

Lakes and Economic Development: Evidence from the Permanent Shrinking of Lake Chad

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Abstract

There is a limited understanding of the role lakes play in economic development, despite lakeshore communities representing 40% of the global population. This knowledge gap is critical as numerous lakes worldwide are shrinking due to climate change. To shed light on the future economic effects of climate change through the *global lake recession phenomenon* that it engenders, we focus on Lake Chad, which used to be the 11th-largest lake in the world. This lake, which was the size of El Salvador, Israel plus the West Bank and Gaza, or Massachusetts, shrunk by 90% for exogenous reasons between 1963 and 1990, providing a historical example of the lake recession phenomenon. The water supply decreased and the land supply increased, generating ambiguous effects. We construct a novel data set tracking population patterns at a fine spatial level from the 1940s to the 2010s for Cameroon, Chad, Nigeria, and Niger – home to 25% of Africa's population –. Difference-in-differences specifications show much slower growth close to the lake after it started shrinking. These effects persisted two decades after it stopped shrinking, implying limited adaptation. The negative water supply effects on fishing, herding, and farming outweighed the growth in land supply and other positive effects. These results are substantiated using historical data on local economic development, environmental change, infrastructure, and conflict. Given the limitations of reduced-form specifications, we develop a dynamic quantitative spatial model and find aggregate losses of 2.7%, which increases to 10% in Lake Chad areas. The model allows us to study non-local effects, further examine mechanisms, study the role of aggravating and mitigating forces, and quantify the effects of policy proposals aimed at replenishing Lake Chad.

JEL Codes: Q56; Q54; Q15; Q20; R11; R12; O13; O44

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38% of the world's population live, and 43% of nighttime lights are located, within 90 km ($\approx$ 55 miles) from a coastline. Strikingly, lakes cover 4% of Earth's non-glaciated land area, but areas within 90 km from a lake concentrate 43% and 48% of global population and lights, implying that lakes might be as important economically as coastlines.¹

While lakes are valued as amenities in developed economies, lakes remain significant productive assets in primary sector-oriented developing economies, due to their roles in fishing, transport, or as a source of water for herders and farmers (UNEP, 2006). Sub-Saharan Africa (SSA) houses 10 of the 50 largest lakes in the world. While 26% of SSA's population lives within 90 km from the coast, 42% of its population lives close to a lake. Their economic role has also increased over time; the proportion of SSA's population living close to a lake is two percentage points higher now than in 1975.²

Due to reduced rainfall and higher temperatures, half of large lakes in the world are shrinking (Yao et al., 2023; The Guardian, 2023b). There are examples in the U.S. (Appx. Section B): Lake Tahoe, Pyramid Lake, Lake Powell, the Great Salt Lake, the Salton Sea, Walker Lake, Mono Lake, and Lake Owens.³ There are examples in developing countries (Ibid.): the Dead Sea, Lake Tuz and Hamun Lake which are some of the Middle East's largest lakes, Qinghai Lake and Poyang Lake which are China's largest and 3rd largest lakes, Lakes Maracaibo, Titicaca and Poopo which are South America's largest, 2nd largest and 3rd largest lakes, and Lake Chapala, Mexico's largest lake.⁴ Using the data from Yao et al. (2023), 22% of the global population lives within 90 km from a drying lake, and 49% of drying lakes are located in dry areas in low or lower-middle-income countries.

Despite such facts, there are to our knowledge no economic studies on the importance of lakes for economic development or the economic effects of lake shrinkage.

Therefore, it is essential to design research methodologies that can help quantify the effects of lake recessions to predict the impacts of current and future climate change, as well as investigate the effects of policies that could help alleviate economic losses from such trends. Specifically, in the case of shrinking lakes, the water supply decreases and

¹L.A. is the coastal city that extends the most in the world from its coastline (by 90 km). We use "large lakes" as defined by WWF (2004), which includes "the 3,067 largest lakes ($\geq 50 \text{ km}^2$) and 654 largest reservoirs ($\geq 0.5 \text{ km}^3$) worldwide." We find 22%-27% for lakes larger than Lake Como (146 km^2). These facts hold with 75 km (Chicago is the lake city that extends the most from its shore). See Appx. Section A.

²Using lakes larger than Lake Como, we find 34% in 2015, which is ~ 1.5 p.p. higher than in 1975.

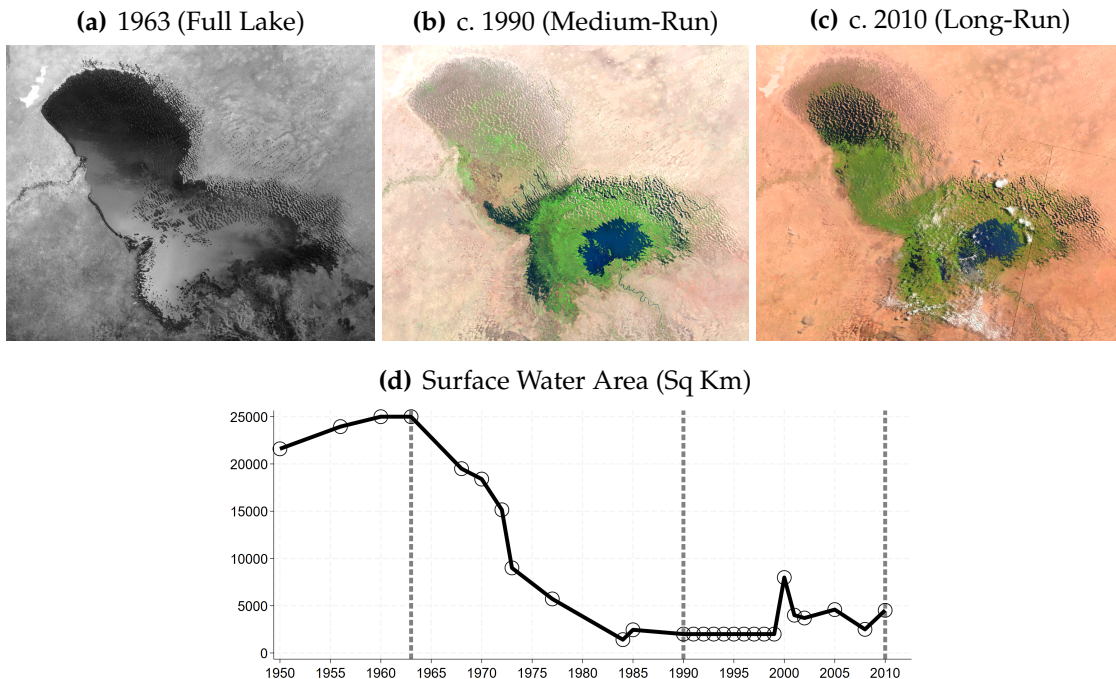
³"Climate change and rapid population growth are shrinking the [Great Salt] Lake [which has lost two-thirds of its area], creating a bowl of toxic dust that could poison the air around Salt Lake City" (New York Times, 2022). The dry lakebed of the disappeared Salton Sea has become "the biggest manmade source of hazardous dust in the U.S." and LA has spent \$1.2 billion dollars to try to suppress it (The Atlantic, 2015).

⁴The New York Times (2016) writes: "The birds that had fed on the fish had little choice but to abandon Lake Poopo, once Bolivia's second-largest but now just a dry, salty expanse. Many of the Uru-Murato people, who had lived off its waters for generations, left as well, joining a new global march of refugees fleeing [...]" The L.A. Times (2021) writes: "The Dead Sea is dying. Drinking water is scarce. Jordan faces a climate crisis [...]" The Guardian (2023a) writes: "The waters of South America's largest freshwater lake [Lake Titicaca] have severely receded, leaving the Indigenous people around its shores struggling [...]"

the land supply *increases*, in contrast to sea level rise where there is more water and land supply *decreases*. Given the negative effects of water supply decreases and the positive effects of land supply increases – especially in a context of high land pressure as in Africa –, lake recessions may generate *ambiguous* local and aggregate economic effects.

However, since most of the shrinking episodes observed globally have occurred in the past decade only, it is not yet possible to know the long-run effects of the global lake recession phenomenon. We thus rely on a natural experiment that allows us to do so. More precisely, we combine novel data, plausibly causal empirical evidence, and theory to study, over a 70-year period, the economic effects of the almost complete disappearance of Lake Chad, historically the 11th largest lake in the world. Lake Chad gradually lost 90% of its surface area – 23,000 sq km – between 1963 and 1990 (see Figure 1), roughly the area of El Salvador, Israel plus the West Bank and Gaza, or Massachusetts.

Figure 1: Evolution of Lake Chad, 1950-2010



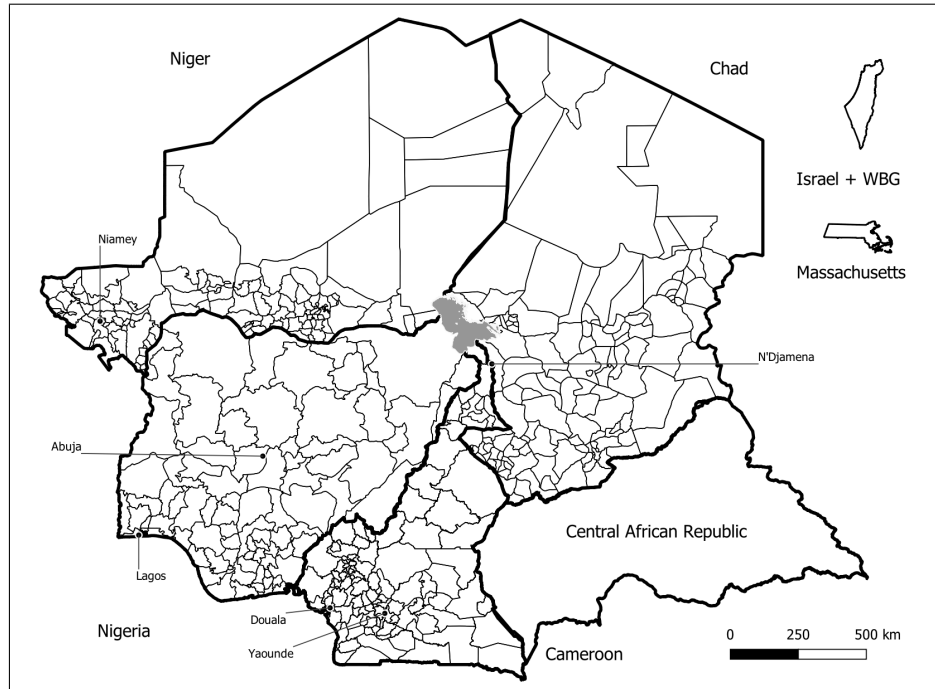
Notes: Sources: (a) USGS EROS Archive - Declassified Data - Declassified Satellite Imagery – 1 (1963); (b) covers the period 01-31-87 / 02-09-87 and comes from the Landsat 4-5 TM C2 L1 data set; and (c) covers the period 05-14-13 / 05-23-13 and comes from the Landsat 8 OLI/TIRS C2 L1 data set. See Data Appendix Section C for details on the sources use to construct subfigure (d).

We study four countries that were low-income economies in the 20th century and whose territory borders Lake Chad: Cameroon, Chad, Niger, and Nigeria. They account for 25% of SSA's population today. The shrinkage of the lake starting in 1963 began with reduced rainfall in a fifth country 800 km away from the lake itself, the Central African Republic (CAR) (see Fig. 2 below). This is because two rivers – the Chari and the Logone – flow from the CAR through Chad and into Lake Chad, which is a sink. Once one controls for proximity to these rivers, the lake's drying is plausibly exogenous to local conditions.

For our analysis, we use census and administrative count data to construct a novel

data set tracking population patterns at a fine spatial level over 70 years: 113, 138, 119, and 83 subdistricts in Cameroon, Chad, Niger, and Nigeria, respectively (Figure 2; 453 subdistricts in total). For each country, we use (relative) population growth as our main outcome of interest, finding in a panel difference-in-difference (DiD) framework: (i) limited effects of proximity to the lake before 1963; (ii) very negative effects of proximity to the lake in 1963-1990; and (iii) effects that remain strongly negative post-1990. In the long run, locations close to the lake grew $\approx 28\text{-}46\%$ slower than other locations.

Figure 2: Location of Lake Chad and Subdistrict Boundaries for the 4 Countries of Study



Notes: Lake Chad is in the middle across the four countries. Cameroon, Chad, Niger, and Nigeria are divided into 113, 138, 119, and 83 subdistricts, respectively (453 subdistricts in total). We show the location of the capital and largest city of each country.

