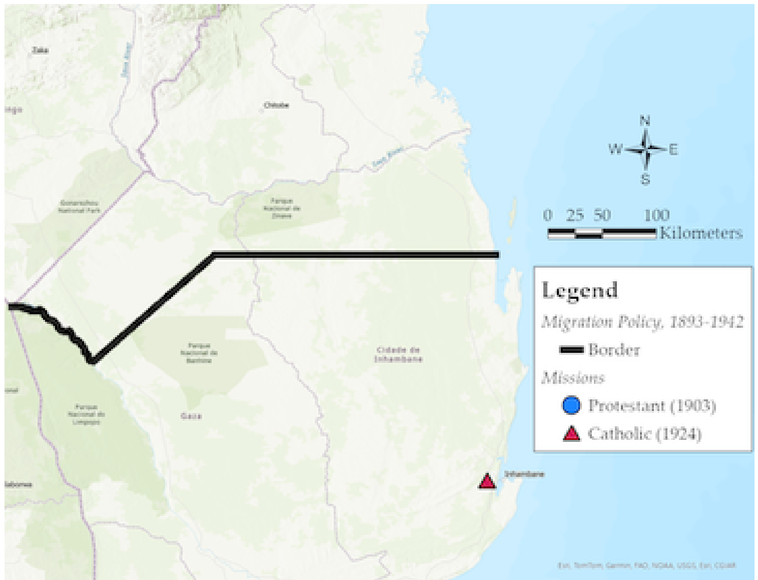


(c) Uppsala Conflict Data Program, 1989-92

Notes: The top left map shows the number of known and suspected landmines per gridcell reported in Republic of Mozambique (2008). The top right map shows the number of 1978-92 violent events per gridcell from the Global Terrorism Database (START, 2022). The bottom map shows the number of 1989-92 violence events per gridcell from the Uppsala Conflict Data Program (Sundberg and Melander, 2013).

B7. Colonial Missionary Presence

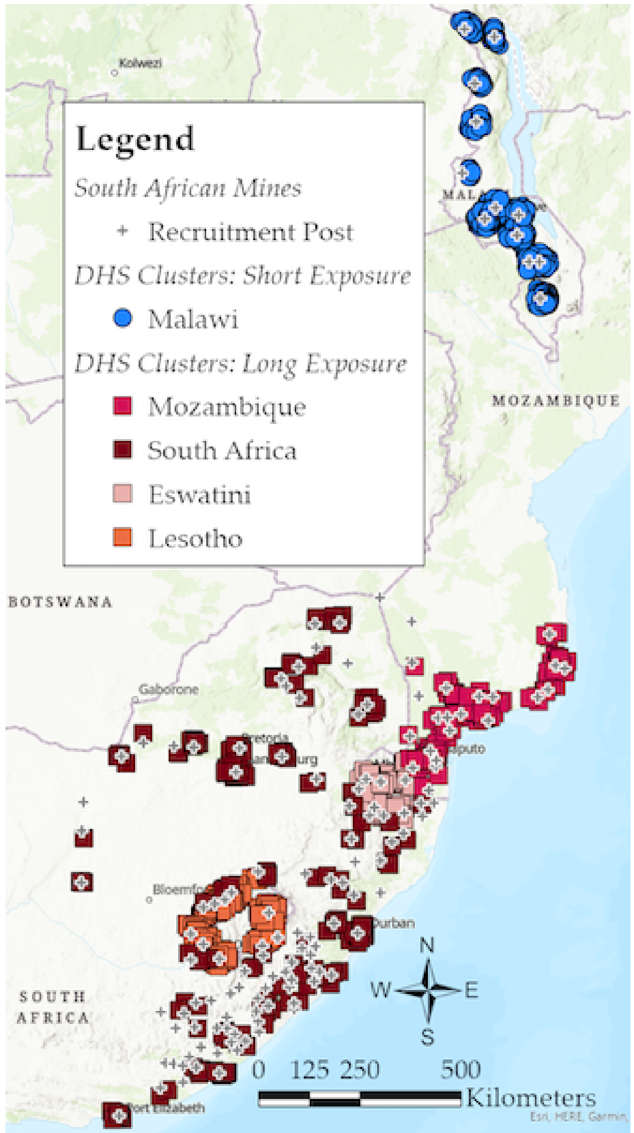
Figure B7: Colonial Missionary Presence [31]



Notes: The map shows the locations of Protestant missions in 1903 and Catholic mission in 1924 from Cagé and Rueda (2016).

B8. Mine Labor Recruitment Posts and DHS Clusters in Southern Africa

Figure B8: DHS Clusters within 25 km of Recruitment Posts [32]

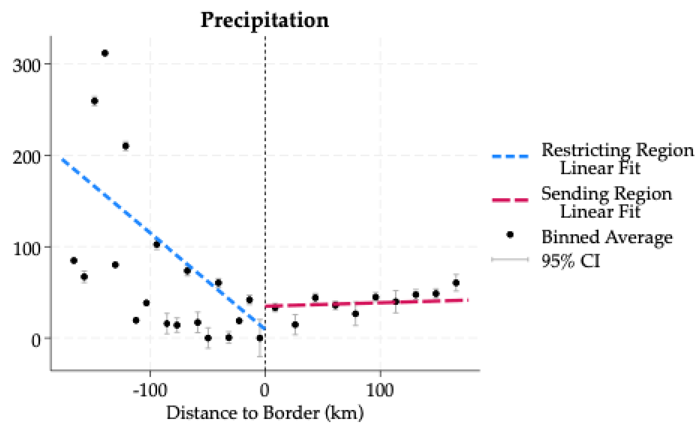


Notes: The map shows the locations of historical NRC and WNLA recruitment posts from the Transvaal Chamber of Mines (1946) overlaid on georeferenced DHS survey clusters in the respective countries.

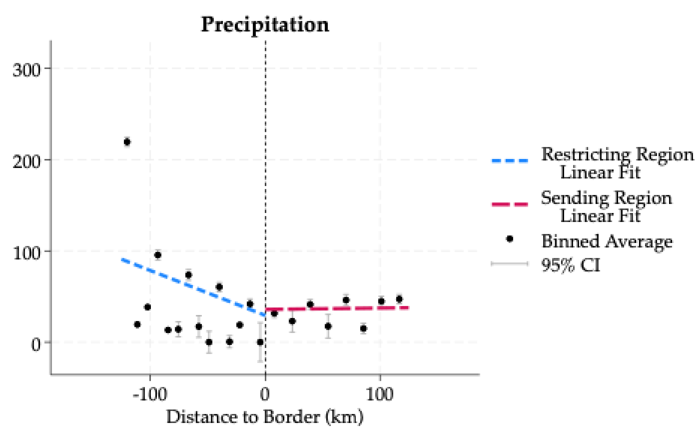
Appendix C. Robustness Checks: Present-Day Effects

C1. Balance Test: RD Plots

Figure C1: Balance Tests at the Border [16]



(a) Precipitation: Optimal Bandwidth

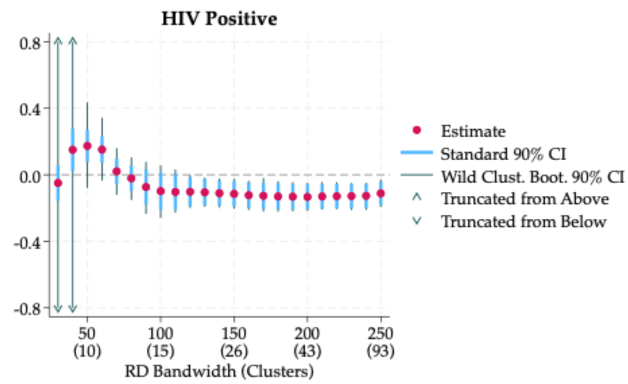


(b) Precipitation: Constant Bandwidth

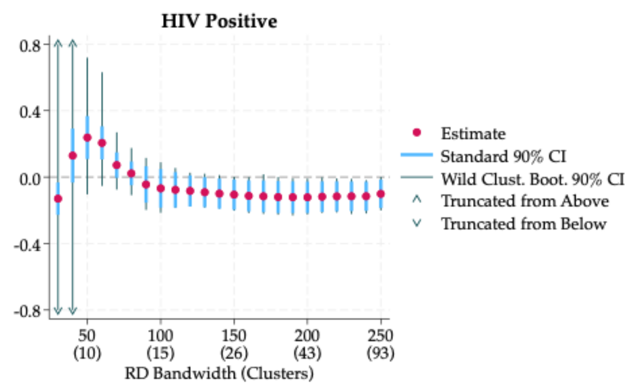
Notes: The graphs show average precipitation in mm within a bin and linear fits within each region after adjusting for longitude. The RD bandwidth is MSE-optimal in the top graph and 125 km in the bottom graph.

C2. HIV RD Results: Varying Local Linear Bandwidths

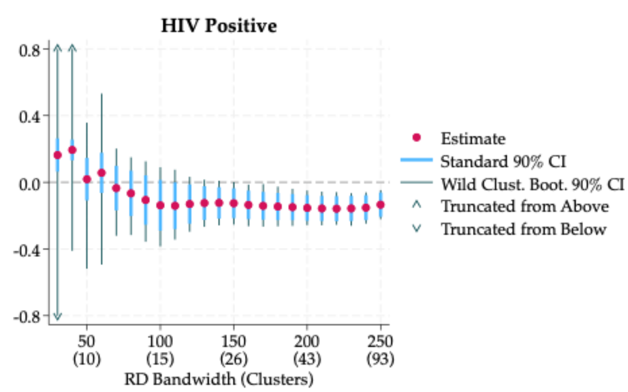
Figure C2: HIV Prevalence [20]



(a) HIV Positive: Pooled



(b) HIV Positive: Women

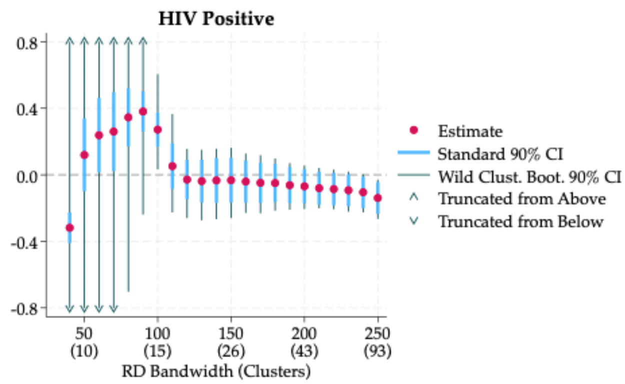


(c) HIV Positive: Men

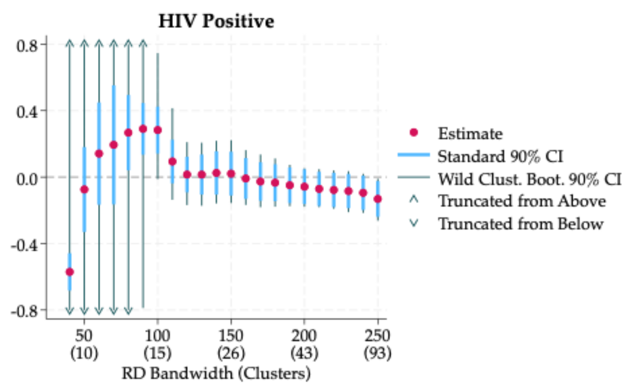
Notes: The graphs show RD estimates and different 90-percent confidence intervals for HIV prevalence across a range of bandwidths using a linear polynomial for the respective groups.

C3. HIV RD Results: Varying Local Quadratic Bandwidths

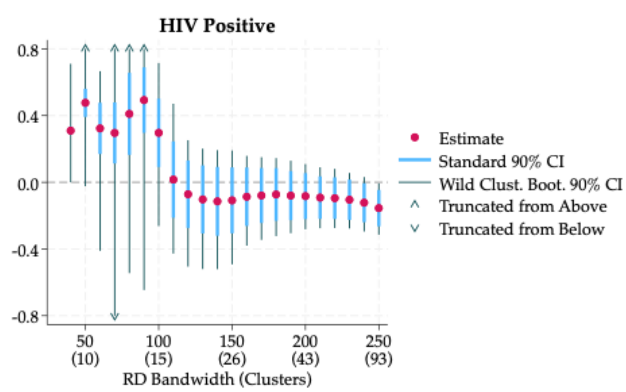
Figure C3: HIV Prevalence [20]



(a) HIV Positive: Pooled



(b) HIV Positive: Women

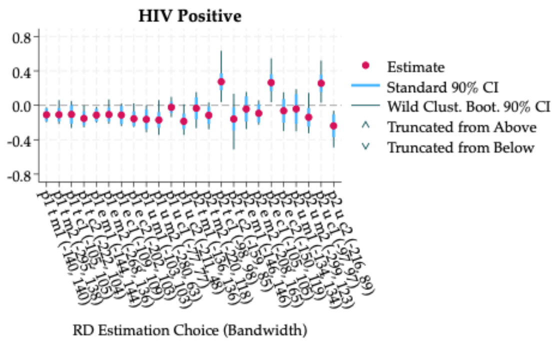


(c) HIV Positive: Men

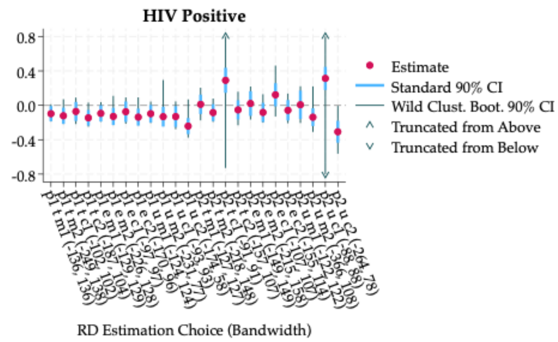
Notes: The graphs show RD estimates and different 90-percent confidence intervals for HIV prevalence across a range of bandwidths using a quadratic polynomial for the respective groups.

C4. HIV RD Results: Varying RD Parameters

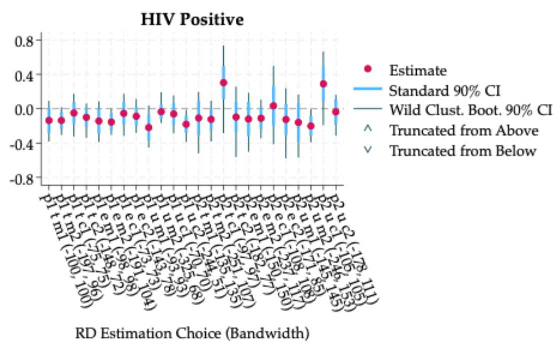
Figure C4: HIV Prevalence [20]



(a) HIV Positive: Pooled



(b) HIV Positive: Women



(c) HIV Positive: Men

Notes: The graphs show RD estimates and different 90-percent confidence intervals for HIV prevalence among the respective groups when using linear (p1) or quadratic (p2) RD polynomials, triangular (t), Epanechnikov (e), or uniform (u) weighting kernels, and symmetric MSE-optimal (m1), asymmetric MSE-optimal (m2), symmetric CER-optimal (c1), or asymmetric CER-optimal (c2) RD bandwidth selection methods, where CER stands for coverage error rate. Bandwidths selected for each combination of parameters are in parentheses.

C5. *HIV and Development RD Results Using Data Collapsed into Clusters*

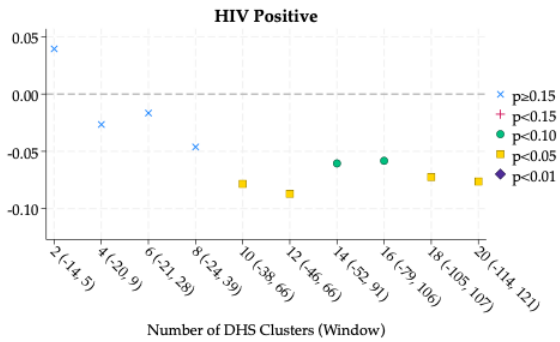
Table C1: HIV Prevalence and Development Outcomes [20]

	HIV Positive			Assets	Schooling	
	Pooled (1)	Women (2)	Men (3)	Pooled (4)	Female (5)	Male (6)
Panel A. Optimal Bandwidth						
Sending Region	-0.150	-0.119	-0.239	-0.514	0.284	0.032
	(0.042)	(0.059)	(0.094)	(0.398)	(0.253)	(0.753)
	[0.026]	[0.031]	[0.062]	[0.226]	[0.187]	[0.654]
Observations	23	23	15	19	27	28
Bandwidth	139.7	136.0	99.5	48.8	91.2	96.5
Restricting Region Mean	0.210	0.209	0.210	-0.393	2.45	3.28
Restricting Region SD				0.150	0.70	0.90
Panel B. Constant Bandwidth						
Sending Region	-0.151	-0.112	-0.155	-0.272	0.034	-0.353
	(0.050)	(0.063)	(0.058)	(0.149)	(0.239)	(0.567)
	[0.032]	[0.032]	[0.043]	[0.122]	[0.201]	[0.534]
Observations	21	21	21	45	40	40
Bandwidth	125	125	125	125	125	125
Restricting Region Mean	0.209	0.208	0.210	-0.289	2.45	3.23
Restricting Region SD				0.357	0.65	0.94
Panel C. Randomization Inference						
Sending Region	-0.084	-0.075	-0.099	-0.128	-0.242	-0.251
	{0.16}	{0.29}	{0.14}	{0.24}	{0.63}	{0.80}
Observations	10	10	10	10	10	10
Bandwidth	-38, 66	-38, 66	-38, 66	-28, 18	-28, 18	-28, 18
Restricting Region Mean	0.198	0.192	0.202	-0.401	2.42	3.04
Restricting Region SD				0.041	0.74	0.51

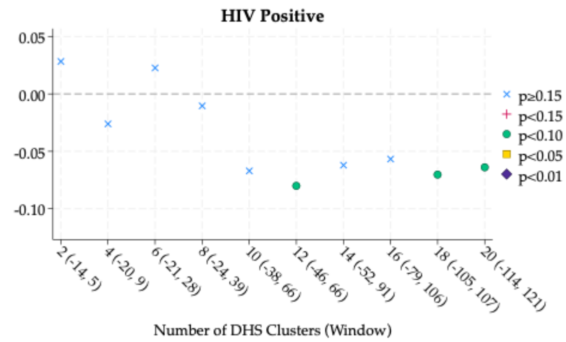
Notes: The table replicates Table 2 using data collapsed to DHS survey cluster-level means.

C6. *HIV Randomization Inference: Varying Windows*

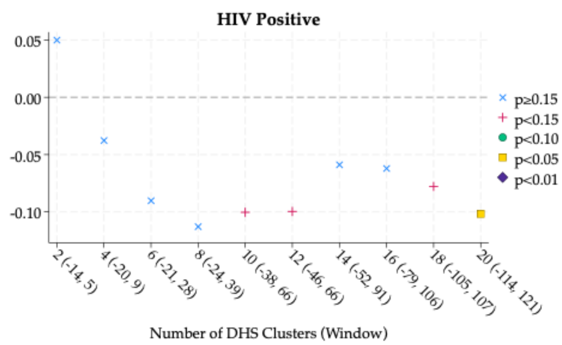
Figure C5: HIV Prevalence [20]



(a) HIV Positive: Pooled



(b) HIV Positive: Women



(c) HIV Positive: Men

Notes: The graphs show randomization inference estimates and statistical significance for HIV prevalence among the respective groups when including a range of DHS survey clusters in the sample. Randomization inference windows are in parentheses.

C7. HIV and Development Randomization Inference: Placebo Windows

Table C2: HIV Prevalence and Development Outcomes [20]

	HIV Positive			Assets	Schooling	
	Pooled	Women	Men	Pooled	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Restricting Region						
Placebo Treatment	-0.039	-0.058	-0.004	-0.343	-0.449	-0.739
	{0.37}	{0.29}	{1.00}	{0.00}	{0.08}	{0.02}
Observations	420	272	148	1,152	448	389
Clusters	10	10	10	10	10	10
Placebo Cutoff	-42.0	-42.0	-42.0	-29.0	-29.0	-29.0
Window	-14, -114	-14, -114	-14, -114	-14, -52	-14, -76	-14, -76
Placebo Control Mean	0.240	0.250	0.220	-0.060	2.75	3.78
Placebo Control SD				0.720	2.78	3.33
Panel B. Sending Region						
Placebo Treatment	0.048	0.066	0.001	-0.026	-0.254	-0.704
	{0.23}	{0.18}	{1.00}	{0.24}	{0.31}	{0.01}
Observations	399	268	131	1,092	479	374
Clusters	10	10	10	10	10	10
Placebo Cutoff	66.0	66.0	66.0	18.5	18.5	18.5
Window	5, 121	5, 121	5, 121	5, 44	5, 51	5, 51
Placebo Control Mean	0.120	0.120	0.110	-0.550	2.05	2.67
Placebo Control SD				0.370	2.45	2.68

Notes: The table replicates Table 2 Panel C when moving the border 5 clusters north into the former restricting region (Panel A) or 5 clusters south into the former sending region (Panel B).

C8. Placebo Test: Niassa Company Concession

Table C3: HIV and Development RD Results: Niassa Company Border [20]

	HIV Positive			Assets	Schooling	
	Pooled (1)	Women (2)	Men (3)	Pooled (4)	Female (5)	Male (6)
Panel A. Optimal Bandwidth						
Placebo Sending Region	-0.020	-0.027	0.024	-0.123	1.20	0.78
	(0.022)	(0.035)	(0.032)	(0.161)	(0.61)	(0.43)
	[0.025]	[0.040]	[0.039]	[0.158]	[0.56]	[0.43]
Observations	1,220	777	623	5,329	1,600	1,839
Clusters	34	40	38	65	45	51
Bandwidth	47.8	54.2	51.0	40.2	37.0	38.6
Wild Cluster Bootstrap p-value	0.47	0.49	0.50	0.49	0.05	0.11
Niassa Company Mean	0.081	0.111	0.062	-0.424	2.84	3.80
Niassa Company SD				0.737	3.32	3.50
Panel B. Constant Bandwidth						
Placebo Sending Region	-0.016	-0.048	0.024	-0.147	0.29	-0.01
	(0.024)	(0.036)	(0.032)	(0.149)	(0.50)	(0.40)
	[0.025]	[0.041]	[0.040]	[0.146]	[0.51]	[0.43]
Observations	1,303	710	593	6,534	2,267	2,291
Clusters	36	36	36	78	62	62
Bandwidth	50	50	50	50	50	50
Wild Cluster Bootstrap p-value	0.58	0.30	0.54	0.36	0.59	0.98
Niassa Company Mean	0.086	0.105	0.064	-0.415	2.73	3.74
Niassa Company SD				0.745	3.21	3.52
Panel C. Randomization Inference						
Placebo Sending Region	-0.031	-0.050	-0.009	-0.010	0.28	0.04
	{0.30}	{0.25}	{1.00}	{0.34}	{0.27}	{0.90}
Observations	340	182	158	780	325	300
Clusters	10	10	10	10	9	9
Bandwidth	-15, 22	-15, 22	-15, 22	-9, 8	-9, 8	-9, 8
Niassa Company Mean	0.065	0.073	0.056	-0.792	1.52	2.55
Niassa Company SD				0.175	2.12	2.77

Notes: The table replicates Table 2 using the former Niassa Company's border with territory ruled by the colonial state in northern Mozambique. See Appendix B1 for a map.

C9. Blood Test Outcomes

Table C4: HIV Blood Test Refusals and ARV Biomarkers [20]

	Refused Test			ARV
	Pooled	Women	Men	Pooled
	(1)	(2)	(3)	(4)
Panel A. Optimal Bandwidth				
Sending Region	0.005	0.007	-0.003	0.197
	(0.005)	(0.007)	(0.003)	(0.236)
	[0.004]	[0.006]	[0.003]	[0.077]
Observations	303	195	121	57
Clusters	8	8	9	8
Bandwidth	83.7	83.0	94.5	83.1
Wild Cluster Bootstrap p-value	0.53	0.52	0.48	0.52
Restricting Region Mean	0.000	0.000	0.000	0.303
Panel B. Constant Bandwidth				
Sending Region	0.004	0.009	-0.007	0.049
	(0.007)	(0.009)	(0.006)	(0.234)
	[0.006]	[0.008]	[0.006]	[0.117]
Observations	412	277	135	80
Clusters	11	11	11	11
Bandwidth	125	125	125	125
Wild Cluster Bootstrap p-value	0.60	0.48	0.40	0.91
Restricting Region Mean	0.005	0.008	0.000	0.250
Panel C. Randomization Inference				
Sending Region	0.000	0.000	0.000	0.034
	{1.000}	{1.000}	{1.000}	{1.000}
Observations	154	95	59	39
Window	-28, 18	-28, 18	-28, 18	-38, 66
Restricting Region Mean	0.000	0.000	0.000	0.316

Notes: The outcomes of interest are whether a respondent did not consent to a blood test for HIV and whether a respondent's blood contained biomarkers for antiretroviral drugs. See the notes to Table 2.