Remarkably, 90 percent of rainfall comes from the evaporation of oceans, seas, and lakes (USGS, 2021a). Lakes also have a cooling effect on their environment (USGS, 2021b). Therefore, when a large lake dries out, it may permanently alter climate conditions (UNEP, 2006). Lake Chad is an endorheic lake, which means it loses most of its water through evaporation. The DiD suggests that rainfall decreased and temperature increased close to the lake. Thus, (global) climate change can beget (local) climate change.

Our interpretation of the results is that the rural fishing, farming, and herding sectors were negatively impacted by the lake's receding. As real incomes and welfare decreased in the area, households migrated away to other areas. Thus, the negative effects of the loss in water supply outweighed the positive effects of increased land supply. We confirm these facts by employing data on rural and urban populations, crop and livestock production, greenness, nighttime lights, and building footprints and volumes. Data on roads, health and education facilities, and conflict also show that lake locations have

experienced declines in infrastructure investments and are more prone to violence today.

To rationalize the observed local effects, study non-local effects, quantify aggregate impacts, study mechanisms for which data is not available, and examine the effects of mitigating forces and policies, we develop a dynamic Quantitative Spatial Model (QSM) based on the frameworks of Artuc et al. (2010) and Caliendo et al. (2019). The model features multiple locations and sectors connected via input-output linkages and sector-level trade flows governed by gravity equations. Agents are forward-looking and decide each period where to live and work based on real income and expected future utility.

We calibrate the model for two sectors – a rural and urban sector - and 453 subdistricts, using output and population data c. 1963. We infer pre-shock migration flows from historical localized data on ethnic composition and derive trade flows from road networks digitized from historical maps. With spatialized data on sectoral production, migration, and trade, we implement the dynamic approach of Caliendo et al. (2019) to simulate a counterfactual scenario where the lake disappears. To calibrate the productivity shocks caused by the lake’s shrinkage, we adopt an indirect inference approach that matches the model-implied population responses to the reduced-form estimates for a given migration elasticity. This procedure yields a migration elasticity of 5 and reveals large rural productivity declines and moderate urban declines in the directly affected locations.

The disappearance of Lake Chad led to substantial welfare losses, measured by the net present value of the compensated variation in 1960. Welfare declines by 2.7%, which is large considering that the Lake Chad Region (LCR) consisting of subdistricts located within 450 km from the lake only accounted for $\sim 8\%$ of total population and area c. 1963. Losses exceed 10% in the LCR, and average 1.5% in other regions, due to trade and migration linkages that impact wages and prices. These findings are robust across several alternative model specifications, including different values for the agglomeration, trade and migration elasticities, exclusion of input-output linkages, inclusion of the rest of the world, and CES instead of Cobb-Douglas preferences. Following the analysis of Fan et al. (2023), we also study the role of optimistic expectations and find that “mistakes” about future productivity shocks due to the lake’s shrinkage raise losses to 4.0%.

The QSM allows us to study the broader effects of the shock. Using model-simulated data, we analyze the effects on both quantities and prices, i.e., rural and urban output, employment and land use, wages, land prices, and consumer prices. The model enables us to move beyond relative changes and estimate aggregate impacts, addressing the issue of the “missing intercept” in DiD frameworks. The shock caused a dramatic contraction in rural output and wages, declining by up to 70% in directly affected areas. Prices in these areas rose by up to 8%, reflecting the increased scarcity of rural goods there. Due to general equilibrium effects, prices also significantly increased in areas not directly impacted by the shock. Hence, the reallocation of productive factors between lake and non-lake locations did not fully compensate for the productivity shock from the lake.

In addition, the QSM allows us to evaluate the mitigating role of trade and migration. Reducing trade barriers modestly attenuates the negative impact of the shock, while increasing migration frictions substantially amplifies welfare losses. If workers had been unable to move to other subdistricts, overall losses would have increased by a third, from 2.7% to 3.6%. Losses for lake residents would have almost tripled, from 11.0% to 27.0%.

Finally, we evaluate the cost-effectiveness of two current policy proposals consisting of large-scale inter-basin water transfer projects promoted by the inter-governmental Lake Chad Basin Commission. The Transaqua project aims to fully replenish Lake Chad by diverting water from the Congo River Basin (DRC) via a new 2400 km canal. However, the cost of US\$50 billion exceeds the estimated NPV gains of US\$7-20 billion. The less ambitious but also cheaper Kotto-Ubangui project would use both gravity and pumping to divert water from a new dam on the Kotto river (CAR), restoring 25% of the lake's area. Again, the cost of US\$14.5 billion exceeds the estimated NPV gains of US\$3-7 billion.

Our main contribution is to be, to our knowledge, the first economic study on the economic effects in developing countries of having or losing a lake, as well as on the economic effects of global climate change through lake recessions specifically.

We contribute to a recent literature using QSMs to study the effects of environmental change (Desmet et al., 2021; Conte et al., 2021; Conte, 2021; Cruz, 2023; Hsiao, 2023; Carleton et al., 2023; Farrokhi et al., 2023; Cruz and Rossi-Hansberg, 2024; Balboni, 2025; Balboni et al., 2025) (see Balboni and Shapiro (2025) for a survey). The same type of models has been used to study the aggregate and spatial effects of migration frictions (Bryan and Morten, 2019; Allen et al., 2018), place-based policies (Morten and Oliveira, 2024; Sotelo, 2020; Balboni et al., 2021; Pellegrina and Sotelo, forthcoming), and historical development when data is lacking (Barjamovic et al., 2019; Boehm and Chaney, 2024) (see Bryan et al. (2025) for a survey focusing on poorer economies). We show how such models can help analyze the local and aggregate effects of lake recessions.⁵

Shrinking lakes is one hitherto unexplored mechanism through which climate change (CC) will impact the economy. Our natural experiment can also speak more broadly about the effects of CC. According to the IPCC (2013), CC “refers to a change in the state of the climate that can be identified [...] by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades”. In addition, “since the late 1950s, many of the observed changes are unprecedented [...]”. Thus, to examine the effects of past CC and shed light on the effects of future CC, one ideally needs: (i) A permanent but gradual change in climate-driven geographical conditions; (ii) The change must take place slowly; (iii) The change must be exogenous; (iv) Localized data must be available before, during, and after the change; and (v) A model that helps rationalize the effects, understand mitigation forces, and study policy proposals. Our focus on a natural

⁵The emergence of new land raises questions regarding property rights and other aspects of rural land development, similar to studies of frontier economies (e.g., Pellegrina and Sotelo, forthcoming; Nagy, 2023).

experiment that “mimics” the gradualness of CC and our QSM allows us to do the above.

More theoretical studies tend to simulate the effects of future CC. While such studies have considerably deepened our understanding of the mechanisms by which CC may have aggregate and spatial effects, they are predictive exercises. As such, they do not aim to study the effects of the CC that has been occurring since the late 1950s.⁶

Conversely, empirical studies of the effects of CC rely on climate deviations for their analyses. While such studies have improved our understanding of the effects of CC, they rarely examine changes in the mean over several decades. Most reduced-form studies miss general equilibrium effects and cannot estimate aggregate losses and policy effects. Additionally, the negative effects of climate variations should compound over time the longer they last. However, since CC is unfolding gradually, agents can engage in a wider set of adaptations. Lastly, studies have questioned to what extent weather changes can be man-made, hence endogenous (Braun and Schlenker, 2023; Grosset et al., 2023).⁷

We focus on four countries among the most likely to be impacted by CC. Studies have shown that CC is a major driver of conflict, epidemics, and poverty in Africa (McGuirk and Burke, 2020; McGuirk and Nunn, 2025; Archibong and Annan, 2022; Eberle et al., 2025). Other literature on the determinants of Africa’s lack of economic development has examined the roles of institutions (Michalopoulos and Papaioannou, 2013, 2014, 2016; Archibong and Obikili, forthcoming), infrastructure (Jedwab and Moradi, 2016; Jedwab and Storeygard, 2021; Alesina et al., 2021; Chiovelli et al., forthcoming), and conflict (Yanagizawa-Drott, 2014; Chiovelli et al., 2021; Couttenier et al., 2024).

Finally, there is literature on the effects of natural disasters (e.g., Kahn, 2005; Boustan et al., 2012; Hornbeck, 2012; Boustan et al., 2020). However, most studies are reduced form in nature and do not quantify aggregate losses and policy effects. Our study and some others typically find high outmigration rates in impacted areas, suggesting that migration is one method by which countries adapt to geographical shocks. Our QSM confirms that losses would have been even higher without migration. At the same time, the fact that losses remain high despite the high observed outmigration rates implies that spatial factor reallocation over decades cannot fully offset the negative impacts of large shocks such as lake recessions, at least in our African context where adaptation capacity is likely limited.

The paper is structured as follows: Section 1. provides the background and introduces our novel data. Sections 2. and 3. present the reduced-form results. Section 4. presents the QSM analysis based on the reduced-form results. Section 5. concludes.

⁶Theoretical studies include Desmet and Rossi-Hansberg (2015); Costinot et al. (2016); Conte et al. (2021); Desmet et al. (2021); Conte (2021); Cruz and Rossi-Hansberg (2024); Cruz (2023); Bilal and Rossi-Hansberg (2023). Bilal and Rossi-Hansberg (2023) and Cruz (2023) link their model to reduced-form evidence.

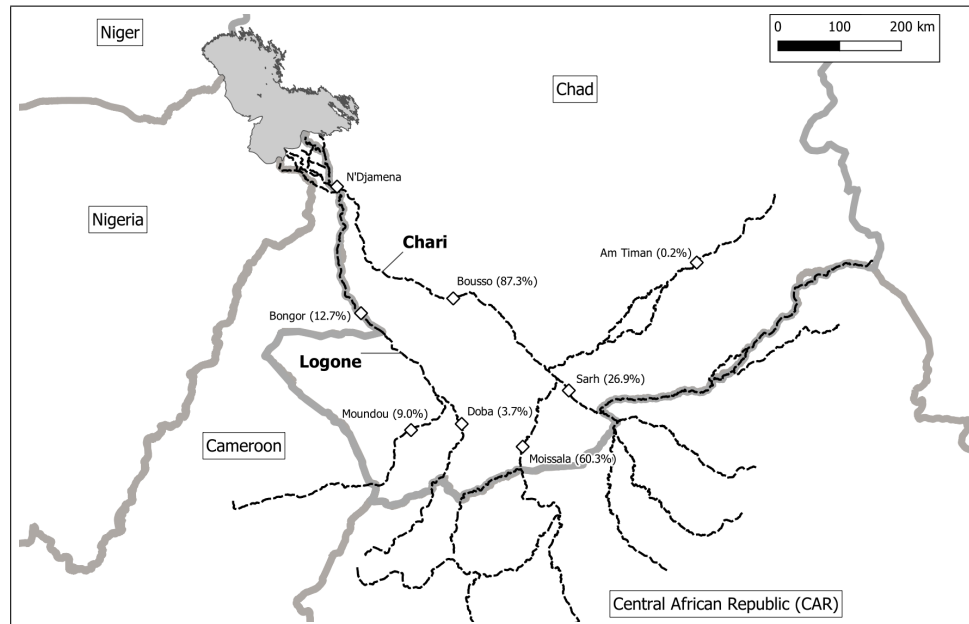
⁷Reduced-form studies have examined various outcomes: economic development (Schlenker et al., 2005; Deschenes and Greenstone, 2007; Dingel and Meng, 2025), conflict (McGuirk and Burke, 2020; McGuirk and Nunn, 2025), mortality (Barreca et al., 2015; Carleton et al., 2022), and migration (Deschenes and Moretti, 2009). Studies of long-term weather changes include Burke and Emerick (2016) and Liu et al. (2023).

1. Background and Data

1.1. Why Lake Chad Shrunk

Lake Chad is a sink that receives water from the Chari-Logone (CL) river system (see Figure 3 below). The river system primarily originates from heavy seasonal rainfall in the northern mountainous areas of the Central African Republic (CAR), located more than 800 km (500 miles) away from the lake itself (South-East corner in Figure 3).

Figure 3: Rivers of the Chari-Logone River System Feeding Lake Chad



Notes: We show in bold the main rivers of the Chari-Logone (CL) river system. For selected upstream sites of the CL river system, we show their percentage contribution to the overall decline in the discharge rate into the lake between 1950-1963 and 1963-1975.

The CAR's climate is tropical, and the wet season lasts from June to September in the north. Rainstorms occur daily, and rivers originating in the Karre Mountains in the northwest and the Fertit Hills in the northeast carry water towards the north. Coe and Foley (2001, p. 3349) writes: "The Lake Chad drainage basin has a monsoon climate, with the majority of the rainfall occurring in the southern one third [...]; arid conditions dominate the northern two thirds. As a result, significant runoff is generated only in the southernmost regions [...] Rainfall over the drainage basin has decreased greatly since the early 1960s, largely because of a decrease in the number of large rainfall events."