C10. Development Results Using Geospatial Data

Table C5: Development Results Using Geospatial Data [20]

	VIIRS Nighttime Lights			LandScan Population Density	
	Any Light	Intensity	Log(Intensity+1)	People/km^2	Log(People/km^2+1)
	(1)	(2)	(3)	(4)	(5)
Panel A. Optimal Bandwidth					
Sending Region	0.000	0.023	-0.001	0.989	0.199
	(0.000)	(0.029)	(0.001)	(6.685)	(0.243)
	[0.000]	[0.026]	[0.001]	[4.904]	[0.264]
Observations	147	296	220	200	147
Clusters	27	76	43	37	27
Bandwidth	123.9	275.9	193.8	172.4	121.6
Wild Cluster Bootstrap *p*-value	1.00	0.73	0.43	0.88	0.48
Restricting Region Mean	0.000	0.050	0.000	14.59	0.684
Restricting Region SD	0.000	0.560	0.000	71.73	1.133
Panel B. Constant Bandwidth					
Sending Region	0.000	0.000	0.000	8.338	0.194
	(0.000)	(0.000)	(0.000)	(6.834)	(0.249)
	[0.000]	[0.000]	[0.000]	[6.457]	[0.264]
Observations	163	163	163	164	164
Clusters	28	28	28	28	28
Bandwidth	125	125	125	125	125
Wild Cluster Bootstrap *p*-value	1.00	1.00	1.00	0.19	0.47
Restricting Region Mean	0.000	0.000	0.000	13.40	0.756
Restricting Region SD	0.000	0.000	0.000	77.53	1.175
Panel C. Randomization Inference					
Sending Region	0.000	0.000	0.000	0.087	-0.060
	{1.00}	{1.00}	{1.00}	{0.92}	{0.76}
Observations	46	46	46	46	46
Window	-42, 35	-42, 35	-42, 35	-42, 35	-42, 35
Restricting Region Mean	0.000	0.000	0.000	0.610	0.397
Restricting Region SD		0.000	0.000	0.66	0.404

Notes: The outcomes of interest for 2019 VIIRS nighttime lights (Román et al., 2018) are whether a gridcell contains any, the average intensity within a gridcell, and its log. The outcomes of interest for 2019 LandScan population density (Rose et al., 2020) are people per square kilometer and its log. See the notes to Table 1.

C11. Development Results Using Census Data

Table C6: Human Capital and Migration Results Using Census Data [20]

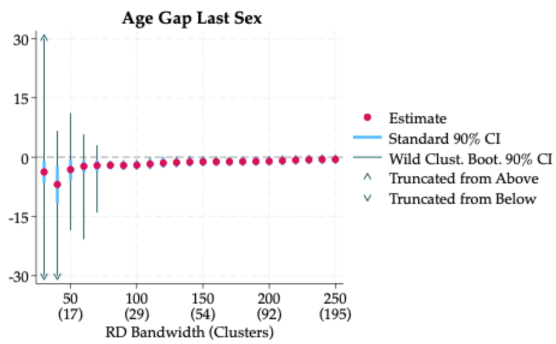
	Literate		Any Schooling		Reside Birth Dist.	
	Women	Men	Women	Men	Women	Men
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Optimal Bandwidth						
Sending Region	0.061	0.053	0.056	0.080	0.055	0.016
	(0.067)	(0.066)	(0.066)	(0.082)	(0.039)	(0.062)
	[0.057]	[0.059]	[0.060]	[0.075]	[0.043]	[0.054]
Observations	17,350	10,295	14,964	8,231	17,003	8,778
Clusters	14	13	13	10	14	11
Bandwidth	124.5	121.8	118.3	98.5	124.2	105.0
Wild Cluster Bootstrap p-value	0.57	0.60	0.65	0.66	0.50	0.87
Mobility Restricting Mean	0.282	0.629	0.330	0.623	0.831	0.806
Panel B. Constant Bandwidth						
Sending Region	0.060	0.053	0.052	0.070	0.057	0.024
	(0.068)	(0.067)	(0.066)	(0.075)	(0.040)	(0.062)
	[0.057]	[0.058]	[0.058]	[0.070]	[0.043]	[0.059]
Observations	17,350	11,607	17,386	11,605	17,003	11,350
Clusters	14	14	14	14	14	14
Bandwidth	125	125	125	125	125	125
Wild Cluster Bootstrap p-value	0.57	0.59	0.67	0.58	0.50	0.77
Mobility Restricting Mean	0.282	0.627	0.305	0.623	0.831	0.841
Panel C. Randomization Inference						
Sending Region	0.044	0.046	0.039	0.041	0.055	0.069
	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}	{0.00}
Observations	12,192	8,239	12,210	8,231	12,004	8,084
Window	-77, 77	-77, 77	-77, 77	-77, 77	-77, 77	-77, 77
Restricting Region Mean	0.318	0.632	0.331	0.623	0.791	0.806

Notes: The outcomes of interest are whether a respondent in the IPUMS 10-percent sample of the 2007 census of Mozambique was literate, had any schooling, and lived in their district of birth. Standard errors clustered by administrative post are in parentheses. See the notes to Table 2.

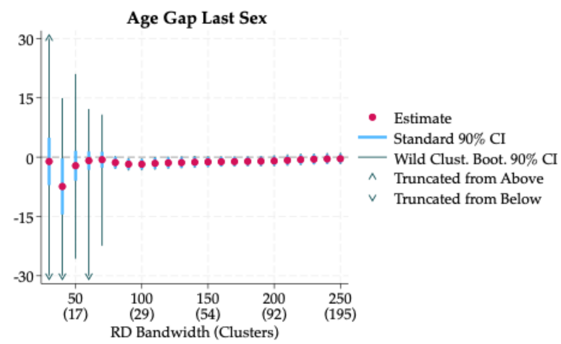
Appendix D. Robustness Checks: Proximate Causes

D1. Marriage RD Results: Varying Local Linear Bandwidths

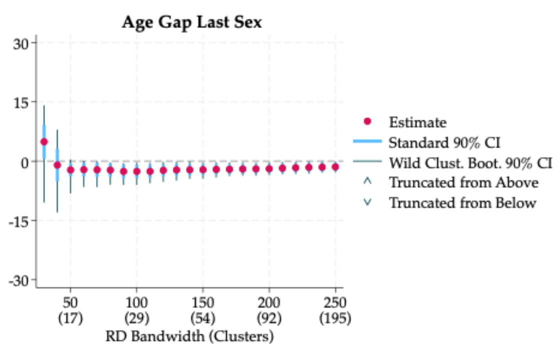
Figure D1: Age-Disparate Relationships [23]



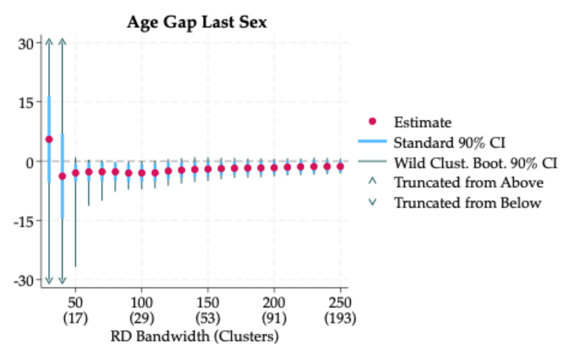
(a) Age Gap at Last Sex: Women



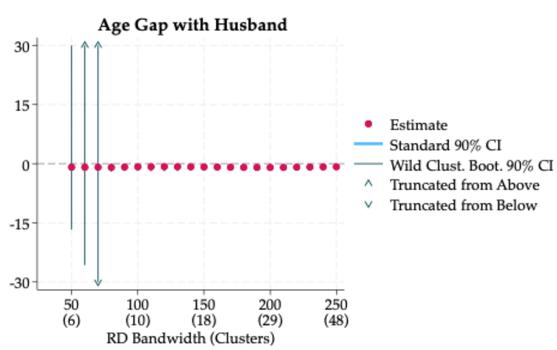
(b) Age Gap at Last Sex: Married Women



(c) Age Gap at Last Sex: Men



(d) Age Gap at Last Sex: Married Men

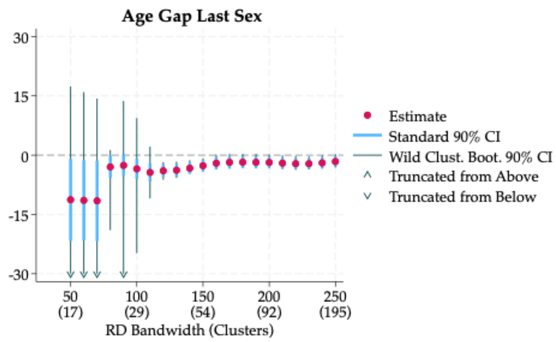


(e) Age Gap with Husband: Women

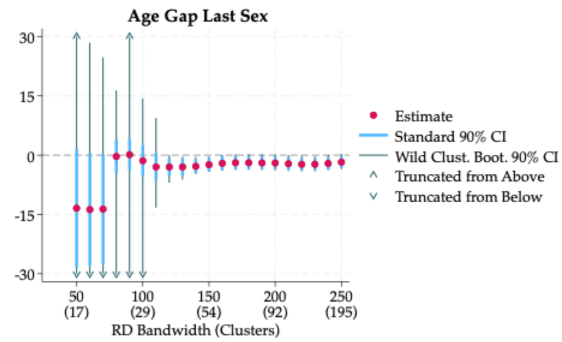
Notes: The graphs show RD estimates and different 90-percent confidence intervals for HIV prevalence across a range of bandwidths using a linear polynomial for the respective groups.

D2. Marriage RD Results: Varying Local Quadratic Bandwidths

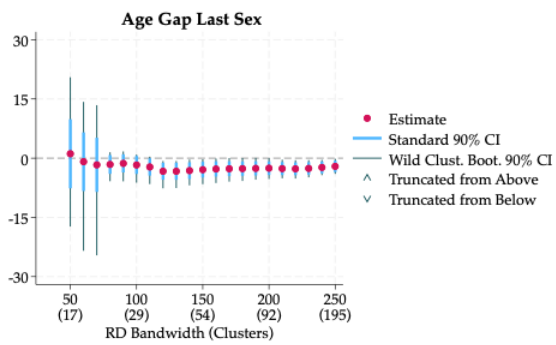
Figure D2: Age-Disparate Relationships [23]



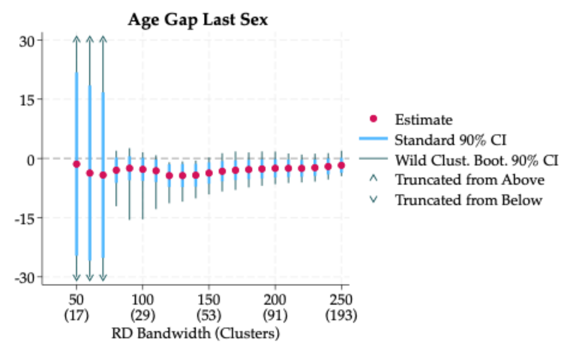
(a) Age Gap at Last Sex: Women



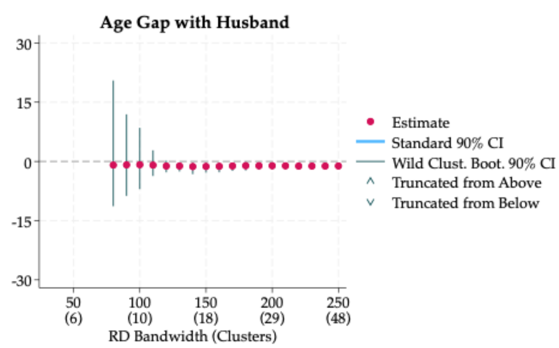
(b) Age Gap at Last Sex: Married Women



(c) Age Gap at Last Sex: Men



(d) Age Gap at Last Sex: Married Men

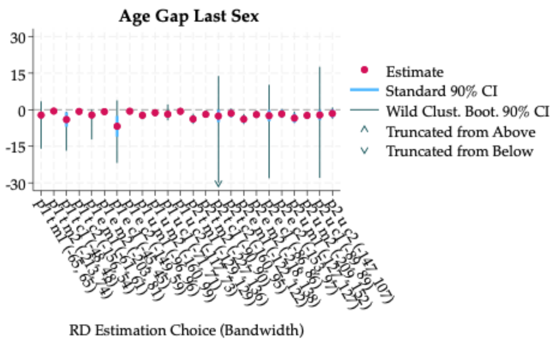


(e) Age Gap with Husband: Women

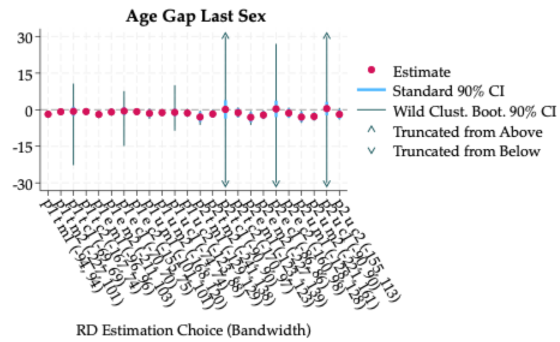
Notes: The graphs show RD estimates and different 90-percent confidence intervals for HIV prevalence across a range of bandwidths using a quadratic polynomial for the respective groups.