Because the discharge rate of the CL rivers depends almost exclusively on rainfall in the CAR, lack of rainfall over the CAR from 1962 was likely the main reason behind the drop in water area observed from 1963 (UNEP, 2004; Magrin et al., 2015; Pham-Duc et al., 2020). This lack of rainfall was likely due to global climate change impacting Central Africa since the 1950s (UNEP, 2006; Aguilar et al., 2009; Hwang et al., 2013; De Wasseige et al., 2015). One hypothesis is that aerosols from coal burning in the U.S. and Europe cooled the Northern Hemisphere, shifting tropical rain bands south, drying out Central

Africa (Hwang et al., 2013). Discussing Lake Chad, the authors explain that its shrinking and the prolonged drought were “initially blamed on overgrazing and bad agricultural practices. More recently, Lake Chad became an example of global warming.” In contrast, rainfall in Cameroon and Chad only very marginally contributed to the system (Magrin et al., 2015; Pham-Duc et al., 2020). Lastly, UNEP (2004, p. 43) explains that “global [climatic] changes from anthropogenic sources” are behind the lake’s shrinkage.⁸

Studies confirm that water withdrawals had hardly any impact on water losses (Olivry et al., 1996; Coe and Foley, 2001; Pham-Duc et al., 2020; Nour et al., 2021).⁹ Rather, in a water-scarce context, withdrawals from the lake itself should have led to positive, not negative local impacts. However, withdrawals from the CL rivers could have led to positive impacts along the rivers, which could explain the negative DiD estimates. We will verify that results hold when controlling for the CL rivers, anthropogenic activities, irrigation, or dams, or dropping river areas. Back-of-the-envelope calculations will show that withdrawals for irrigation, drinking water and livestock watering contributed little to the shock. Data will also confirm that no dams were built along the CL river system.

Data on discharge rates along the river system from the 1940s to the 1980s confirm that the decline in discharge rates started in 1963, one year after rainfall began declining in the CAR.¹⁰ Figure 3 shows each site’s percentage contribution to the overall decline in discharge rates between, before, and after 1963. Most of the collapse close to the lake – in N’Djamena (~400 m³/s annually) – came from the Chari River (Bouso: 87.3%), not the Logone River (Bongor: 12.7%). In turn, the decline in the Chari came from the CAR. The contribution of Am Timam (Chad) was 0.2%. For Moissala and Sarh, the entry points of the CAR’s rainfall into the Chari, it was 60.3% and 26.9%, respectively. Lastly, on the Logone, the contribution of Moundou and Doba was 9.0% and 3.7%, respectively. With two thirds of Moundou’s water coming from Cameroon, 95% of the decline of the CL river system came from the CAR (results will hold if we drop CL river areas in Cameroon).¹¹

Because the CL rivers go through the territory of Cameroon and Chad, control locations along the river system may have been negatively affected. Likewise, given how

⁸Appx. Fig. F.1 shows stable rainfall patterns before 1963 and far stronger rainfall declines after 1963 in the Northern areas of the CAR than in the subdistricts close to Lake Chad in the four countries of study. For these latter areas, the decline can be observed from 1970, seven years after the lake started shrinking. We show later that the post-1970 decrease in rainfall was likely due to the drying of the lake itself.

⁹Coe and Foley (2001) find that irrigation only accounted for 5% of the decrease before 1975. By then, the lake had already shrunk by 70%. Irrigation demands increased fourfold from the mid-1980s (Ibid.). The lake had already shrunk by 90% then. Olivry et al. (1996) also find 5% and argue that the small amount of water extraction barely impacted the lake. UNEP (2004, p.43) writes that “during the 1960s discharge losses due to irrigation were almost nonexistent” and withdrawals only increased after 1983. Gao et al. (2011) argue that the lake’s volume would have recovered by half post-1990 had withdrawals not taken place. They do not use data on withdrawals, instead relying on an imperfect model-based approach (Nour et al., 2021). Nour et al. (2021) argues that the data “shows no evidence of an anthropogenic impact” until 2010.

¹⁰The lake being shallow, its water level responds fast to runoff changes (Olivry et al., 1996).

¹¹Each site’s patterns are shown in Appx. Fig. F.2 (sources and calculations provided in the figure notes).

spatially correlated weather changes are, control locations in the two countries may have been negatively affected when rainfall decreased in the CAR. Econometrically, these facts should only lead us to underestimate how negative the local effects of the lake's shrinkage are. We will also control for proximity to the CL rivers or drop CL river areas entirely. Next, in some robustness checks we control for local rainfall, proximity to the CAR, or exposure to the CAR rainfall shock. Lastly, the river system is not present in Niger or Nigeria and these two countries also do not share a border with the CAR, making them clean environments for our analysis. However, minor rivers of the CL system follow the Cameroon-Nigeria border. We will thus control for proximity to the extended CL system.

Finally, splitting Lake Chad in half is the *Grande Barrière*, an elevated area that divided the lake into two. It was only when the water level of the southern pool was high enough that water crossed the Grande Barrière (Pham-Duc et al., 2020). As the Chari-Logone rivers' discharge rate declined, it created a northern pool that had dried out completely by 1975 and a southern pool that retained some water (Fig. 1 above) (Magrin et al., 2015). We will exploit this fact by showing stronger effects for the Northern pool.

To conclude, the decline of rainfall in a fifth country appears to have caused the shock. Note that we will find similar local growth patterns for the four countries, giving us confidence that we are controlling for any bias generated by correlated weather patterns, proximity to the CAR, CL rivers, and withdrawals, and also ensuring external validity.

1.2. Potential Economic Impacts of Lake Chad's Shrinkage

Based on the sectoral data from Section 2., in 1963, fishing, farming, livestock herding, and urban activities accounted for respectively 10%, 60%, 20%, and 10% of the total output of all subdistricts located within 450 km from the lake, which we call the "Lake Chad region" (LCR). Within 150 km, fishing's output share increases to 35%, at the expense of farming and urban activities. The LCR, while drier, was then not systematically more, or less, warm or developed than other regions.¹² The shock likely impacted all sectors.

Fishing. Lake Chad's fisheries were "among the largest and most productive in the whole of Africa" (UNEP, 2004). However, by 1990, only 3 out of 13 shore subdistricts still had access to the lake. The lake's drying has also been associated with higher ambient water temperatures, lower dissolved oxygen, and the disappearance of spawning places for young fishes, hence lower fish stocks (UNEP, 2006). While some fishing communities kept following the lake shore, others gave up and switched to farming (UNEP, 2004).

¹²Appx. Table F.1 shows the mean per capita output, population density, urban population share, and urban output share of the LCR and non-LCR c. 1963. The table also reports mean temperature and rainfall in 1950-1964 (years chosen to be consistent with Table 5). No significant differences are observed for Cameroon and Chad. In Niger, only density is significantly lower in the LCR. In Nigeria, the LCR appears significantly less developed than the non-LCR. We will show that the parallel trends assumption is nonetheless satisfied in both countries. Regarding temperatures, the LCR is relatively warmer in Cameroon and Chad and colder in Niger and Nigeria. We will show that results hold when controlling for initial conditions and the weather.

Farming. Some farming communities took advantage of the newly emerged land. Yet, the former lake areas remain largely underdeveloped today, due to incomplete property rights and land markets, lacking infrastructure, and security issues (Batello et al., 2004; UNEP, 2006).¹³ Also and as seen in Fig. 1 above, the emerged land consists of “disjoint marshy zones separated by dry land and [sandy] dunes” (Puzović et al., 2006).¹⁴

The lake’s drying changed the local environment, which also became drier, mostly due to reduced moisture recycling (UNEP, 2004). For example, some of the lake’s water used to seep through the ground into the Lake Chad transboundary aquifer. The resulting loss of groundwater and vegetation then impacted local farming and herding communities.

Livestock Herding. The lake’s drying led to species extinction. While there were 200,000 Kuri cattle heads in 1972, there were only 10,000 heads left in 2002.¹⁵ Importantly, this breed has a milk yield that is two times greater than other breeds (Santoze and Gicheha, 2018). For pastoralists, the lake was also a feeding and watering zone during the dry season before the migration south to livestock markets in Cameroon and Nigeria. Lastly, “reduced grazing land across the entire basin [...] encouraged herders to shift from grazing animals (cattle and camels) to browsing animals (sheep and goats), which affected the area’s vegetation through the consumption of woody plants” (UNEP, 2004, p.52).

Transport & Cities: Roads in 1963 were of poor quality and it was sometimes cheaper to move goods by boat across the lake (Magrin et al., 2015). With the shock, trade costs increased (UNEP, 2006) and trade declined (Olivry et al., 1996). Cities were impacted because they served as logistical hubs or places where rural products were processed.

1.3. Baseline Data for the Reduced-Form Analysis

An analysis of the impact of the lake’s drying demands localized data for the period 1963-2010 and the pre-1963 period. Since population flows are a sufficient statistic to measure the economic impacts of localized shocks (Artuc et al., 2010), we focus on total population as our baseline measures. Typically, the sources that we were able to get ahold of report population data at the subdistrict level. As boundaries changed over time, we aggregated subdistricts to reconstruct a set of consistently defined subdistricts over periods spanning 70 years. Our data set contains 119 subdistricts for Niger (1951-2017), 113 for Cameroon (1963-2005), 138 for Chad (1948-2009), and 93 for Nigeria (1952-2006) (Fig. 2 above).¹⁶ The mean subdistrict is 4-11 thousand sq km (the mean U.S. county is 3 thousand sq km).

In Niger (N = 119 subdistricts), we have population data in 1951, 1956, 1957, 1958,

¹³They write: “[Though] there is great potential for increasing food production [...] production is still for household consumption and only a small portion of the cereals produced [...] reaches the marketplace.”

¹⁴Satellite data on night lights c. 2010 and built volumes c. 2015 (see Section 3. for the sources) suggest a development rate of ~25% *inside* the former lake areas relative to areas *outside* (in the same subdistricts). To compare shore-like locations, we only consider outside areas located within 10 km from the former shore.

¹⁵For Mpofu and Rege (2002), the “importance of the Kuri lies [...] in its meat and milk production potentials. The breed is so acclimatized to the environs of Lake Chad that it is unable to survive elsewhere.”

¹⁶*Communes* in Niger, *arrondissements* in Cameroon, *sous-prefectures* in Chad, and *divisions* in Nigeria.

1959, 1960, 1961, 1962, 1969, 1988, 2001, 2012, 2013, 2014, 2015, 2016 and 2017. Values for the years 1988, 2001, and 2012 come from population censuses. Data for the other years come from colonial or post-colonial administrative censuses and statistical abstracts.

The Cameroon data set ($N = 113$) includes the years 1963 and 1967 (administrative censuses) and 1976, 1987, and 2005 (population censuses; no census post-2005) since 2005. To examine whether the parallel trends assumption holds for Cameroon, we add the year 1956 (administrative census) by using total population data at the district level ($N = 47$).

The Chad data set ($N = 138$) includes the years 1948, 1953, 1963, 1993, and 2009. Measures for the years 1948 and 1953 are based on colonial administrative censuses. For the year “1963”, we use information from the 1962 administrative census and the 1964 *Enquête Démographique*.¹⁷ Lastly, we use census figures for the years 1993 and 2009.

The Nigeria data set ($N = 83$) includes the census years 1952, 1963, 1991, and 2006.

Finally, we employ data on rural and urban populations, fishing, agriculture, livestock herding, irrigation, dams, urban production, nighttime lights, building footprints and volumes, the local climate, greenness, conflict, roads, health and education facilities, and migration flows. We describe the sources used below when we first use each variable.

2. Reduced-Form Effects

The drop in water levels starting in 1963 and ending c. 1990 allows us to study the effects of the drying lake on nearby communities at different points in time. Using a panel-DiD framework, we examine the effect of proximity to the lake on population patterns. For subdistrict s and year t and *each country at a time*, we estimate the following log-log model:

$$\ln(\text{Pop.})_{s,t} = \alpha + \sum_v \beta_v \text{Proxi.Lake}_s \times \mathbb{1}(v = t) + \lambda_s + \theta_t + D_d * t + X_s B_t + \mu_{s,t}. \quad (1)$$

$\ln(\text{Pop.})_{s,t}$ is log total population. The variables of interest are the interactions between the time-invariant measure of proximity to the lake (Proxi.Lake) – log Euclidean distance from the subdistrict’s centroid to the centroid of Lake Chad within the country’s territory (Appx. Fig. F.3) – and year dummies (we omit the latest year available before 1963).

We add subdistrict (λ_s) and year (θ_t) fixed effects, as well as district-specific linear trends ($D_d \times t$) to control for regional patterns of economic development over time (similar to U.S. states).¹⁸ We use Conley SE (distance cut-off of 100 km). Lastly, our specification includes several time-invariant controls (X_s) that we interact with year effects (we get B_t).