D3. Marriage RD Results: Varying RD Parameters

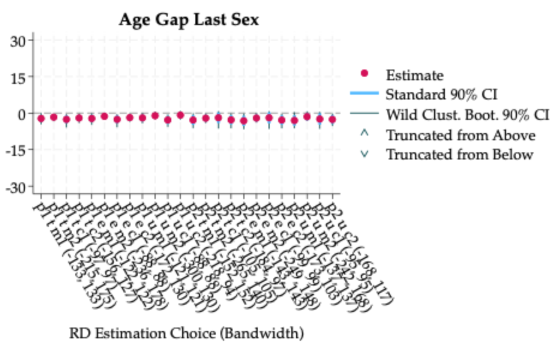
Figure D3: Age-Disparate Relationships [23]



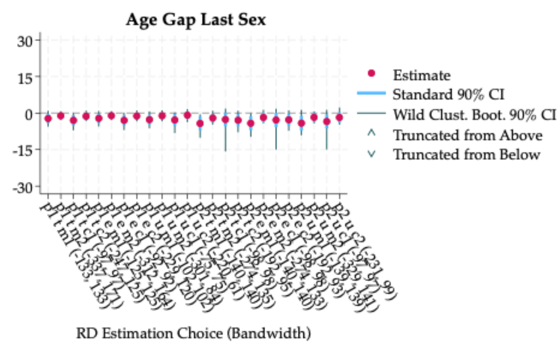
(a) Age Gap at Last Sex: Women



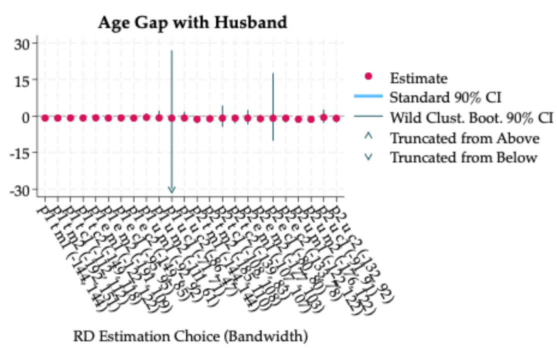
(b) Age Gap at Last Sex: Married Women



(c) Age Gap at Last Sex: Men



(d) Age Gap at Last Sex: Married Men



(e) Age Gap with Husband: Women

Notes: The graphs show RD estimates and different 90-percent confidence intervals for the respective outcomes and groups when using linear (p1) or quadratic (p2) RD polynomials, triangular (t), Epanechnikov (e), or uniform (u) weighting kernels, and symmetric MSE-optimal (m1), asymmetric MSE-optimal (m2), symmetric CER-optimal (c1), or asymmetric CER-optimal (c2) RD bandwidth selection methods. Bandwidths selected for each combination of parameters are in parentheses.

D4. Results Using Data Collapsed into Clusters: Marriage

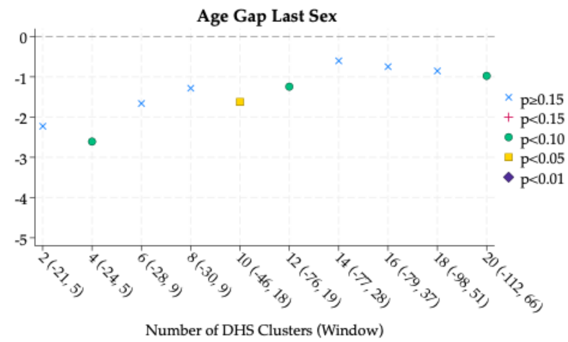
Table D1: Age-Disparate Partnerships [23]

Male-Female Age Gap with:	Last Sexual Partner				Spouse
	Women 15-49		Men 15-49		Women
	All	Married	All	Married	
	(1)	(2)	(3)	(4)	(5)
Panel A. Optimal Bandwidth					
Sending Region	-3.03	-2.46	-1.29	-1.41	-0.56
	(1.38)	(1.08)	(1.25)	(1.68)	(0.28)
	[0.73]	[0.75]	[1.09]	[1.74]	[0.22]
Observations	14	22	41	35	18
Bandwidth	65.4	94.1	133.1	132.6	144.5
Restricting Region Mean	7.50	7.33	5.79	7.10	8.39
Restricting Region SD	1.15	1.27	2.49	1.92	0.58
Panel B. Constant Bandwidth					
Sending Region	-1.79	-1.60	-1.31	-1.48	-0.42
	(0.91)	(0.92)	(1.33)	(1.78)	(0.44)
	[0.79]	[0.86]	[1.17]	[1.82]	[0.29]
Observations	30	30	38	32	14
Bandwidth	125	125	125	125	125
Restricting Region Mean	7.05	7.17	5.80	7.11	8.39
Restricting Region SD	1.16	1.22	2.50	1.91	0.60
Panel C. Randomization Inference					
Sending Region	-1.75	-1.77	-2.00	-3.50	-0.99
	{0.09}	{0.09}	{0.24}	{0.08}	{0.04}
Observations	10	10	10	10	10
Bandwidth	-46, 18	-46, 18	-28, 18	-30, 18	-77, 77
Restricting Region Mean	7.30	7.43	5.55	7.04	8.44
Restricting Region SD	1.09	1.16	2.67	1.82	0.73

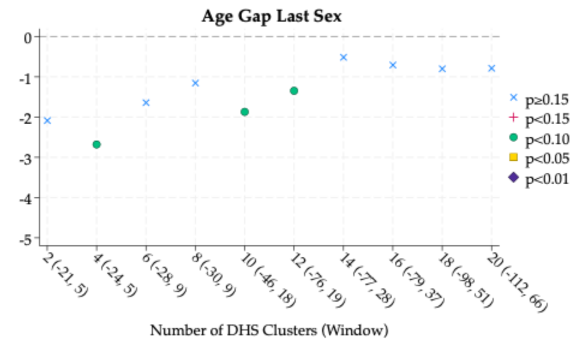
Notes: The table replicates Table 3 using data collapsed to DHS survey cluster-level means.

D5. Marriage Randomization Inference: Varying Windows

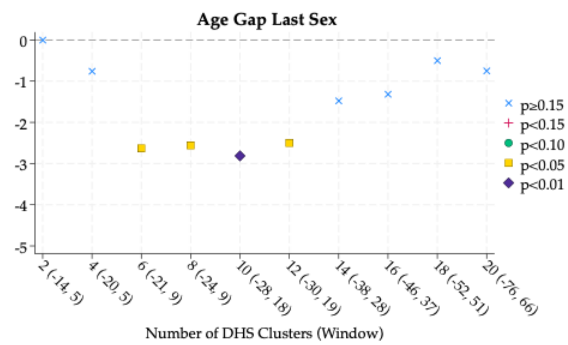
Figure D4: Age-Disparate Relationships [23]



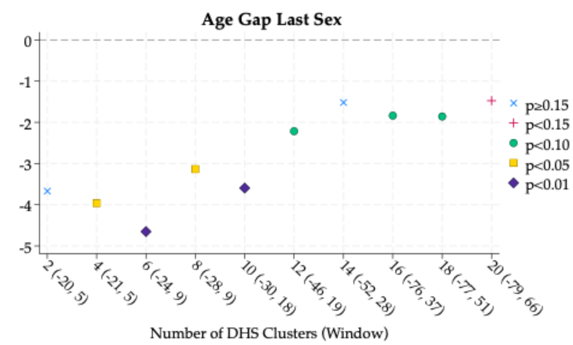
(a) Age Gap at Last Sex: Women



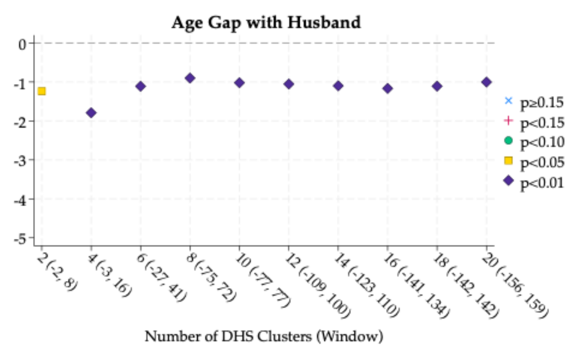
(b) Age Gap at Last Sex: Married Women



(c) Age Gap at Last Sex: Men



(d) Age Gap at Last Sex: Married Men



(e) Age Gap with Husband: Women

Notes: The graphs show randomization inference estimates and statistical significance for the respective outcomes and groups when including a range of DHS survey clusters in the sample. Randomization inference windows are in parentheses.

D6. Marriage Randomization Inference: Placebo Windows

Table D2: Age-Disparate Relationships [23]

Male-Female Age Gap with:	Last Sexual Partner				Spouse
	Women 15-49		Men 15-49		Women
	All	Married	All	Married	
	(1)	(2)	(3)	(4)	(5)
Panel A. Restricting Region					
Placebo Treatment	0.76	1.06	1.93	1.89	-0.03
	{0.32}	{0.20}	{0.13}	{0.21}	{0.85}
Observations	158	138	68	53	5,809
Clusters	10	10	10	10	10
Placebo Cutoff	-61.4	-61.4	-29.0	-38.1	-93.4
Bandwidth	-21, -112	-21, -112	-14, -76	-20, -79	-2, -156
Placebo Control Mean	6.58	6.49	4.83	6.00	8.38
Placebo Control SD	4.37	4.26	4.85	4.80	6.29
Panel B. Sending Region					
Placebo Treatment	0.46	1.01	2.62	2.96	0.07
	{0.53}	{0.27}	{0.01}	{0.02}	{0.69}
Observations	152	125	61	51	6,921
Clusters	10	10	10	10	10
Placebo Cutoff	18.5	18.5	18.5	18.5	88.5
Bandwidth	5, 66	5, 66	5, 66	5, 66	8, 159
Placebo Control Mean	5.71	5.68	3.94	4.29	7.32
Placebo Control SD	4.74	4.97	3.79	3.98	6.78

Notes: The table replicates Table 3 Panel C when moving the border 5 clusters north into the former restricting region (Panel A) or 5 clusters south into the former sending region (Panel B).

D7. Placebo Test: Niassa Company Concession

Table D3: Partner Age Gap Results: Niassa Company Border [23]

Male-Female Age Gap with:	Last Sexual Partner				Spouse
	Women 15-49		Men 15-49		Women
	All	Married	All	Married	
	(1)	(2)	(3)	(4)	(5)
Panel A. Optimal Bandwidth					
Sending Region	-1.19	-1.01	0.22	-0.23	0.86
	(0.97)	(1.12)	(0.82)	(0.99)	(0.32)
	[0.96]	[1.11]	[0.77]	[0.96]	[0.28]
Observations	1,497	1,247	924	684	22,653
Clusters	102	102	116	101	30
Bandwidth	96.6	96.3	90.2	89.8	47.7
Wild Cluster Bootstrap *p*-value	0.35	0.59	0.82	0.86	0.14
Restricting Region Mean	6.28	6.32	5.32	5.51	6.30
Restricting Region SD	4.94	5.03	4.31	4.42	5.98
Panel B. Constant Bandwidth					
Sending Region	-2.11	-1.88	0.41	-0.03	0.85
	(1.39)	(1.59)	(1.10)	(1.25)	(0.32)
	[1.39]	[1.54]	[0.92]	[1.10]	[0.27]
Observations	660	548	436	326	27,453
Clusters	43	43	57	48	33
Bandwidth	50	50	50	50	50
Wild Cluster Bootstrap *p*-value	0.23	0.46	0.78	0.98	0.11
Restricting Region Mean	6.13	6.18	4.98	5.40	6.54
Restricting Region SD	4.94	5.10	4.17	4.28	6.03
Panel C. Randomization Inference					
Sending Region	-2.23	-2.18	0.63	0.71	0.78
	{0.03}	{0.05}	{0.54}	{0.55}	{0.00}
Observations	111	99	71	61	7,620
Clusters	10	10	10	10	10
Window	-8, 11	-8, 11	-8, 11	-8, 11	-14, 19
Niassa Company Mean	7.09	7.08	4.43	4.55	5.92
Niassa Company SD	5.78	5.99	3.93	4.00	5.85

Notes: The table replicates Table 3 using the former Niassa Company's border with territory ruled by the colonial state in northern Mozambique. See Appendix B1 for a map.