X_s includes the logged Euclidean distances to the largest city and the capital city, and their square, in order to control for spatial development patterns due to nation-building and political and economic centralization in post-independence Africa (Herbst, 2000).

¹⁷A few subdistricts have incomplete 1963 data. We adjust their estimates using a 1968 administrative census that only covered a few regions. That should, if anything, lead to more conservative estimates.

¹⁸We consider 31, 47, 36, and 24 districts in Niger, Cameroon, Chad, and Nigeria, respectively. The district boundaries more or less correspond to *departements*, *prefectures* or *states* in the 1960s.

For historical reasons, northern areas have been growing slower than southern areas in each country (Boone and Simson, 2019). Geography also varies with latitude, with declining vegetation as one moves north (Mortimore, 1989). X_s thus includes latitude.

Following Section 1., X_s includes dummies for whether the subdistrict is crossed by a major river or a minor river of the Chari-Logone river system.

Nigeria discovered oil c. 1960, which increased spatial inequality (Zainab, 2022). We add three controls to X_s for it: (i) the share of the subdistrict's territory that contained oil deposits c. 1960;¹⁹ (ii) the logged Euclidean distance to Port Harcourt, the capital city of the oil-rich Delta region, and its square; and (iii) the logged Euclidean distance to Kano, the North's capital, and its square (oil revenues are shared with the two regions).

Lastly, a log-log model is specifically chosen because the impact of proximity to Lake Chad is non-linear, as we will show below using a distance bin specification. The log-log model has the advantage that we only need to estimate one coefficient per year.

A. Main Results. Table 1 shows the effects every five years before the shock begins and every ten years after. For Niger (col. (1)), we find short-term effects of -0.23*** c. 1970 (-21%), medium-term effects of -0.41*** c. 1990 (-34%), and longer-term effects of -0.33* c. 2010 (-28%). The short-term effects are similar for Cameroon ((3)). The medium- and long-term effects are similar for Nigeria ((2)), Cameroon ((3)), and Chad ((6)).

The pre-trends in Niger and Nigeria ((1)-(2)) do not significantly differ from 0 and do not seem to explain our post-1963 effects. Appx. Fig. F.4 shows that the post-1963 effects in Niger are large and significant when compared to the extrapolated pre-trend values of the same years (estimated using non-parametric kernel regressions; see figure notes for details). Appx. Fig. F.5 shows similar patterns for Nigeria (extrapolated pre-trend values are estimated using linear interpolation as there is only one year of pre-1963 data).²⁰

Cameroon does not have subdistrict-level data before 1963 ((3)). But we have pre-1963 data at the district level (N=47). (4) does not include district-specific trends (since the analysis is now at the district level). (5) adds region(N=10)-specific trends. Negative pre-1963 coefficients are observed, suggesting growing population levels around the lake before the shock. The coefficients are, however, not significant. In Chad, the pre-1963 coefficients are significant ((6)), indicating the attractiveness of Lake Chad pre-shock. If anything, this should lead to conservative estimates of the negative impacts of the shock.

B. Robustness: Chari-Logone (CL) Rivers. If the lower flow of the CL rivers had a local negative impact in Chad, Cameroon and Nigeria (Fig. 3), this phenomenon should, if anything, lead to conservative estimates of the negative effects of the lake shrinking because some control locations would be negatively impacted. Furthermore, Appx. Table F.2 shows that results: (i) do not depend on whether we control for the presence of rivers

¹⁹The source is *Petrodata* from Prio. Accessed 06-17-2022. Url: <https://www.prio.org/data/11>.

²⁰The difference is not significant in 2006 (p-value≈0.155), due to the confidence intervals expanding over time as some lake locations declined more slowly than others, implying heterogeneity in the local impacts.

Table 1: Reduced-Form Effects of Proximity to Lake Chad, Total Population, 1950-2020

Dependent Variable: Spatial Unit s : Country of Study:	Log Total Population of Spatial Unit s in Year t					
	(1) - Niger	(3) Subdistrict Nigeria	(5) District Cameroon	(4) - District Cameroon	(6) Subdistrict Chad	
Proximity to Lake (log) * c. 1950	0.08 [0.07]	0.03 [0.13]				-0.27*** [0.10]
Proximity to Lake (log) * c. 1955	0.07 [0.06]			-0.13 [0.29]	-0.24 [0.17]	-0.28*** [0.10]
Proximity to Lake (log) * c. 1960	0.00 [0.01]					
Proximity to Lake (log) * c. 1963	...	...	...	...	...	...
Proximity to Lake (log) * c. 1970	-0.23*** [0.08]		-0.19** [0.08]	-0.32 [0.23]	-0.26** [0.11]	
Proximity to Lake (log) * c. 1980			-0.27** [0.11]	-0.62*** [0.24]	-0.41* [0.25]	
Proximity to Lake (log) * c. 1990	-0.41*** [0.11]	-0.46** [0.20]	-0.40*** [0.12]	-0.88*** [0.27]	-0.50 [†] [0.33]	-0.54*** [0.20]
Proximity to Lake (log) * c. 2000	-0.31** [0.14]					
Proximity to Lake (log) * c. 2010	-0.33* [0.17]	-0.49* [0.26]	-0.36** [0.14]	-1.13*** [0.31]	-0.46 [0.40]	-0.62*** [0.16]
Proximity to Lake (log) * c. 2020	-0.36* [0.18]					
Observations	2,023	332	563	282	282	690
Spatial Unit FE, Year FE	Y	Y	Y	Y	Y	Y
District-Specific Linear Trends	Y	Y	Y	N	N	Y
Region-Specific Linear Trends	N	N	N	N	Y	N
Baseline Controls	Y	Y	Y	Y	Y	Y

Notes: *Proximity to Lake* is the negative of the log Euclidean distance to the centroid of Lake Chad within the country's territory. Niger: 119 subdistricts x 17 years (1951-2017) = 2,023. c.1950=1951, c.1955=1956, c.1960=1960, c.1963=1962, c.1970=1969, c.1990=1988, c.2000=2001, c.2010=2012, c.2020=2017. Nigeria: 83 subdistricts x 4 years (1948-2006) = 332. c.1950=1952, c.1963=1963, c.1990=1991, c.2010=2006. Cameroon: 113 subdistricts x 5 years (1963-2005) = 563 and 47 districts x 6 years (1956-2005) = 282. c.1955=1956, c.1970=1967, c.1980=1976, c.1990=1987, c.2010=2005. Chad: 138 subdistricts x 5 years (1948-2009) = 690. c.1950=1948, c.1955=1953, c.1990=1993, c.2010=2009. There are 31, 24, 47 and 36 districts in Niger, Nigeria, Cameroon and Chad, respectively (10 regions in Cameroon). See text for details on the controls. Conley SEs 100 Km. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, [†] $p < 0.15$.

or not, suggesting limited local impacts of the slower flow itself; (ii) hold when controlling for the log Euclidean distance to these rivers interacted with year fixed effects (instead of dummies for whether CL rivers cross the subdistrict), using the ones within the countries of study or the ones that specifically originate from the Central African Republic; and (iii) hold when excluding all subdistricts crossed by a major or minor CL river. Lastly, Niger does not include any CL river, so its estimates are cleaner with respect to this concern.²¹

²¹Results hold if we control for whether the subdistrict contains: (i) the Komadugu-Yobe River (Appx. Tables F.3-F.4), a river that follows the Niger-Nigeria border and flows into the lake. Its annual discharge rate has been stable around 15 m³/s (vs. 1,400 m³/s for the CL pre-1963) (Martinsson, 2010); and (ii) the Bahr el-Ghazal, a dry riverbed that was pre-1900 an outflowing river of Lake Chad (Appx. Table F.5).

C. Robustness: CAR Shock. Since lower rainfall in Northern CAR was responsible for the lake shock, we verify that the results hold with the following time-invariant controls interacted with year FE (Appx. Table F.7): (i) the log Euclidean distance to the CAR's border; (ii) the log Euclidean distance to the Chari-Logone river system within the CAR's territory; and (iii) measures of the extent to which each subdistrict was spatially exposed to rainfall losses in the CAR and their local impacts.²² This should only affect Cameroon and Chad (Niger and Nigeria do not share a border with the CAR). In both countries, results hold if we exclude subdistricts within 150 or 300 km from the border (not shown).²³

D. Robustness: Weather Shocks. Results hold if we control for rainfall and temperature, in case they are correlated spatially with rainfall in Northern CAR. We control for mean temperature and the log of mean annual rainfall in $[t-5; t]$ (Appx. Tables F.3-F.6). Results further hold if we (Appx. Table F.8): (i) consider 10, 30, or 50 years instead of 5 years before; or (ii) control for circa 1963 absolute changes in mean temperature and log mean annual rainfall, interacted with year fixed effects.²⁴ Lastly, we show below that results hold if we control for initial economic conditions (i.e., sectoral exposure), irrigation infrastructure, and dams, so whether the subdistrict more heavily relies on rainfall.

E. Robustness: Water Withdrawals. Results hold if we control for irrigation in case it caused the shock. We consider the following variables interacted with year fixed effects (Appx. Table F.9): (i) the log of area equipped for irrigation c. 2005; and (ii) the log of area equipped for irrigation that was actually irrigated c. 2005. Had water withdrawals locally shrunk the lake, it should have led to conservative estimates of the shock's negative impacts since irrigation promotes development.²⁵ In addition, only 0.1-0.6% of cropland was irrigated in the four countries of study plus the CAR in 1985 (FAO, 2025) (compared to 26%, 39% and 49% in India, China and Pakistan). Between 1963 and 1985 when the lake had shrunk by 90%, the amount of irrigated land increased by 410 sq km across the five

²²For each subdistrict i and each of the 14 CL subdistricts j in the CAR c. 1963 (out of 38 subdistricts), we know the Euclidean distance between i and j as well as the average rainfall level (mm) in 1950-62 and 1963-69. For each subdistrict i , we obtain across all 14 subdistricts j the mean of the distance-weighted average rainfall level, defined as $\text{rainfall}/\text{distance}^\alpha$. Next, when aggregating the average rainfall across all 14 subdistricts j , we use as weights the area or population c. 1963 of each CAR subdistrict. Finally, we obtain for each subdistrict i the percentage loss in "nearby" CAR rainfall between 1950-62 and 1963-69.

²³Rainfall losses in the CAR likely had minimal spill-over economic impacts. First, they were occurring in its Northern, more mountainous regions. Second, the CAR accounted for only 2.7% of the total population and GDP of the four countries c. 1963. Third, in 1990, there were only 17,000 and 8,000 CAR migrants in Cameroon and Chad (Niger and Nigeria do not border the CAR). Lastly, agricultural trade in the 1960s, which could have been impacted by the reduced rainfall, was on average 11 times lower between the CAR and each country than between the four sample countries themselves (data from Hausmann et al. (2014)).

²⁴We test changes for the periods 1950-59 and 1960-69, 1950-61 and 1962-69, and 1950-63 and 1964-69. As we show below that the shock reduced rainfall in the long run, there is a risk that we over-control when considering rainfall in year t . However, this should lead us to underestimate the negative impacts of the shock. The previous test also only considers rainfall changes before 1970, which should minimize the issue.

²⁵Water withdrawals along the Chari-Logone rivers could have increased economic development there. However, we showed that the results hold when controlling for these rivers or dropping river subdistricts.

countries. Back-of-the-envelope calculations in Appx. Table F.10 suggest that irrigation caused far less than 5% of the lake's shrinkage. Indeed, the calculations unrealistically assume the same water application rates and technologies as in the U.S. and that all irrigation infrastructure investments took place close to Lake Chad.²⁶ The contribution of water withdrawals to the shock was likely minimal (Section 1.).²⁷

F. Robustness: Dams. Results hold if we add two dummies for whether the subdistrict had a reservoir or an electricity-generating river barrier in year t as well as the logged numbers of reservoirs and river barriers in year t (Appx. Table F.9). More generally, there are no dams within 450 km from the lake in Chad and Niger, and the dams that were built within 450 km in Cameroon and Nigeria were completed after 1978 and 1982, respectively. By then, the lake had already shrunk by 80%-90%. Furthermore, no dams were ever built along the CL river system. Dams are thus unlikely to explain the lake's shrinkage.²⁸

G. Robustness: Initial Conditions. The Lake Chad region was not systematically more, or less, developed than other regions c. 1963 (Section 1.2.). We also found no negative pre-trends.²⁹ Subdistrict FE, district trends, and the baseline controls for economic and physical geography should then capture any impact that initial differences could have over time. Finally, results hold if we control for initial (c. 1963) economic conditions interacted with year fixed effects, in particular variables that capture historical structural change (Appx Table F.12): (i) the urban share of total population or output; (ii) log urban population and log rural population; or (iii) log urban output, log fishing output, log farming output and log livestock output. See table notes for details on the sources.