Appendix E. Additional Results: Proximate Causes

E1. HIV Risk Factors Associated with Age-Disparate Relationships

Table E1: Risk Factors Associated with Age Disparities [24]

	Men	Women				
	Multiple Partners (1)	Polygynous Marriage (2)	Virgin: Ages 15-24 (3)	Condom Last Sex (4)	Forced Sex Ever (5)	Decision Share (6)
Panel A. Optimal Bandwidth						
Sending Region	-0.085	-0.043	-0.033	0.066	-0.028	0.023
	(0.084)	(0.051)	(0.035)	(0.036)	(0.033)	(0.071)
	[0.068]	[0.068]	[0.045]	[0.051]	[0.030]	[0.071]
Observations	623	444	475	538	347	604
Clusters	71	26	56	29	30	38
Bandwidth	175.2	87.6	154.4	104.8	127.8	146.1
Wild Cluster Bootstrap p-value	0.34	0.62	0.49	0.20	0.51	0.77
Restricting Region Mean	0.242	0.341	0.171	0.081	0.061	0.631
Panel B. Constant Bandwidth						
Sending Region	-0.033	-0.009	-0.057	0.035	-0.027	0.037
	(0.107)	(0.047)	(0.038)	(0.033)	(0.035)	(0.078)
	[0.089]	[0.058]	[0.046]	[0.035]	[0.030]	[0.077]
Observations	404	690	337	764	347	491
Clusters	40	40	40	40	30	30
Bandwidth	125	125	125	125	125	125
Wild Cluster Bootstrap p-value	0.78	0.91	0.31	0.33	0.53	0.66
Restricting Region Mean	0.219	0.328	0.143	0.075	0.061	0.649
Panel C. Randomization Inference						
Sending Region	-0.014	-0.053	-0.054	-0.014	-0.029	0.019
	{1.00}	{0.55}	{0.50}	{0.93}	{0.84}	{0.73}
Observations	138	180	108	185	89	128
Window	-28, 28	-28, 18	-38, 37	-28, 18	-28, 18	-28, 18
Restricting Region Mean	0.181	0.356	0.104	0.061	0.029	0.579

Notes: The outcome of interest for male respondents is whether he respondent has had multiple sexual partners. The outcomes of interest for female respondents are whether she is in a polygynous marriage, is a virgin, used a condom in her last sexual intercourse, and has ever had forced sexual contact as well as the share of household decisions she makes alone or is included in (on her own health, major household purchases, visiting her family, and how to spend her earnings). See the notes to Table 3.

E2. *Public-Sector Health Infrastructure*

Table E2: Public-Sector Health Facilities, 2018 [24]

	Any Facility (1)	Facilities (2)	Log(Facilities+1) (3)
Panel A. Optimal Bandwidth			
Sending Region	-0.018	-0.098	-0.031
	(0.095)	(0.198)	(0.101)
	[0.125]	[0.197]	[0.110]
Observations	171	146	146
Clusters	30	25	25
Bandwidth	135.3	112.5	115.8
Wild Cluster Bootstrap p-value	0.87	0.65	0.77
Restricting Region Mean	0.390	0.561	0.333
Restricting Region SD		0.862	0.449
Panel B. Constant Bandwidth			
Sending Region	0.007	-0.144	-0.045
	(0.103)	(0.192)	(0.098)
	[0.129]	[0.200]	[0.109]
Observations	168	168	168
Clusters	29	29	29
Bandwidth	125	125	125
Wild Cluster Bootstrap p-value	0.96	0.47	0.65
Restricting Region Mean	0.400	0.613	0.350
Restricting Region SD		0.985	0.474
Panel C. Randomization Inference			
Sending Region	-0.040	-0.240	-0.092
	{1.00}	{0.44}	{0.55}
Observations	50	50	50
Window	-42, 35	-42, 35	-42, 35
Restricting Region Mean	0.360	0.600	0.330
Restricting Region SD		1.041	0.495

Notes: The outcomes of interest for 2018 public-sector health facilities (Maina et al., 2019) are whether a gridcell contains any, the number within a gridcell, and its log. See the notes to Table 1.

E3. Landmines

Table E3: Known and Suspected Landmines, October 2007 [24]

	Any Landmine (1)	Landmines (2)	Log(Landmines+1) (3)
Panel A. Optimal Bandwidth			
Sending Region	0.042	-0.364	-0.074
	(0.134)	(0.587)	(0.216)
	[0.103]	[0.379]	[0.143]
Observations	203	200	206
Clusters	38	36	38
Bandwidth	169.3	157.7	174.9
Wild Cluster Bootstrap p-value	0.78	0.66	0.80
Restricting Region Mean	0.303	0.876	0.371
Restricting Region SD		2.083	0.630
Panel B. Constant Bandwidth			
Sending Region	0.065	-0.152	-0.022
	(0.136)	(0.586)	(0.217)
	[0.098]	[0.300]	[0.121]
Observations	168	168	168
Clusters	29	29	29
Bandwidth	125	125	125
Wild Cluster Bootstrap p-value	0.68	0.84	0.94
Restricting Region Mean	0.293	0.880	0.350
Restricting Region SD		2.193	0.629
Panel C. Randomization Inference			
Sending Region	0.040	-0.280	-0.039
	{0.94}	{0.61}	{0.94}
Observations	50	50	50
Window	-42, 35	-42, 35	-42, 35
Restricting Region Mean	0.240	0.800	0.321
Restricting Region SD		1.803	0.638

Notes: The outcomes of interest for October 2007 known and suspected landmines (Republic of Mozambique, 2008) are whether a gridcell contains any, the number within a gridcell, and its log. See the notes to Table 1.

E4. Civil War Violence: Global Terrorism Database

Table E4: Violent Events and Deaths in Mozambique's Civil War [24]

	Any Event (1)	Log(Events+1) (2)	Any Death (3)	Log(Deaths+1) (4)
Panel A. Optimal Bandwidth				
Sending Region	-0.015	-0.021	-0.013	-0.031
	(0.015)	(0.021)	(0.014)	(0.039)
	[0.012]	[0.019]	[0.012]	[0.035]
Observations	110	114	114	115
Clusters	20	20	20	20
Bandwidth	81.9	85.7	84.7	87.6
Wild Cluster Bootstrap p-value	0.32	0.45	0.40	0.48
Restricting Region Mean	0.000	0.000	0.000	0.000
Restricting Region SD		0.000		0.000
Panel B. Constant Bandwidth				
Sending Region	0.025	0.015	0.013	0.039
	(0.019)	(0.014)	(0.015)	(0.045)
	[0.019]	[0.015]	[0.015]	[0.045]
Observations	168	168	168	168
Clusters	29	29	29	29
Bandwidth	125	125	125	125
Wild Cluster Bootstrap p-value	0.23	0.30	0.54	0.54
Restricting Region Mean	0.013	0.009	0.000	0.000
Restricting Region SD		0.080		0.000
Panel C. Randomization Inference				
Sending Region	0.000	0.000	0.000	0.000
	{1.00}	{1.00}	{1.00}	{1.00}
Observations	50	50	50	50
Window	-42, 35	-42, 35	-42, 35	-42, 35
Restricting Region Mean	0.000	0.000	0.000	0.000
Restricting Region SD		0.000		0.000

Notes: The outcomes of interest for GTD violent events and deaths (START, 2022) are whether a gridcell contains any, the number within a gridcell, and its log. See the notes to Table 1.

E5. *Civil War Violence: Uppsala Conflict Data Program*

Table E5: Violent Events and Deaths in Mozambique's Civil War [24]

	Any Event (1)	Log(Events+1) (2)	Any Death (3)	Log(Deaths+1) (4)
Panel A. Optimal Bandwidth				
Sending Region	-0.038	-0.020	0.015	0.029
	(0.073)	(0.053)	(0.061)	(0.122)
	[0.046]	[0.031]	[0.040]	[0.079]
Observations	146	138	174	151
Clusters	25	24	30	27
Bandwidth	115.0	101.5	139.0	119.5
Wild Cluster Bootstrap p-value	0.46	0.58	0.68	0.74
Restricting Region Mean	0.030	0.022	0.039	0.027
Restricting Region SD		0.122		0.219
Panel B. Constant Bandwidth				
Sending Region	-0.046	-0.069	0.003	0.027
	(0.073)	(0.059)	(0.065)	(0.122)
	[0.047]	[0.047]	[0.039]	[0.081]
Observations	168	168	168	168
Clusters	29	29	29	29
Bandwidth	125	125	125	125
Wild Cluster Bootstrap p-value	0.34	0.14	0.91	0.75
Restricting Region Mean	0.067	0.046	0.040	0.057
Restricting Region SD		0.174		0.287
Panel C. Randomization Inference				
Sending Region	-0.040	-0.028	0.000	0.000
	{1.00}	{1.00}	{1.00}	{1.00}
Observations	50	50	50	50
Window	-42, 35	-42, 35	-42, 35	-42, 35
Restricting Region Mean	0.080	0.055	0.040	0.072
Restricting Region SD		0.192		0.358

Notes: The outcomes of interest for UCDP violent events and deaths (Sundberg and Melander, 2013) are whether a gridcell contains any, the number within a gridcell, and its log. See the notes to Table 1.

E6. HIV Risk Factors Not Linked to Southern Mozambican History

Table E6: Unrelated HIV Risk Factors [25]

	Genital Ulcer in Last Year		Paid for Sex	Medically Circumcised
	Women	Men	Men	Men
	(1)	(2)	(3)	(4)
Panel A. Optimal Bandwidth				
Sending Region	0.059	0.027	-0.012	0.024
	(0.027)	(0.014)	(0.091)	(0.157)
	[0.028]	[0.017]	[0.070]	[0.075]
Observations	414	235	156	585
Clusters	19	26	29	77
Bandwidth	58.1	87.5	127.1	188.2
Wild Cluster Bootstrap p-value	0.07	0.21	0.84	0.89
Restricting Region Mean	0.005	0.008	0.047	0.154
Panel B. Constant Bandwidth				
Sending Region	0.044	0.025	-0.012	0.069
	(0.017)	(0.015)	(0.095)	(0.201)
	[0.019]	[0.018]	[0.072]	[0.092]
Observations	930	343	156	344
Clusters	40	39	29	39
Bandwidth	125	125	125	125
Wild Cluster Bootstrap p-value	0.05	0.26	0.84	0.75
Restricting Region Mean	0.008	0.006	0.047	0.234
Panel C. Randomization Inference				
Sending Region	0.043	0.026	0.011	0.052
	{0.10}	{0.47}	{1.00}	{0.49}
Observations	203	164	85	164
Window	-28, 18	-46, 39	-46, 39	-46, 39
Restricting Region Mean	0.000	0.000	0.053	0.256

Notes: The outcomes of interest are whether a respondent reports having had a genital ulcer in the last year and whether a man reports having ever paid for sex and having been medically circumcised. See the notes to Table 3.