H. Robustness: Placebo Lakes. Chad has in its territory portions of both the northern and southern pools of the lake (Appx. Fig. F.3). Col. (2) of Table 2 below shows less negative long-run effects if the lake centroid is defined using the southern pool, likely due to migration from the dried-out northern pool to the never-completely dry southern pool. For Chad, we also study the effects of proximity to Lakes Fitri, Iro, and Lere, Chad's three

²⁶UNEP (2004) explain that "95% of crops in the Basin are traditional and [...] do not rely on" irrigation.

²⁷Appx. Table F.10 shows that water withdrawals for drinking water and livestock watering accounted for far less than 12% and 2% of the lake's shrinkage. For drinking water, this unrealistically assumes the same water consumption levels as in the U.S. and that the lake's water was transported over long distances, in a context where no aqueducts were built. More generally, Ngatcha et al. (2010) writes: "Regarding water uses (water supplies for drinking, industry and agriculture), demand in the Lake Chad Basin is satisfied mainly with groundwater." Likewise, wells are a commonly used water source for livestock watering.

²⁸The dams built in Nigeria only impacted the Komadugu-Yobe river, which barely contributed to the lake's inflow (UNEP, 2004). The dams built in Cameroon and Nigeria also had little impact on irrigation capacity (Ibid.). The lake's shrinkage made irrigation schemes fail, not the other way around. UNEP (2004, p. 49) writes the following about the South Chad Irrigation Project: "A system of pumps and canals was to carry water from the lake shore intake point to farmers' inland fields. But the plans were dependent on the lake's level. When the Lake fell below 279.9 m [...] no irrigation could take place." They also write: "The Baga Polder Project had a goal of irrigating 20 000 ha [...]. by 1996 only 1 000 ha were under irrigation [...]. The original polder that was constructed for irrigation purposes is now several km from the lake shore."

²⁹Nigeria is the only country where the LCR was significantly less developed than other regions c. 1963. However, we showed above that the population pre-trends did not significantly differ from 0 there.

other largest lakes, which have not shrunk like Lake Chad. They= provide a placebo test of whether the estimated effects are a consequence of changes in lake-related activities. No negative effect is found for them ((3)-(5)). We also find no significant negative effect when using the three largest lakes in the other three countries (Appx. Table F.11).³⁰

Table 2: Reduced-Form Effects, Total Population, Chad 1950-2010, Additional Strategies

Dependent Variable:	Log Total Subdistrict Population in Year t				
Placebo Lake:	(1) Baseline	(2) South Pool	(3) Lake Fitri	(4) Lake Iro	(5) Lake Lere
Proxi. to Lake Chad (Log)*c. 1990	-0.54*** [0.20]	-0.71** [0.31]	-0.48** [0.20]	-0.53*** [0.20]	-0.57*** [0.21]
Proxi. to Lake Chad (Log)*c. 2010	-0.62*** [0.16]	-0.47*** [0.13]	-0.57*** [0.16]	-0.63*** [0.16]	-0.64*** [0.17]
Proxi. to Placebo Lake (Log)*c. 1990		0.19 [0.23]	0.17 [0.11]	0.00 [0.12]	-0.18 [0.13]
Proxi. to Placebo Lake (Log)*c. 2010		-0.29 [0.21]	0.15 [0.13]	-0.06 [0.11]	-0.14 [0.18]
Subdistrict (138) FE, Year (5) FE	Y	Y	Y	Y	Y
District (36) Trends & Controls, Obs.	Y, 690	Y, 690	Y, 690	Y, 690	Y, 690

Notes: 138 subdistricts $\times$ 5 years (1948, 1953, 1965, 1993, 2009) = 690 obs. For each subdistrict centroid, *Proximity to Lake (log)* is the negative of the log Euclidean distance to the selected lake centroid. We only report the estimated coefficients for the closest years to the year 1990 and the year 2010. (1): The lake centroid that we use is the centroid of the Northern section of the lake that belongs to Chad's territory (Appx. Fig. F.3). (2): We use both the Northern and Southern centroids. (3)-(5): We also consider the centroid of Lakes Fitri, Iro and Lere which are fully contained within Chad's territory. See text for details on the controls. Conley SEs 100 Km.

I. Robustness: Specification. Results generally hold if we: (i) remove the controls (Appx. Table F.13); (ii) exclude the district trends or include region trends (Appx. Table F.14),³¹ or (iii) control for longitude interacted with year dummies (Appx. Table F.15).³²

J. Robustness: SE. Results hold if we use 250 km Conley SE (Appx. Tables F.3-F.6).

K. Robustness: Population Data. Shore subdistricts could have seen their census-based population artificially decline if residents from the historical shore areas moved into new unregistered settlements within the former lake areas. This should only be a problem in the short term. By 2010, censuses likely aimed to capture settlements in the former lake areas. Long-term effects should be little affected. Results also hold if we correct the population of shore subdistricts using satellite data on building footprints or volumes (from the 1970s) or lights (1990s) (Appx. Table F.16). The correction ratios use information

³⁰We consider lakes larger than 20 sq km and include natural lakes as well as man-made lakes (reservoirs) built before the 1980s. The only significant negative effect is for the Maga reservoir in Cameroon, but the coefficient is six times lower than for Lake Chad. Other significant coefficients are positive, not negative.

³¹In Chad, controlling for district trends weakens the positive pre-trends observed around Lake Chad. Taking this into account, the differential effects between 2010 (or 1990) and 1950 when not including district trends ((2)) equal the corresponding differential effects when including district ((1)) or region ((3)) trends.

³²Given the shape of Nigeria's territory (Fig. 2), longitude is very strongly correlated with proximity to Lake Chad and the results mechanically disappear. If we use distance bin dummies (0-150, 150-300 and 300-450 km) to capture more local non-linear effects, then the estimates remain similar with longitude controls.

on how much development occurred inside vs. outside (see table notes for details).³³

L. Robustness: Lake Measure. Results hold using distance to (Appx. Tables F.3-F.6): (i) the full lake's centroid or shore (Appx. Fig. F.3); or (ii) the shore in year t (uninteracted with year dummies) (sources from Fig. 1). We only implement this test in Chad, as the value of this measure depends on the lake's shape in each country. In Cameroon, Niger, and Nigeria, the distance to the lake increased almost equally across all subdistricts. In other words, proximity to the lake was *translated* uniformly across space. Since year fixed effects absorb this translation, there is little econometric variation left. Chad's territory contains the lake's two pools, and the Northern one shrunk the most. Some areas thus saw their distance to the lake change more than others. We find that a doubling of the distance to the lake decreased population by 9% (***). Once standardized, the effect is similar to the ones from the other methods (standardized effects shown in Appx. Tables F.3-F.6).

M. Robustness: SUTVA. Results hold when excluding subdistricts located within 450-600 or 450-750 km from the lake (Appx. Table F.17). Indeed, the distance bin-specific analysis explained below shows that the lake's shrinkage had effects until 450 km. Since we use bins of 150 km, we exclude the first bin after 450 km (450-600), and then two bins (450-600 and 600-750). However, general equilibrium (GE) effects imply that SUTVA is always violated in any reduced-form regression. The QSM will thus be important to complement the empirical analysis since estimated aggregate effects take into account GE effects.

N. Robustness: Distance Bins. The log-log model has the advantage of allowing us to estimate only one coefficient per year. We now use a version of eq. (1) where we instead employ three dummies based on the Euclidean distance between a subdistrict's centroid and the centroid of the selected lake area that is within the country's territory, which we interact with the year dummies. We choose 0-150 km, 150-300 km, and 300-450 km:³⁴

$$\begin{aligned} \ln(Pop.)_{s,t} = & \alpha + \sum_v \beta_{150,v} Lake_{150} \times \mathbb{1}(t = v) + \sum_v \beta_{300,v} Lake_{300} \times \mathbb{1}(t = v) \\ & + \sum_v \beta_{450,v} Lake_{450} \times \mathbb{1}(t = v) + \lambda_s + \theta_t + X_s B_t + D_s * t + \mu_{s,t} \end{aligned} \quad (2)$$

Table 3 reports the main effects. For Niger in 2010 ((1)), we find strong negative effects within 150 km (-0.63***, or -47%). The effects for 150-300 km are less strong than the effects within 150 km (-0.42**, or -34%). Likewise for the 300-450 km bin relative to 150-300 km (-0.05, or -5%). We find similar non-linear patterns in the other three countries ((2)-(4)). The gradient in the effects then justifies the log-log model used in eq. (1) above.

Strong effects already appear in 1970. The shock indeed deprived fishing communities of their access to the lake. If the shore recedes by even a few km, a fishing community

³³The reliability of the 1963 Nigeria census has been questioned by experts. Results hold if we (Appx. Table F.4): (i) add region-year FE, as any manipulation took place at the regional level (Ahonsi, 1988); (ii) use population correction ratios from Ahonsi (1988); and (iii) drop 1963 (1952 is the new pre-shock year).

³⁴Appx. Fig. F.6 shows the bins. Were the subdistricts shaped like circles, their radius would be ≈ 36 -59 km across the four countries. We cannot use overly small bins due to the size of the subdistricts.

loses its economic function. N'guigmi, Niger's largest town in the vicinity of the Lake, was before the shock a "centre of Kanuri fishing communities" (Geels, 2006). In the mid-1970s, the shore was already 85 km away from it.³⁵ Consistently, Table 3 shows that the relative effects for the shore locations (0-150 km) vs. the other lake locations were larger in 1970 than in 2010. The impacts were thus disproportionately along the shore initially.

Table 3: Reduced-Form Effects, Total Population, Distance Bins, 1950-2020

Dependent Variable:	Log Total Subdistrict Population in Year t			
(Omitted Year = c. 1963)	(1) Niger	(2) Cameroon	(3) Chad	(4) Nigeria
Lake 0-150 Km Dummy * c. 1970	-0.41*** [0.08]	-0.45*** [0.14]	-	-
Lake 150-300 Km Dummy * c. 1970	-0.13** [0.06]	-0.30*** [0.11]	-	-
Lake 300-450 Km Dummy * c. 1970	0.09 [0.08]	-0.26** [0.11]	-	-
Lake 0-150 Km Dummy * c. 1990	-0.64*** [0.07]	-1.22*** [0.20]	-0.85* (0.48)	-0.79*** [0.30]
Lake 150-300 Km Dummy * c. 1990	-0.60*** [0.09]	-0.85*** [0.14]	-0.19 (0.26)	-0.72*** [0.24]
Lake 300-450 Km Dummy * c. 1990	-0.07 [0.13]	-0.88*** [0.14]	-0.00 (0.20)	-0.32** [0.13]
Lake 0-150 Km Dummy * c. 2010	-0.63*** [0.12]	-1.41*** [0.24]	-1.03*** (0.32)	-1.03** [0.43]
Lake 150-300 Km Dummy*c. 2010	-0.42** [0.17]	-0.98*** [0.11]	-0.96*** (0.26)	-0.83** [0.35]
Lake 300-450 Km Dummy*c. 2010	-0.05 [0.17]	-1.08*** [0.10]	0.01 (0.16)	-0.42*** [0.16]
Subdistrict FE, Year FE	Y	Y	Y	Y
District Trends & Controls, Obs.	Y, 2,023	Y, 563	Y, 690	Y, 332

Notes: Niger: 119 subdist. x 17 years (1951-2017) = 2,023 obs. c.1970 = 1969. c.1990 = 1988. c.2010 = 2012. Cameroon: 113 subdist. x 5 years (1963-2005) = 563 obs. c.1970 = 1967. c.1990 = 1987. c.2010 = 2005. Chad: 138 subdist. x 5 years (1948-2009) = 690 obs. c.1990 = 1993. c.2010 = 2009. Nigeria: 83 subdist. x 4 years (1948-2006) = 332 obs. c.1990 = 1991. c.2010 = 2006. We only report the coefficients for the closest years to the years 1970, 1990 and year 2010. See text for details on the controls. Conley SE 100 Km.

Finally, we find similar spatiotemporal patterns in the four countries, which should also assuage concerns related to causality, measurement error, and external validity.

3. Other Reduced-Form Effects and Mechanisms

In this section, we show that our population estimates appear to be substantiated by results on other economic outcomes, the local climate, conflict, and infrastructure.

³⁵Odada et al. (2003) write: "By the end of the 1960s, drought conditions had started to set in [...] The Lake water receded for more than 150 km from its northern and eastern shores, and by more than 80 km from its western shoreline. Some of the natural fauna and flora disappeared, and sand dunes appeared on the dry lake bed [...] fishing, livestock rearing, and farming were adversely affected [...]" DeGeorges (1979) writes: "Both Bol [Chad] and Baga Kawa [Nigeria] have been removed as important fishing centers because of decreased access to the lake from encroachment by aquatic plants and falling lake levels."

Rural Decline. Since rural sectors – fishing, livestock herding, and farming – were reliant on the lake’s existence and since the four countries were little urbanized in 1963 (UN, 2018), population losses were likely driven by rural decline. We employ our panel-DiD model, considering log rural population and log urban population. To construct rural population (total - urban population), we obtain the population of cities for each country-year. Following Bairoch (1988), a city is a locality with at least 5,000 inhabitants. We focus our data-compiling efforts on localities that reached 5,000 inhabitants at any point, relying on population censuses and administrative counts (see Appx. Section D for details). Our selection process yields 186, 100, and 166 cities in Cameroon, Chad, and Niger, respectively. For each city, we know its population when it is above 5,000. For Nigeria, given the lack of consistent city-level data over time, we rely on total rural and urban population counts from the 1963 and 2006 censuses (missing data in other years).

Table 4: Reduced-Form Effects, Rural and Urban Populations, Distance Bins, 1950-2020

Dependent Variable:	Log Rural Population				Inverse Hyperbolic Sine of Urban Pop.			
	Niger	Cameroon	Chad	Nigeria	Niger	Cameroon	Chad	Nigeria
0-150 Km * c. 1990	-0.63*** [0.11]	-0.66** [0.31]	-0.59* (0.35)	-	-0.11** [0.05]	-0.12 [0.09]	0.05 (0.04)	-
150-300 Km * c. 1990	-0.63*** [0.13]	-0.83*** [0.23]	-0.36 (0.31)	-	-0.10*** [0.04]	0.21*** [0.04]	0.06* (0.03)	-
300-450 Km * c. 1990	-0.03 [0.10]	-0.80*** [0.24]	-0.47† (0.29)	-	-0.07*** [0.02]	0.28*** [0.04]	-0.03 (0.02)	-
0-150 Km * c. 2010	-0.80*** [0.14]	-0.90*** [0.24]	-0.49 (0.51)	-1.44*** [0.56]	-0.13 [0.14]	-0.08 [0.15]	0.12** (0.06)	-0.00 [1.38]
150-300 Km * c. 2010	-0.55*** [0.14]	-1.11*** [0.18]	-0.51 (0.48)	-1.42*** [0.47]	-0.20*** [0.07]	0.34*** [0.06]	0.17*** (0.05)	0.82 [1.07]
300-450 Km * c. 2010	-0.07 [0.14]	-1.10*** [0.17]	-0.50 (0.46)	-0.48** [0.21]	-0.16*** [0.05]	0.50*** [0.05]	-0.01 (0.03)	-0.37 [0.54]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Niger: 119 subdistricts x 17 years (1951-2017) = 2,023 obs. c.1990 = 1988. c.2010 = 2012. Cameroon: 113 subdistricts x 5 years (1963-2005) = 563 obs. c.1990 = 1987. c.2010 = 2005. Chad: 138 subdistricts x 5 years (1948-2009) = 690 obs. c.1990 = 1993. c.2010 = 2009. Nigeria: 83 subdistricts x 2 years (1963, 2006) = 166 obs. c.2010 = 2006. Urban population data is unfortunately not available for the census years 1952 and 1991. We only report the coefficients for the closest years to the years 1990 and 2010. For the inverse hyperbolic sine (I.H.S.) function used for urban population, we express population in 00,000s for Niger, Cameroon, and Chad, and 0,000s for Nigeria (based on our analysis of the country-specific distribution of urban population sizes across subdistricts). The I.H.S. function is used to minimize issues arising from extensive margin effects from the population cut-off used to define localities as cities. See text for details on the controls and details on how urban and rural populations are constructed. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10, † p<0.15.

Table 4 shows strong negative effects for rural populations. The urban population results are more ambiguous (we use an inverse hyperbolic sine (i.h.s.) transformation to deal with censoring from the 5,000 cut-off).³⁶ As in Henderson et al. (2017) who study

³⁶Chen and Roth (2024) highlights the difficulty of interpreting treatment effect estimates that combine

the country-level effects of climate change on urbanization in Africa, there could be cases where the urban sector was directly negatively affected by the shock and there could be other cases where a large number of impacted rural residents moved to cities.³⁷ The effects imply that the rural and urban population of the (0-450 km) Lake Chad region decreased by ~50% and increased by ~30%, respectively. The region went from 8.4% urban in 1960 to 19.9% urban in 2010. However, the total urban population increase was only 220,000, whereas the rural population loss was about 4 million. This loss was essentially driven by rural workers moving to other areas, making it difficult to study aggregate structural change with the reduced-form analysis. For that, we will rely on the QSM below.³⁸

Local Climate. For endorheic lakes, water seeps into the ground and/or evaporates (UNEP, 2004). 90% of rainfall then comes from the evaporation of oceans, seas, and lakes (USGS, 2021a). In warmer climates, lakes also have a cooling effect on their environment (USGS, 2021b). Lastly, groundwater levels can influence vegetation health. When a lake dries out, it may thus alter local climate conditions and geography more generally. UNEP (2004) calculates that the amount of evapotranspiration and infiltration halved as a result of the lake's shrinkage, with the reduced evapotranspiration responsible for 95% of the reduced total water "outflow" from the lake, a result also found by Olivry et al. (1996).

For each subdistrict-year, we observe annual rainfall (mm) and mean temperature (°C) (Appx. Section C). Focusing on the post-1950 period, we obtain the mean of these measures in 13 five-year periods: 1950-54, 1955-59 ... 2010-14. We use the same panel bin specification as eq. (2) but the dependent variable is mean temperature or log rainfall (we now have period FE). We then interact the bin dummies with dummies for each period (omitting the interaction for 2010-14). The controls include latitude and the Chari-Logone river dummies interacted with period fixed effects, as well as the district trends.³⁹

Table 5 reports the difference between the average effect for the full 1980-94 period and the one for the full 1950-64 period, which captures long-run changes post-1963. In Niger, Cameroon, Chad and Nigeria, temperatures increased by 0.0-0.4°C, 0.0-0.9°C, 0.1-0.2°C

extensive and intensive margin responses and the perils of arbitrary scaling. Due to the cut-off, subdistricts have either 0 urban residents or more than 5,000 urban residents. Using $\log(x+1)$ distorts the effects when the shock affects city creation, which we find in Appx. Table F.18. The i.h.s. transformation is a solution, but its reliability depends on the units used. It overweighs the extensive margin effects if the distribution of the i.h.s.-transformed data is U-shaped due to units being overly small (McKenzie, 2023). Here, expressing urban populations in 00,000s or more generates smoother power law distributions, which minimizes the issue. Lastly, the never-nil rural population levels are much higher, so the cut-off has limited impacts.

³⁷With rural population as the outcome and interacting the bin dummies with the urbanization rate or a dummy if there was a city in the subdistrict in 1963, we tend to find weaker population losses in historically more urban areas (Appx. Table F.19). This suggests that, in general, the former effects dominate the latter.

³⁸Since we use the sectoral results to calibrate the QSM, we verify that the parallel trends assumption is satisfied for these regressions (Appx. Table F.20). Given the lack of extensive margin effects for urban areas before 1963, using the inverse hyperbolic sine transformation is not justified here, and we rely on logs. More generally, there were few cities before 1963, and few rural localities passed the 5,000 urban cut-off.

³⁹The exact model for subdistrict s and period t is: $Climate_{s,t} = \alpha + \sum_v \beta_{150,v} Lake_{150} \times \mathbb{1}(t = v) + \sum_v \beta_{300,v} Lake_{300} \times \mathbb{1}(t = v) + \sum_v \beta_{450,v} Lake_{450} \times \mathbb{1}(t = v) + \lambda_s + \theta_t + X_s B_t + District_d * t + \mu_{s,t}$.

and 0.1-0.4°C, respectively. We also find rainfall losses of 4-8%, 5-23%, 3-22% and 9-16%, respectively. In contrast, the mean temperature increase and rainfall decrease across the four countries between 1960 and 2010 was +1°C and 12%, respectively. The effects are stronger closer to the lake, except in Nigeria due to the shape of the subdistricts there ((4)). Nigeria has one 150-300 km subdistrict – Bornu – which is particularly large. Using our pixel-level climate data, we separate Bornu into two subdistricts based on the pixels’ distance to the lake relative to the median distance within Bornu’s territory. The “closer” Bornu now belongs to the 0-150 km bin whereas the “farther” Bornu still belongs to the 150-300 km bin. Using this modified sample, the effects decrease monotonically ((5)).⁴⁰

Table 5: Reduced-Form Effects, Local Climate, Distance Bins, 1950-2015

(benchmark = 1950-1964)	(1) Niger	(2) Cameroon	(3) Chad	(4) - (5) Nigeria	
Dependent Variable:	Mean Monthly Temperature (Celsius) in the Subdistrict in Period t				
Lake 0-150 Km * (1980-1994)	0.38*** [0.08]	0.89*** [0.12]	0.19** [0.08]	0.19*** [0.06]	0.32*** [0.11]
Lake 150-300 Km * (1980-1994)	0.16*** [0.05]	0.31*** [0.11]	0.06 [0.07]	0.35*** [0.07]	0.25*** [0.07]
Lake 300-450 Km * (1980-1994)	-0.22*** [0.04]	0.02 [0.11]	0.05 [0.05]	0.10* [0.06]	0.10* [0.06]
Dependent Variable:	Log Mean Annual Rainfall (mm) in the Subdistrict in Period t				
Lake 0-150 Km * (1980-1994)	-0.08*** [0.01]	-0.26*** [0.03]	-0.25*** [0.04]	-0.13*** [0.02]	-0.17*** [0.04]
Lake 150-300 Km * (1980-1994)	-0.04* [0.03]	-0.05** [0.02]	-0.20*** [0.03]	-0.17*** [0.02]	-0.14*** [0.02]
Lake 300-450 Km * (1980-1994)	-0.06*** [0.01]	-0.05** [0.01]	-0.03** [0.01]	-0.09** [0.04]	-0.09** [0.04]
0-150 Km Subdistrict Cut Into 2	N	N	N	N	Y
Subdistrict FE, Period FE	Y	Y	Y	Y	Y
District Trends & Controls, Obs.	Y, 1547	Y, 1469	Y, 1794	Y, 1079	Y, 1092

Notes: Obs.: (1) Niger: 119 Subdistricts x 13 Periods = 1,547. (2) Cameroon: 113 Subdist. x 13 Periods = 1,469. (3) Chad: 138 Subdist. x 13 Periods = 1,794. (4) Nigeria: 83 Subdist. x 13 Periods = 1,079. (5) We cut Bornu, Nigeria’s only 0-150 km subdistrict, into two subdistricts based on distance to Lake Chad. The first (second) subdistrict aggregates climate information for all climate pixels whose Euclidean distance to the chosen lake centroid is below (above) the median distance observed among all pixels belonging to Bornu (sample = 84 Subdist. x 13 Periods = 1,092). We report the difference between the average effect for 1980-84 + 1985-89 + 1990-94 and the one for 1950-54 + 1955-59 + 1960-64 (the omitted period is 2010-14). Conley SE 100 Km. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

The results show how large the effects are relative to global CC and considering the fact that these countries have low rainfall levels and high temperatures already.⁴¹

Other Economic Outcomes. Night lights data from the DMSP satellites are provided by NGDC (2015).⁴² The data being available at a fine spatial resolution, we obtain the sum

⁴⁰The quality of the climate data depends on proximity to weather stations. Results hold if we pixel-level data and compute the mean temperature and rainfall of each subdistrict-period using (results not shown but available upon request): (i) as weights the distance of each pixel to an active weather station in both 1950-64 and 1980-94; or (ii) pixels located within 100 km or even 50km from an active station in both periods.

⁴¹In our sample of 453 subdistricts the mean average monthly temperature in 1950-64 was already 27°C.

⁴²The radiance calibrated version of this data is used to avoid top-coding complications.

of lights of each subdistrict in 2010. Following Henderson et al. (2012), our dependent variable is log (lights/area) in 2010, which we regress on the lake bin dummies. Lights data being unavailable before c. 1990, we control for economic conditions and electricity generation and consumption c. 1963. We add the baseline controls except the district trends since the model is cross-sectional. As seen in Table 6 where we focus on Cameroon, the lake's drying is associated with lower light intensity ((1)). We focus on Cameroon for this table as it has the best data on health and education facilities. See Appx. Table F.21 for the other countries. Details on the electricity controls are provided in the table notes.