E7. Mediation Analysis of HIV RD Result

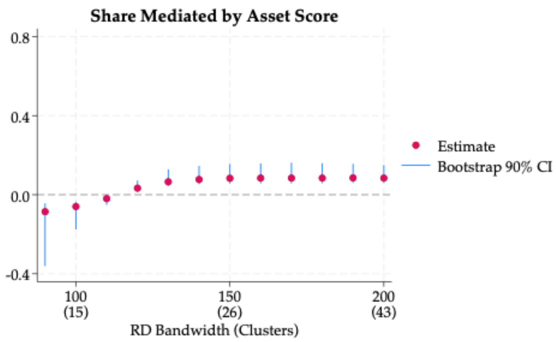
Table E7: Mediation Analysis of HIV RD Result [25]

	Outcome Variable: HIV Positive (Pooled)				
Mediating Variable:	Asset Score (1)	Years of School (2)	Age Gap Last Sex (3)	Multiple Partners (4)	Condom Last Sex (5)
Panel A. Optimal Bandwidth					
Mediation Effect	0.008	-0.004	-0.033	-0.001	-0.001
	[-0.016, 0.035]	[-0.015, 0.002]	[-0.069, -0.003]	[-0.006, 0.004]	[-0.008, 0.004]
Total Effect	-0.138	-0.119	-0.162	-0.128	-0.115
	[-0.234, -0.046]	[-0.200, -0.037]	[-0.263, -0.052]	[-0.204, -0.053]	[-0.203, -0.023]
Share of Total Mediated	-0.054	0.035	0.202	0.005	0.011
	[-0.152, -0.032]	[0.020, 0.100]	[0.123, 0.569]	[0.003, 0.012]	[0.006, 0.041]
Observations	610	719	291	798	610
Bandwidth	103.4	131.8	119.8	118	118.6
Clusters	15	23	17	20	20
Restricting Region Mean	0.202	0.207	0.194	0.211	0.215
Panel B. Constant Bandwidth					
Mediation Effect	-0.007	-0.004	-0.032	-0.001	-0.001
	[-0.023, 0.006]	[-0.015, 0.002]	[-0.066, -0.004]	[-0.008, 0.003]	[-0.007, 0.003]
Total Effect	-0.127	-0.118	-0.148	-0.127	-0.114
	[-0.191, -0.062]	[-0.203, -0.033]	[-0.248, -0.041]	[-0.194, -0.061]	[-0.190, -0.033]
Share of Total Mediated	0.052	0.034	0.211	0.011	0.007
	[0.035, 0.107]	[0.019, 0.108]	[0.123, 0.624]	[0.007, 0.022]	[0.004, 0.022]
Observations	842	677	297	842	645
Bandwidth	125	125	125	125	125
Clusters	21	21	18	21	21
Restricting Region Mean	0.211	0.207	0.194	0.211	0.215
Panel C. Optimal Bandwidth Using Constant Sample					
Mediation Effect	-0.008	0.000	-0.033	-0.003	-0.004
	[-0.030, 0.005]	[-0.006, 0.006]	[-0.068, -0.003]	[-0.014, 0.005]	[-0.017, 0.004]
Total Effect	-0.124	-0.139	-0.146	-0.148	-0.152
	[-0.239, -0.008]	[-0.255, -0.019]	[-0.260, -0.020]	[-0.267, -0.031]	[-0.272, -0.024]
Share of Total Mediated	0.063	-0.001	0.217	0.017	0.026
	[0.029, 0.316]	[-0.005, -0.001]	[0.112, 0.867]	[0.009, 0.064]	[0.014, 0.107]
Observations	317	295	289	289	289
Bandwidth	131.2	122.3	119.9	119.2	118.1
Clusters	19	18	17	17	17
Restricting Region Mean	0.190	0.190	0.190	0.190	0.190

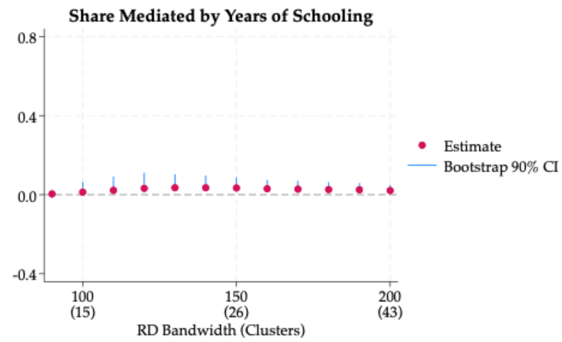
Notes: Bootstrapped 90-percent confidence intervals are in brackets. In Panel A, the RD bandwidths are MSE-optimal for the sample of observations with HIV blood tests and non-missing values for the mediator of interest. In Panel C, the RD bandwidth is MSE-optimal for the sample of observations with HIV blood tests and non-missing values for all 5 mediators. Means and standard deviations are calculated using observations within the RD bandwidth.

E8. RD Mediation Analysis: Varying Local Linear Bandwidths

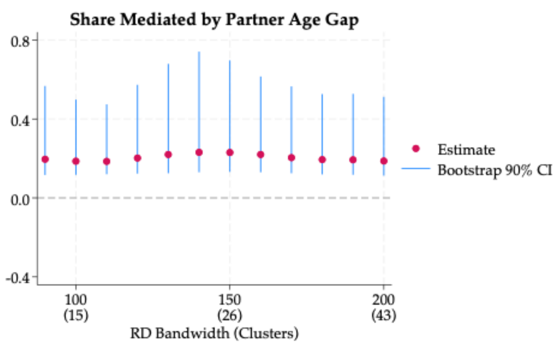
Figure E1: RD Mediation Analysis Estimates [25]



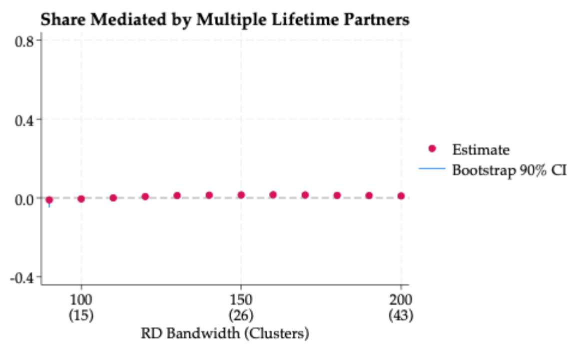
(a) Asset Score



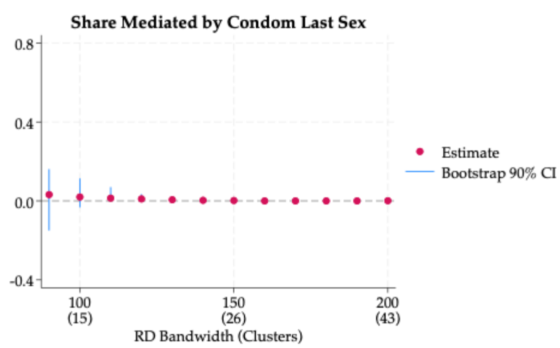
(b) Years of Schooling



(c) Age Gap at Last Sex



(d) Multiple Lifetime Partners

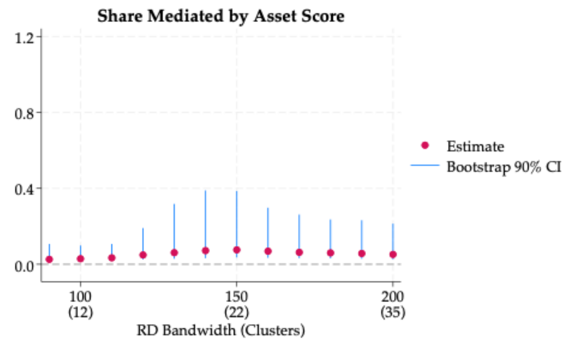


(e) Condom Last Sex

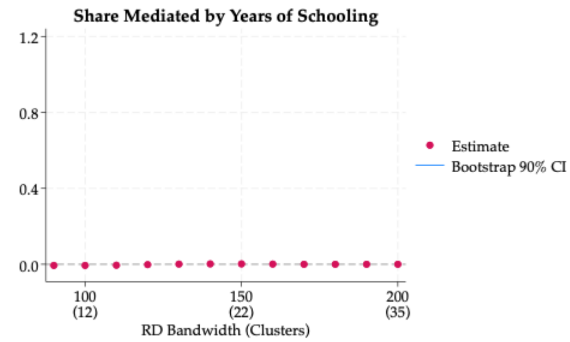
Notes: The graphs show mediation analysis RD estimates and 90-percent bootstrapped confidence intervals for the respective outcomes across a range of bandwidths using observations with HIV blood tests and non-missing values for the mediator of interest.

E9. RD Mediation Analysis: Varying Local Linear Bandwidth with Constant Sample

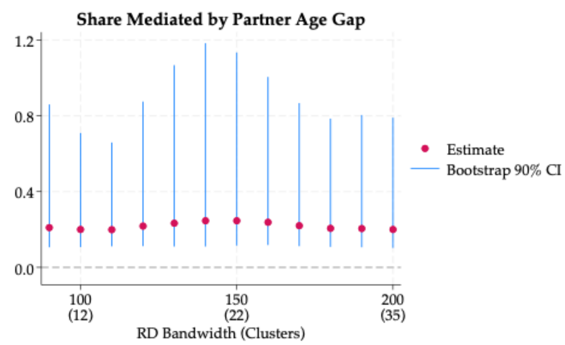
Figure E2: RD Mediation Analysis Estimates with Constant Sample [25]



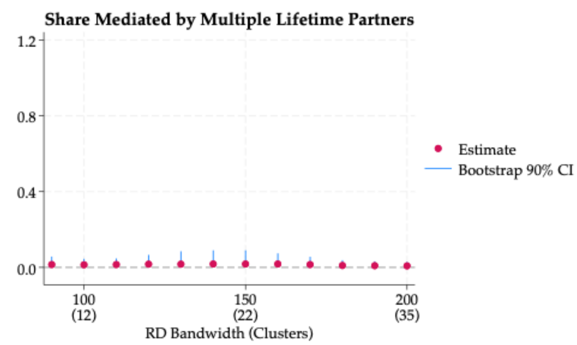
(a) Asset Score



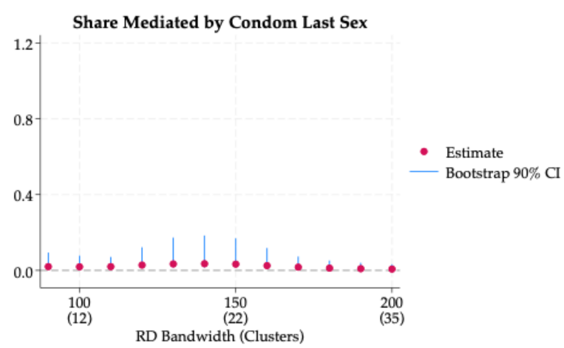
(b) Years of Schooling



(c) Age Gap at Last Sex



(d) Multiple Lifetime Partners



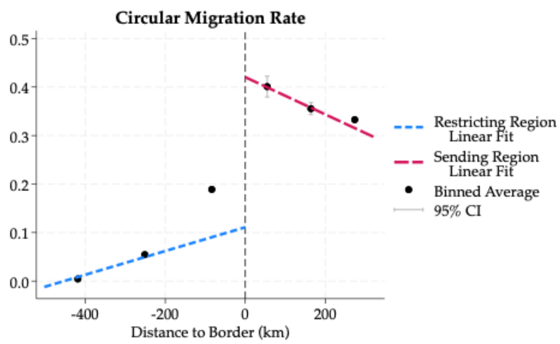
(e) Condom Last Sex

Notes: The graphs show mediation analysis RD estimates and 90-percent bootstrapped confidence intervals for the respective outcomes across a range of bandwidths using observations with HIV blood tests and non-missing values for all mediating variables.