Table 6: Other Outcomes, Distance Bins, Cross-Section, Cameroon (All Countries in (7)-(8))

Dependent Variable c. 2010:	(1) Night Lights	(2) Built Area	(3) Built Volume	(4) Greenness (NDVI)	(5)-(6) Output Crop Livestock		(7)-(8) Conflict Non-Org Org	
Lake 0-150 Km	-0.42* [0.25]	-0.40 [†] [0.25]	-0.47* [0.26]	-0.06*** [0.00]	-2.98*** [0.65]	-1.50*** [0.36]	2.26** (1.12)	1.85*** (0.46)
Lake 150-300 Km	-0.29** [0.14]	-0.24** [0.12]	-0.22* [0.13]	-0.02*** [0.00]	-1.44*** [0.50]	-1.11*** [0.28]	1.44** (0.65)	1.26*** (0.24)
Lake 300-450 Km	-0.27* [0.15]	-0.07 [0.20]	-0.08 [0.20]	-0.02*** [0.00]	-0.98** [0.45]	-1.02*** [0.27]	0.36 (0.48)	-0.52 (0.38)
1963 Controls, Obs	Y, 113	Y, 113	Y, 113	Y, 904	Y, 113	Y, 113	N, 453	N, 453

Dependent Variable c. 2010:	(9) Paved Roads	(10)-(11) Centers Health Medical	(12)-(13) Hospitals Local Regional	(14)-(16) Schools Primary Secondary Tertiary				
Lake 0-150 Km	-0.02 [0.02]	-0.033*** [0.010]	-0.005** [0.002]	-0.002*** [0.001]	0.000 [0.000]	-0.119* [0.066]	-0.048** [0.023]	-0.003** [0.001]
Lake 150-300 Km	-0.00 [0.01]	-0.025*** [0.008]	-0.004*** [0.002]	-0.002*** [0.001]	0.000* [0.000]	-0.069 [0.055]	-0.032* [0.019]	-0.002** [0.001]
Lake 300-450 Km	0.01 [0.01]	-0.017** [0.007]	-0.003** [0.001]	-0.001** [0.001]	-0.000 [0.000]	-0.031 [0.051]	-0.019 [0.018]	-0.002** [0.001]
1963 Controls, Obs	Y, 113	Y, 113	Y, 113	Y, 113	Y, 113	Y, 113	Y, 113	Y, 113
Baseline Controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: (1) Dep. Var. (2010): Log(sum of lights/ Area). 1963 conditions controls: Urban population share, log urban and rural population, and output shares and log output of the farming, livestock, fishing and urban sectors. 1963 electricity controls (1957): Dummy for whether the subdistrict has access to electricity and log of electrical capacity, length of the electrical network, electrical consumption and number of subscribers (existing stations and stations under construction). (2)-(3) Dep. Var. (2015): Log(built area or volume per area). 1963 conditions controls from (1). We control for the dependent variable in 1975. (4) 113 subdistricts x 8 five-year periods = 904 obs. Dep. Var. (t): Mean Normalized Difference Vegetation Index. We include subdistrict FE, period FE, the district trends, and the baseline controls interacted with year FE. We report the effect in 2000-14 (relative to 1982-94). (5) Dep. Var. (2017): Log(value of crop production/area). 1963 controls: Log of total farming output, rural population and area, and GDP share of farming. (6) Dep. Var. (2010): Log(number of total livestock units/area). We control for the dependent variable in 1960. (7)-(8) Dep. Var.: Number of non-organized and organized conflict events in 1997-2019 (Poisson model). (9) Dep. Var. (2008): Log(sq km of paved roads/area). We control for the dependent variable in 1965. (10)-(13) Dep. Var. (c. 2012-18): Log number of health and medical centers and local and regional hospitals per area. 1963 controls (1967): Log number of public and private dispensaries, departmental centers for preventive medicine, and public and private hospitals per area. (14)-(16) Dep. Var. (c. 2024): Log number of primary, secondary and tertiary schools per area. 1963 controls (1961): Log number of public and private junior secondary schools, public and private secondary schools, public and private supplementary schools, technical schools, and senior secondary schools per area. Conley SE 100 Km.

Satellite-based information on built-up area and volume is available from the Global Human Settlement Layer (GHSL) database circa the years 1975 and 2015.⁴³ Using the

⁴³Url: <https://human-settlement.emergency.copernicus.eu/>, last accessed on 04-06-2025.

same cross-sectional model and log (built area/area) or log (built volume/area) as the dependent variable, and controlling for the value of the dependent variable in 1975, we find similar results as for night lights ((2)-(3)). Lights and structures, while capturing development in both rural and urban areas, over-represent urban areas. We verify that the effects are less negative than the mean of the rural and urban effects in Table 4 above. For example, the 0-150 km effects for rural and urban population were -0.90 and 0.08, respectively. The 0-150 effect for lights is -0.42, which is higher than their mean (-0.49). For the other countries, the estimates similarly over-represent the urban population effects, which are not as negative as for rural population (Appx. Table F.21).

Rural Outcomes. From Pinzon et al. (2023), we obtain the mean Normalized Difference Vegetation Index (NDVI) of each subdistrict from 1982 to 2015 and verify that lake locations have become less green over time. Having annual data, we consider a sample with 113 subdistricts times 8 five-year periods (904 obs.). Using the same panel model as for the local climate regressions, we examine the average bin-specific effects for the period 2000-14 relative to the period 1982-94. We add subdistrict FE, period FE, the baseline controls interacted with period FE, and district trends. We find negative effects over time ((4) in Table 6)), which are stronger closer to the lake and meaningful given a mean NDVI of 0.67 in 1982-94. We also find negative effects in other countries (Appx. Table F.22).

IFPRI (2020) provides grid cell level production data for 42 crops in Africa c. 2017. Following the cross-sectional model used for lights, we regress log (crop output/area) on the lake dummies and the baseline controls. Since they did not provide similar data c. 1963, we add our crop-related controls c. 1963: Log of total farming output and rural population (and area), and the GDP share of farming. We find strong negative effects close to the lake ((5) in Table 6). Results are similar in other countries (Appx. Table F.23).

Gilbert et al. (2018) provide grid cell level data on livestock production c. 2010. Since they provide data for cattle, goats, sheep and horses, we use the FAO's total livestock unit (TLU) conversion factors to obtain subdistrict TLUs. Having consistent data c. 1963, we use the cross-sectional model to study the effects of the shock on log (TLU/area) c. 2010 when controlling for log (TLU/area) c. 1963 (adding the baseline controls). We find strong negative effects close to the lake ((6) in Table 6; Appx. Table F.24 for the other countries).

Conflict. The shock increased conflict as incomes decreased and resource competition intensified (Batello et al., 2004). For example, UNEP (2004, p. 56) writes: "There has also been significant migration from the north of the Basin as 'environmental refugees' have fled drought, increasing the pressure on natural resources and inciting social tensions." Likewise, the basin's drying has led pastoralists to move their stocks southwards in search of greener areas, which has increased tensions (Ibid.). Armed clashes between fishermen also took place "over who had the right over the declining fishing resource" (Ibid.).

We use 1997-2019 data from the Armed Conflict Location & Event Data Project (Linke et al., 2010) to examine if conflict correlates with proximity to the lake (conflict data does

not exist before).⁴⁴ We run regressions whereby the dependent variable is the number of conflict events in 1997-2019 and the variables of interest are the lake dummies. Some countries having few conflict events of a certain type, we run pooled regressions with the four countries altogether (incl. country FE). We use a Poisson model, as such models are used to analyze count data where the dependent variable is the number of occurrences of an event within a specific period. We add the baseline controls. (7)-(8) in Table 6 above show larger coefficients closer to the lake for both non-organized violence – protests and riots – and organized violence – mainly battles and violence against civilians.–⁴⁵ However, one caveat here is that we cannot control for conflict before the lake shock.

Infrastructure. The population effects capture the shock’s impacts and policy responses. Governments may increase resources to affected areas to help them cope with the shock or decrease them if fewer people live there after the shock. Locally funded amenities may be negatively impacted. Focusing on paved and improved roads (source: Jedwab and Storeygard (2021)), whose construction is decided by national governments, we do not see any clear patterns when using the cross-sectional model ((9) in Table 6 above shows the results for paved roads and Cameroon; results for all road types and countries in Appx. Table F.26). The dependent variable is the log length of paved or improved roads per area in 2008. We control for the dependent variable in 1965 and the baseline controls.

For the four countries we have data on the location of health and education facilities c. 2010 and 1963. We use the cross-sectional model – controlling for facilities before the shock and adding the baseline controls – to study how proximity to the lake differentially impacted facilities whose funding is national vs. local. As seen for Cameroon in cols. (10)-(16) of Table 6 above, we find more negative impacts for local infrastructure, in particular health centers and primary schools. We do not find large positive effects for national types of facilities (regional hospitals and tertiary schools). Appx. Tables F.27-F.28 confirm those facts for the other countries. Governments did not aim to mitigate the shock using infrastructure, and the decline in local amenities likely reinforced productivity effects.

In the next section, we explain our QSM, which is used to study the local, non-local and aggregate effects of the shock as well as the effects of mitigating forces and policies.

4. Model: Welfare Effects of the Shrinkage of Lake Chad

To quantify the economic impact of the lake’s shrinkage, we develop a dynamic spatial general equilibrium model following the framework of Caliendo et al. (2019). Consistent with the sufficient statistic result in Artuc et al. (2010), and under reasonable assumptions, changes in population flows can be used to infer changes in welfare and local conditions.

⁴⁴Url: <https://acleddata.com/>. Last accessed: 03-28-2023.

⁴⁵Appx. Table F.25 shows similar results for the main subcategories of conflict events. One interpretation is that the lake shock dramatically, and durably, reduced standards in the living in the area, decreasing the opportunity cost of violence and leading to a “spatial conflict trap”, i.e., a self-perpetuating cycle of violence where entrenched poverty due to the shock increases the likelihood of recurring conflict.

We leverage our reduced-form estimates showing that the lake's drying strongly reduced population in nearby areas. The sectoral effects are thus used to calibrate the model and back out sectoral productivity declines in lake-adjacent locations. These inferred sectoral productivity declines capture not only the shock's direct effects, but also related indirect effects through environmental change, conflict exposure, and infrastructure disruptions.⁴⁶

4.1. Model

4.1.1. Preferences

The model includes a set of N locations indexed by n and i . We calibrate the model for the 453 subdistricts across the four countries (later, we include the rest of the world as a 454th location). There are then J sectors indexed by j and k . In our case, we consider a rural sector and an urban sector. At $t = 0$, a mass of households are employed in the J sectors.⁴⁷ As in Caliendo et al. (2019), preferences are Cobb-Douglas across sectors:

$$C_t^{nj} = \prod_{k=1}^J \left(\frac{c_t^{nj,k}}{\alpha^{nk}} \right)^{\alpha^{nk}},$$

where $c_t^{nj,k}$ denotes the consumption of sector k goods by workers from sector j living in location n . The parameter α^{nk} represents the expenditure share of sector k goods in location n . The price index in location n is then given by

$$P_t^n = \prod_{k=1}^J \left(P_t^{n,k} \right)^{\alpha^{nk}}.$$

Households are forward-looking and solve a dynamic optimization problem. In each period, workers can reallocate across *markets*, where a market is a sector of employment j in a location n . Moving between markets involves mobility costs, denoted by $f^{nj,ik} > 0$, which represent the utility cost of moving from market (n, j) to market (i, k) . These costs are assumed to be time-invariant, additive, and taken as given by households.

Workers also receive *idiosyncratic preference shocks* each period, denoted ϵ_t^{ik} , which affect their location-sector choice. These shocks are drawn from an *Extreme Value Type I* distribution with CDF, $F(\epsilon) = e^{-e^{(-\frac{\epsilon}{\nu})}}$, where the parameter ν controls the dispersion of the idiosyncratic mobility shocks. The worker's value function is:

$$v_t^{nj} = U(C_t^{nj}) + \max_{\{i,k\}} \{ \beta E[v_{t+1}^{ik}] - f^{nj,ik} + \epsilon_t^{ik} \}, \quad (3)$$

where $C_t^{nj} = w_t^{nj} / P_t^{nj}$ corresponds to the real income for a worker employed in sector j in location n . Taking expectations over the idiosyncratic shocks, we define $V_t^{nj} = \mathbb{E}[v_t^{nj}]$,

⁴⁶These effects also implicitly capture the fact that land supply increased as new land emerged when the shore receded. In the model, this effect is included in the net effects on productivity, which are negative, suggesting that the sum of negative impacts dominated the sum of positive impacts in our context.