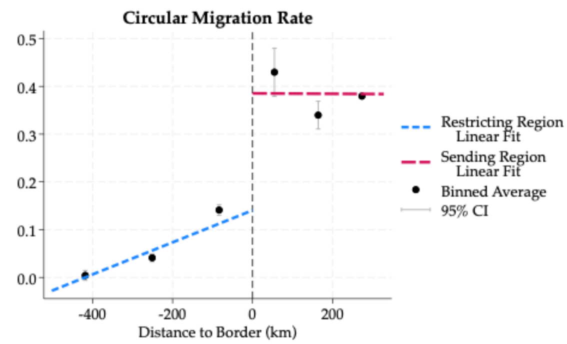
Appendix F. Robustness Checks: Historical Channels

F1. *1940 Circular Migration RD Results by Age Group*

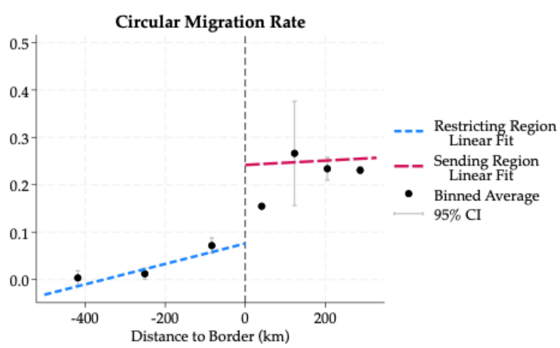
Figure F1: 1940 Circular Migration Rates [28]



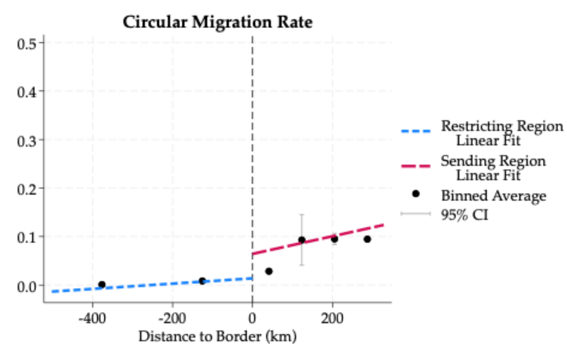
(a) Men 15-24



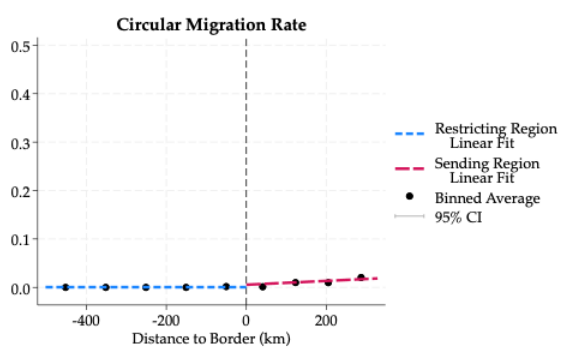
(b) Men 25-34



(c) Men 35-44



(d) Men 45-54

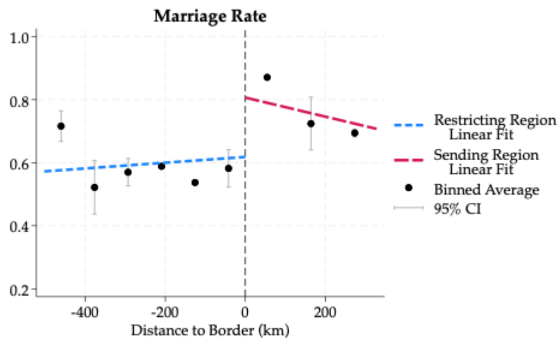


(e) Men 55-64

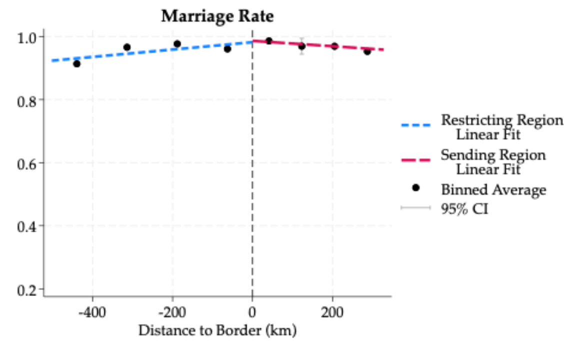
Notes: The graphs show circular migration rates for men in the respective age groups. See the notes to Figure 8.

F2. Marriage RD Results by Age Group

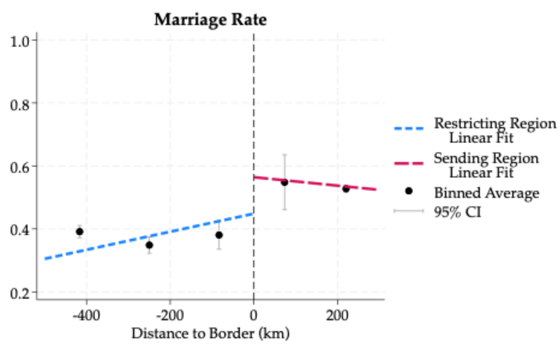
Figure F2: Marriage Rates [28]



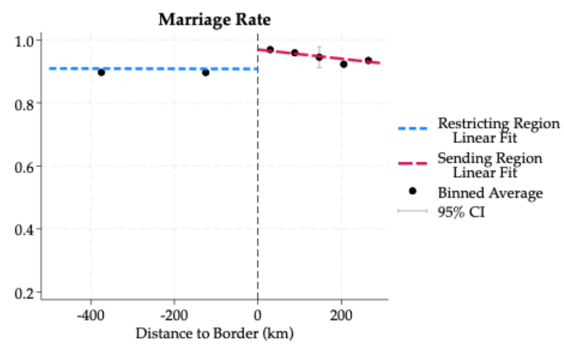
(a) 1940: Men 15-34



(b) 1940: Men 35-54



(c) 1960: Men 15-34

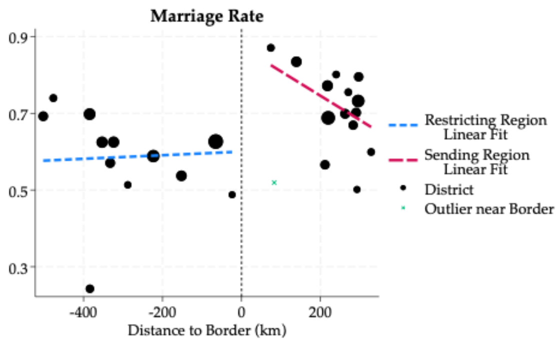


(d) 1960: Men 35-54

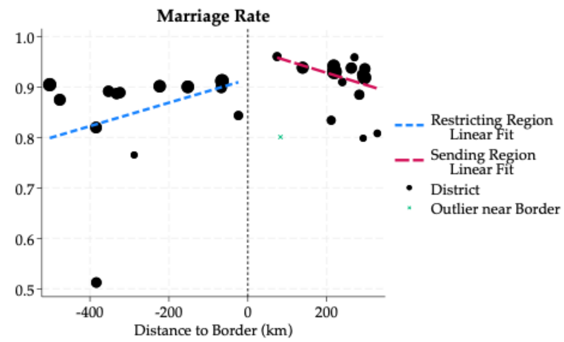
Notes: The graphs show marriage rates for men in the respective age groups. See the notes to Figure 8.

F3. 1940 RD Plots Highlighting Excluded Outliers

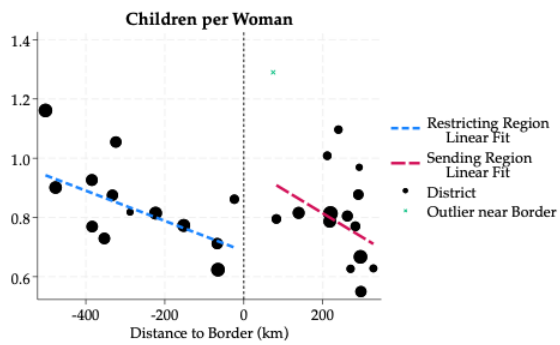
Figure F3: 1940 RD Plots [31]



(a) Marriage Rate: Men 15-34



(b) Marriage Rate: Women 15-34

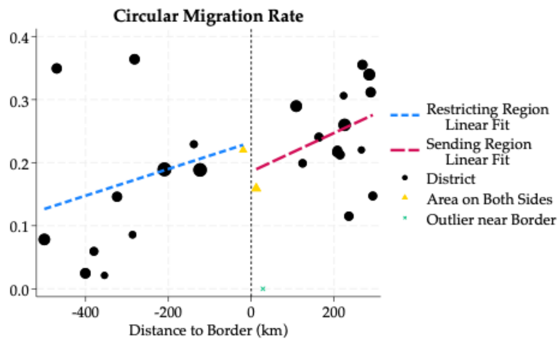


(c) Children per Women

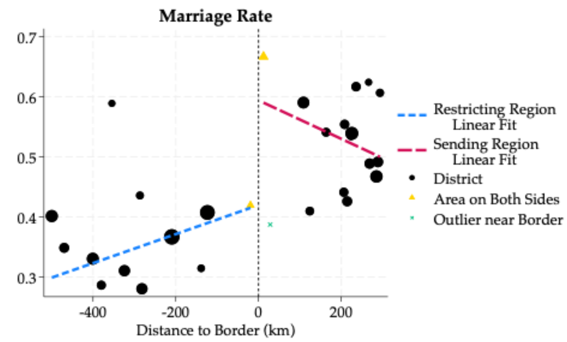
Notes: The graphs show each group's outcome in each district, which is weighted by the size of the group in it. A district excluded as an outlier is shown as a green x. The running variable is a district's distance to the historical border and the linear fits on each side are estimated using a triangular kernel.

F4. 1960 RD Plots Highlighting Excluded Outliers

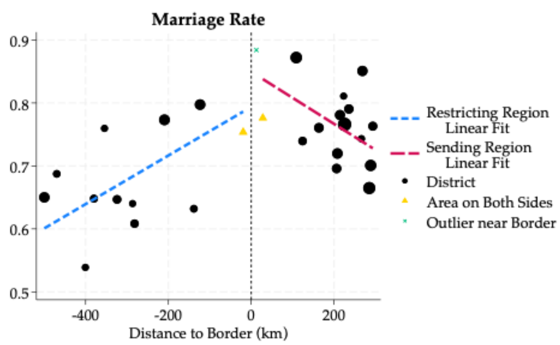
Figure F4: 1960 RD Plots [31]



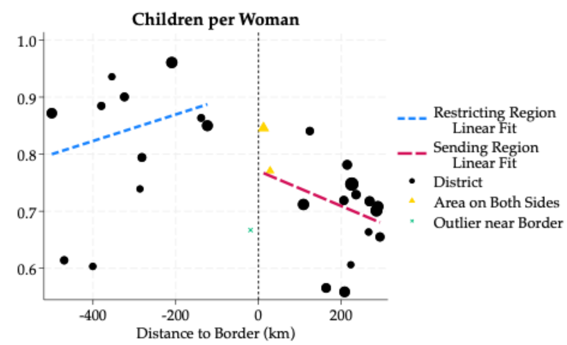
(a) Circular Migration Rate



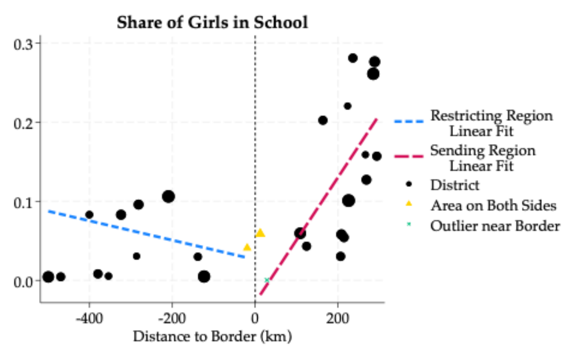
(b) Marriage Rate: Men 15-34



(c) Marriage Rate: Women 15-34



(d) Children per Women

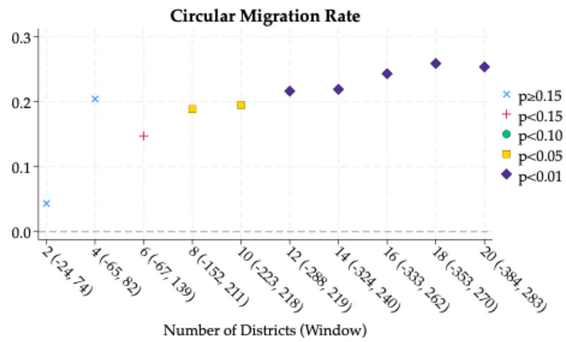


(e) Schooling Rates: Girls

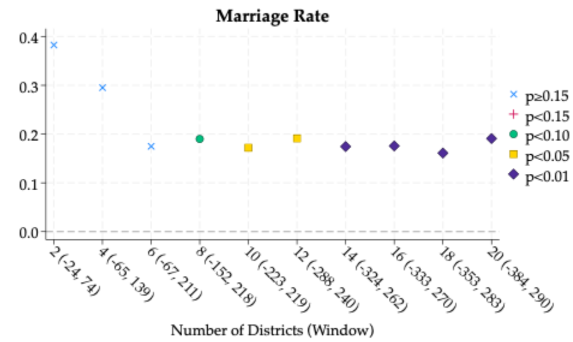
Notes: The graphs show each group's outcome in each district, which is weighted by the size of the group in it. A district with area on both sides of the former border is shown as a yellow triangle, and district excluded as an outlier is shown as a green x. The running variable is a district's distance to the historical border and the linear fits on each side are estimated using a triangular kernel.

F5. 1940 Randomization Inference: Varying Windows

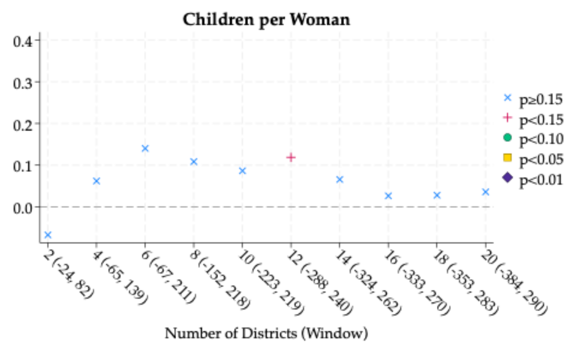
Figure F5: 1940 Results [31]



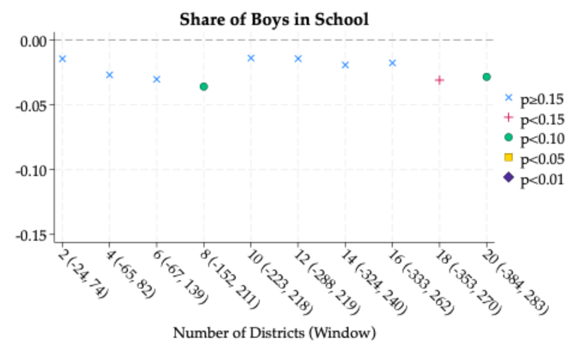
(a) Circular Migration Rate



(b) Marriage Rate: Men 15-34



(c) Children per Woman

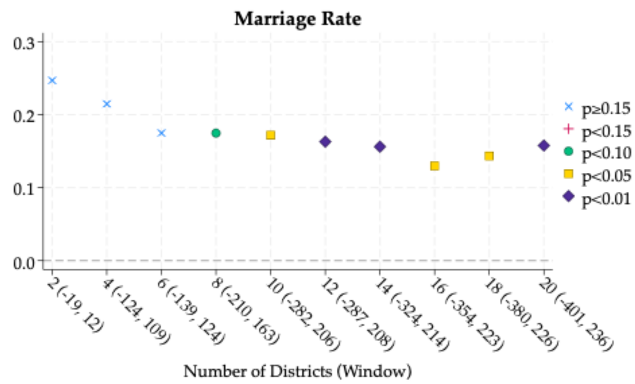


(d) Schooling Rates: Boys

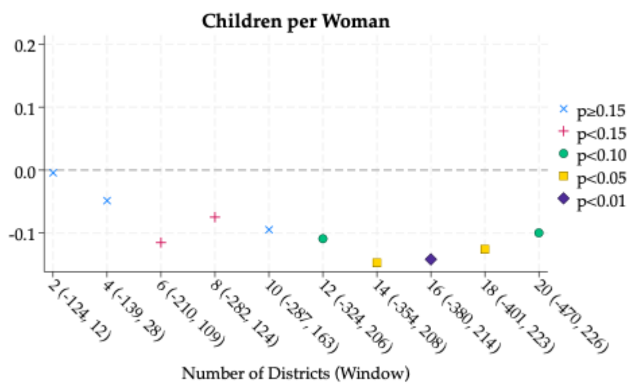
Notes: The graphs show randomization inference estimates and statistical significance for the respective outcomes and groups when including a range of districts in the sample. Randomization inference windows are in parentheses.

F6. 1960 Randomization Inference: Varying Windows

Figure F6: 1960 Results [31]



(a) Marriage Rate: Men 15-34



(b) Children per Woman

Notes: The graphs show randomization inference estimates and statistical significance for the respective outcomes and groups when including a range of districts in the sample. Randomization inference windows are in parentheses.

F7. 1940 Randomization Inference: Placebo Windows

Table F1: 1940 Outcomes [31]

	Men Migrants (1)	Women Farming (2)	Men Married (3)	Women Married (4)	Children per Woman (5)	Boys in School (6)	Girls in School (7)
Panel A. Restricting Region							
Placebo Treatment	0.115	0.007	0.059	0.102	-0.092	-0.013	-0.004
	{0.14}	{0.81}	{0.52}	{0.16}	{0.21}	{0.71}	{0.51}
Observations	10	10	10	10	10	10	10
Placebo Cutoff	-255.7	-255.7	-255.7	-255.7	-255.7	-255.7	
Window	-24, -384	-24, -384	-24, -384	-24, -384	-24, -384	-24, -384	-24, -384
Placebo Control Mean	0.000	0.950	0.520	0.790	0.850	0.050	0.010
Placebo Control SD					0.130		
Panel B. Sending Region							
Placebo Treatment	0.003	-0.005	-0.021	0.002	-0.009	-0.016	-0.001
	{0.98}	{0.68}	{0.72}	{0.97}	{0.91}	{0.64}	{0.86}
Observations	10	10	10	10	10	10	10
Placebo Cutoff	218.5	218.5	229.5	229.5	218.5	218.5	
Window	74, 283	74, 283	74, 290	74, 290	82, 290	74, 283	74, 283
Placebo Control Mean	0.310	0.950	0.750	0.920	0.840	0.020	0.010
Placebo Control SD					0.090		

Notes: The table replicates Table 4 Panel B when moving the border 5 districts north into the restricting region (Panel A) or 5 districts south into the sending region (Panel B).

F8. 1960 Randomization Inference: Placebo Windows

Table F2: 1940 Outcomes [31]

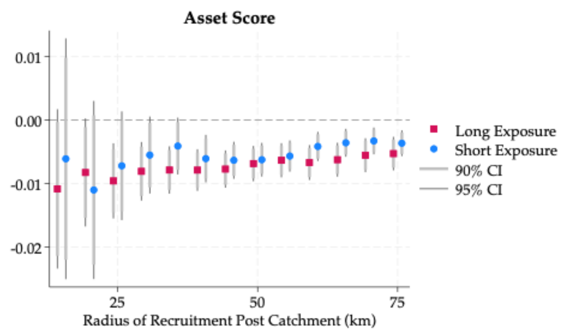
	Men Migrants (1)	Women Farming (2)	Men Married (3)	Women Married (4)	Children per Woman (5)	Boys in School (6)	Girls in School (7)
Panel A. Restricting Region							
Placebo Treatment	0.171	-0.002	-0.033	0.066	0.054	-0.038	0.013
	{0.00}	{0.17}	{0.64}	{0.29}	{0.46}	{0.27}	{0.61}
Observations	10	10	10	10	10	10	10
Placebo Cutoff	-284.2	-284.2	-284.2	-284.2	-284.2	-284.2	
Window	-19, -401	-19, -401	-19, -401	-19, -401	-124, -470	-19, -401	-19, -401
Placebo Control Mean	0.070	1.000	0.390	0.650	0.790	0.120	0.040
Placebo Control SD					0.160		
Panel B. Sending Region							
Placebo Treatment	0.002	0.002	0.004	0.005	-0.064	-0.004	0.064
	{0.99}	{0.49}	{0.93}	{0.84}	{0.34}	{0.91}	{0.19}
Observations	10	10	10	10	10	10	10
Placebo Cutoff	207.2	184.8	207.2	207.2	207.2	184.8	
Window	12, 236	12, 226	12, 236	28, 236	12, 226	12, 226	12, 236
Placebo Control Mean	0.220	1.000	0.530	0.770	0.750	0.110	0.080
Placebo Control SD					0.120		

Notes: The table replicates Table 4 Panel D when moving the border 5 districts north into the former restricting region (Panel A) or 5 districts south into the former sending region (Panel B).

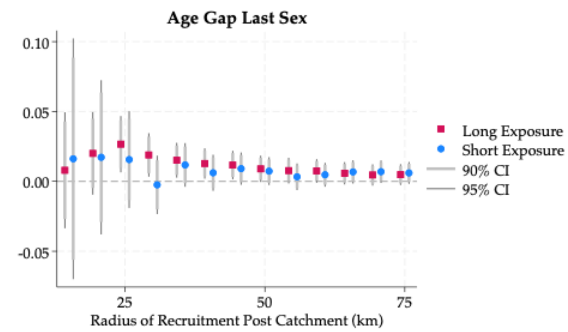
Appendix G. Robustness Checks: Effects of Circular Migration across Southern Africa

G1. Asset Ownership and Age-Disparate Relationships

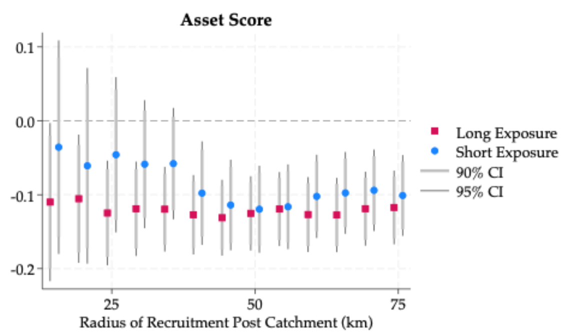
Figure G1: Varying Catchment Radius and Distance Measure [34]



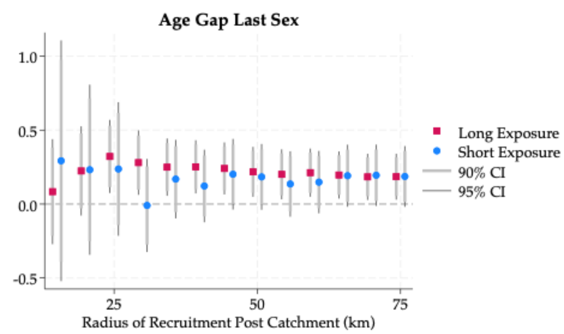
(a) Asset Score: Distance to Post



(b) Partner Age Gap: Distance to Post



(c) Asset Score: Log Distance to Post

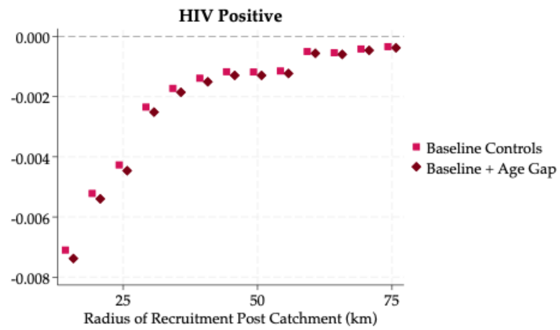


(d) Partner Age Gap: Log Distance to Post

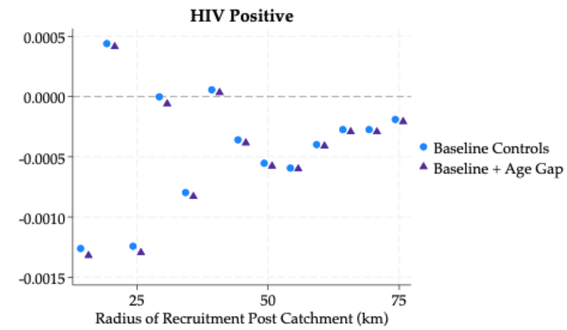
Notes: The graphs show regression estimates and 90- and 95-percent confidence intervals for the respective outcomes and measures of distance across a range of catchment radii. See the notes to Figure 9.

G2. Suppression of HIV-Migration Link by Age-Disparate Relationships

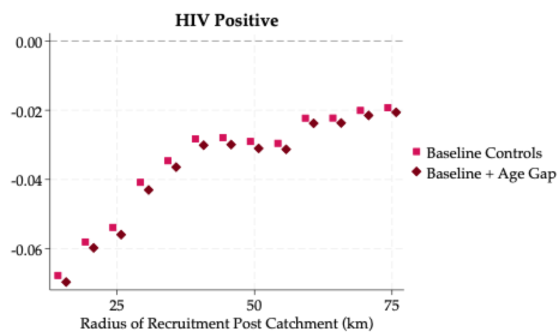
Figure G2: Varying Catchment Radius and Distance Measure [34]



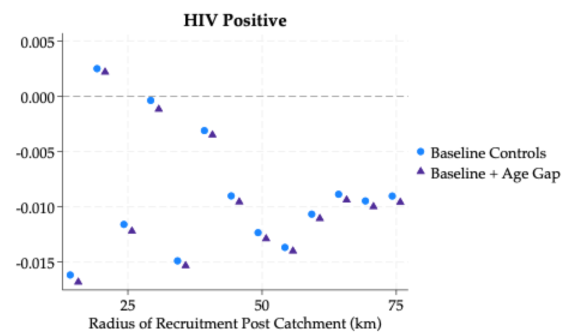
(a) HIV Positive: Long-Exposure Countries Using Distance to Post



(b) HIV Positive: Short-Exposure Countries Using Distance to Post



(c) HIV Positive: Long-Exposure Countries Using Log Distance to Post



(d) HIV Positive: Short-Exposure Countries Using Log Distance to Post

Notes: The graphs show regression estimates for the respective outcomes and measures of distance across a range of catchment radii. Lighter-colored shapes on the left side of each pair are estimates including baseline controls only. Darker-colored shapes on the right side of each pair are estimates baseline controls and partner age gaps. Confidence intervals are omitted to make the differences between estimates apparent. See the notes to Figure 9.