⁴⁷We abstract from population growth in the model. We also ignore age structures and unemployment and employment equals population. We thus alternatively use the words "employment" and "population".

which summarizes for market nj the expected welfare value and the option value of reallocating to other markets. The expected value function can be written as:

$$V_t^{nj} = U(C_t^{nj}) + \nu \ln \left(\sum_{i=1}^N \sum_{k=0}^J \exp(\beta V_{t+1}^{ik} - f^{nj,ik})^{\frac{1}{\nu}} \right) + \gamma_\nu, \quad (4)$$

where γ_ν is the Euler-Macheroni constant arising from integrating over the extreme value shocks, and $1/\nu$ represents the migration elasticity, which measures the responsiveness of migration decisions to changes in economic conditions. The implied choice probabilities (migration shares) of workers moving from market (n, j) to market (i, k) are given by

$$\mu_t^{nj,ik} = \frac{\exp(\beta V_{t+1}^{ik} - f^{nj,ik})^{1/\nu}}{\sum_{r=1}^N \sum_{h=1}^S \exp(\beta V_{t+1}^{rh} - f^{nj,rh})^{1/\nu}}. \quad (5)$$

In the limit, as $\nu \rightarrow 0$, the migration elasticity approaches ∞ , implying that workers can switch across regions and sectors without frictions. Employment evolves according to:

$$L_{t+1}^{nj} = \sum_{i=1}^N \sum_{k=1}^J \mu_t^{ik,nj} L_t^{ik}. \quad (6)$$

This equation determines the dynamics of labor allocation across markets over time.

4.1.2. Production

Firms in each sector and location produce a set of varieties of intermediate goods. The technology to produce these requires labor, land, and intermediate inputs, which consist of goods produced from all sectors. TFP of an intermediate good in region n and sector j is composed of two terms: a sector-location component A_t^{nj} , which is common to all intermediate producers in a location-sector, and a specific variety component, z^{nj} , that is drawn from a Fréchet distribution. The production function takes the following form:

$$q_t^{nj} = z_t^{nj} A_t^{nj} (\ell_t^{nj})^{\eta^{nj} \phi^{nj}} (h_t^{nj})^{(1-\eta)^{nj} \phi^{nj}} \prod_{s=1}^S (M_t^{nj,ns})^{\phi^{nj,ns}}, \quad (7)$$

where $z_t^{nj} A_t^{nj}$ corresponds to TFP, ℓ_t^{nj} and h_t^{nj} correspond to labor and land, respectively, and $M_t^{nj,s}$ to sector s material inputs demanded by sector j firms in location n . η^{nj} is the share of labor in value-added, ϕ^{nj} corresponds to the value-added share, and $\phi^{nj,ns}$ to the expenditure share in intermediate inputs from sector s . Firms have constant returns to scale, meaning that $(\phi^{nj} + \sum_s \phi^{nj,ns} = 1)$. The unit cost of an input bundle, x_t^{nj} , is:

$$x_t^{nj} = (w_t^{nj})^{\phi^{nj} \eta^{nj}} (r_t^{nj})^{\phi^{nj} (1-\eta^{nj})} \prod_{s=1}^J (P_t^{ns})^{\phi^{nj,ns}}, \quad (8)$$

where w_t^{nj} is the wage per efficiency unit of labor, r_t^{nj} the price of land, and P_t^{ns} the price of sector s in location n . The price is applied to all final goods and used intermediate inputs in location n . The unit cost of an intermediate good indexed by z_t^{nj} is given by

x_t^{nj}/z_t^{nj} . Following Caliendo et al. (2019), we denote the iceberg trade costs as $\kappa_t^{nj,ij} \geq 1$. In particular, one unit of any sector j variety shipped from location i to n requires producing $\kappa_t^{nj,ij}$ in location i . Competition implies that the price of a good j variety in location n is given by the minimum unit cost across locations, taking into account trade costs. The vector of productivity draws for each good j variety by the various locations is $z^j = (z^{1j}, z^{2j}, \dots, z^{NJ})$. The price index of sector j goods for consumers in location n is:

$$p_t^{nj}(z^j) = \min \left\{ \frac{\kappa_t^{nj,ij} x_t^{ij}}{z^{ij} A_t^{ij}} \right\}.$$

Prices increase with trade costs and decrease with productivity. For the urban sector, we introduce agglomeration forces such that $A_t^{nu} = \tilde{A}_t^{nu} (L_t^{nu}/K^n)^\gamma$, where K^n denotes the total land in location n , which is fixed over time. γ captures the strength of agglomeration forces. We assume a small value in order to avoid multiple steady-state equilibria.⁴⁸

4.1.3. Local Sectoral Aggregate Goods

Intermediate goods demanded from sector j in all locations are aggregated into a sectoral good denoted by Q :

$$Q_t^{nj} = \left(\int \tilde{q}_t^{nj}(z_j)^{\frac{\sigma^j-1}{\sigma^j}} d\phi^j(z^j) \right), \quad (9)$$

where $\phi^j(z^j)$ is the joint distribution over the vector z^j that we assume is the PDF of a Fréchet distribution. Local sectoral aggregate goods are used as intermediate inputs by other sectors or for final consumption in location n . Given the properties of extreme value type shocks, the price of the sectoral aggregate good j in location n at time t is:

$$P_t^{nj} = \gamma^{nj} \left(\sum_{i=1}^N (x_t^{ij} \kappa_t^{nj,ij})^{-\theta^j} (A_t^{ij})^{\theta^j} \right)^{\frac{-1}{\theta^j}}, \quad (10)$$

where γ^{nj} is a constant term that corresponds to the Gamma function evaluated at $1 - \theta^j$. θ^j is the trade elasticity. In location n , the expenditure share of goods j from location i is:

$$\pi_t^{nj,ij} = \frac{(x_t^{ij} \kappa_t^{nj,ij})^{-\theta^j} (A_t^{ij})^{\theta^j}}{\sum_{m=1}^N (x_t^{mj} \kappa_t^{nj,mj})^{-\theta^j} (A_t^{mj})^{\theta^j}}. \quad (11)$$

Then, a region exports more if it is more productive, if the cost of producing one unit of the good is cheaper, or if the iceberg transport cost is lower.

4.1.4. Market Clearing Condition – Sequential equilibrium

Following Caliendo et al. (2019), let X_t^{nj} be the total expenditure on sector j good in location n . The market clearing condition implies that:

⁴⁸We derive conditions for the existence and uniqueness in the steady-state equilibrium following Allen et al. (2024) and verify that the equilibrium is unique in our simulations (results available upon request).

$$X_t^{nj} = \sum_{k=1}^J \phi^{nj,nk} \underbrace{\sum_{i=1}^N \pi_t^{ik,nk} X_t^{ik}}_{Y_t^{nk}: \text{Gross production } nk} + \alpha^{nj} \underbrace{\left(\sum_{k=1}^J w_t^{nk} L_t^{nk} + r_t^n K_t^n + D_t^n \right)}_{\text{Final consumers}}. \quad (12)$$

The first term captures the demand for intermediate inputs, and the second term the demand for final goods. Final consumption depends on final expenditure: labor income, $w_t^{nk} L_t^{nk}$, rents, $r_t^n K_t^n$, and the initial deficits, D_t^n . The labor market clearing condition is:

$$L_t^{nj} = \left(\frac{\eta^{nj} \phi^{nj}}{w_t^{nj}} \right) \sum_{i=1}^N \pi_t^{ij,nj} X_t^{ij}. \quad (13)$$

The market-clearing conditions characterize the equilibrium in each period of the static framework. Following Caliendo et al. (2019), we distinguish three types of equilibria: (i) the *static equilibrium* solves the model period by period; (ii) the *sequential equilibrium* solves the full dynamic problem (dot system); and (iii) the *counterfactual equilibrium* solves the model under alternative sequences of economic fundamentals (hat system). We compute a baseline equilibrium and the counterfactuals using observed trade and migration flows across locations, along with sectoral and regional revenues, without requiring direct information on baseline fundamentals.⁴⁹

4.1.5. Welfare Measure

We consider the net present value of the permanent equivalent variation in real income for workers initially employed in sector s in location i (Caliendo et al., 2019; Rodriguez-Clare et al., forthcoming):

$$\ln(\zeta^{nj}) = \sum_{t=1}^{\infty} \beta^t \ln \left(\frac{\hat{w}_t^{nj}}{(\hat{\mu}_t^{nj})^\nu} \right), \quad (14)$$

where ζ^{nj} is the welfare measure, β^t is the discount factor, and $\hat{w}_t^{nj} = \hat{w}_t^{nj} / \hat{P}_t^n$ is the change in real income, with $\hat{w}_t^{nj}$ denoting the change in wages and $\hat{P}_t^n$ the change in the price index. The term $(\hat{\mu}_t^{nj})^\nu$ captures how the outside options for workers in sector s and location i evolve over time. If outside options improve after the shock, more workers reallocate toward these better opportunities, raising welfare gains. Conversely, if outside options deteriorate, fewer workers move, and welfare gains are smaller, reflecting the fact that locations or sectors with higher mobility experience larger declines in real income.

4.2. Model Data, Calibration, and Shocks

To calibrate the model, we use data for the 453 subdistricts of the four countries and two sectors: a *rural* sector and an *urban* sector. See the notes of Figure 4 below for a list of the parameters (most of them come from our context, Africa, or the developing world).

⁴⁹The equations for the sequential and counterfactual equilibria are derived in the [web model appendix](#).

A. Sectoral output in each subdistrict: From the sources listed in the notes of Appx. Table F.12, we obtain circa the year 1963 *urban output* (industry + service) as well as fishing output, farming output, and livestock output, which allows us to calculate *rural output*.

B. Output elasticities: For the rural sector, studies report a land share close to 0.6.⁵⁰ Based on input–output tables for the four countries in the 1950s–early 1960s,⁵¹ we set the rural labor share to 0.3 and the share of intermediate inputs to 0.1 (0.03 for urban-sourced inputs and 0.07 for rural-sourced inputs). For the urban sector, Tsivanidis (forthcoming) and Khanna et al. (2020) estimate a land share of 0.2 for Bogotá and Medellín (Valentinyi and Herrendorf (2008) find 0.2 globally).⁵² From the input–output data, we set the labor share to 0.53 and use 0.19 and 0.08 for urban and rural intermediate inputs, respectively.

C. Sectoral employment in each subdistrict: We use the rural and urban population data.

D. Labor mobility: We need information on mobility flows to solve the sequential and counterfactual equilibria. Data comparable to the U.S. CPS do not exist for our countries in the 1950s–60s, which prevents us from directly constructing mobility matrices across locations and sectors. We use localized data on ethnic composition from the 1950s–60s and infer pre-shock internal migration flows by comparing the spatial distribution of each ethnic group then with the location of their historical homelands, as mapped by Murdock (1967).⁵³ Appx. Figure F.7 displays the raw ethnic data for Cameroon and Niger. Using various sources, we obtain for each country c. 1963 the share of residents coming from the other countries, allowing us to reconstruct external migration flows.⁵⁴ Lastly, following Ulate et al. (2025), we assume perfect mobility across sectors within each subdistrict.

E. Trade & sectoral expenditure shares: To obtain trade flows across subdistricts, we proceed in two steps. We first compute trade costs using the road quality database from Jedwab and Storeygard (2021), which digitizes Michelin road maps from 1965 to 2014. Using their methodology, we construct a grid of $0.1^\circ \times 0.1^\circ$ ($\approx 11 \times 11$ km) cells and assign each cell a travel time based on the best road quality in 1965, using the authors’ chosen speed for each type.⁵⁵ We then compute travel times for all subdistrict pairs. Following Allen and Arkolakis (2022), we parametrize trade costs as a function of travel times:

$$\tau_{ijs} = \exp(\delta \cdot t_{ij}),$$

⁵⁰Using Avila et al. (2010)’s estimates, we obtain a land share of 0.56 for the four countries in 1961–80. Chen et al. (2017) find 0.58 (Malawi). Gollin and Udry (2021) find 0.61–0.53 (Tanzania and Uganda).

⁵¹See Appendix Section E for the sources used for each country.

⁵²We did not find reliable estimates of the urban land share in Africa. However, 0.2 is a canonical number.

⁵³The methodology used is fully described in Appx. Section E. This approach is, to our knowledge, the first to reconstruct historical migration flows using localized ethnic composition data. We view this as a methodological innovation that can be applied to other settings where direct mobility data are unavailable.

⁵⁴Our approach requires: (i) localized ethnic data; (ii) data on the “staying rate” (the share of residents living in their place of origin); and (iii) data on the share of residents from the other countries of study. See the notes of Appx. Fig. F.7 for details on the sources. The 201, 152, 208, and 34 groups in the Cameroon, Chad, Niger, and Nigeria data are respectively matched to 176, 45, 117, and 26 groups in Murdock (1967).

⁵⁵We consider highways (80 kph), other paved roads (60), improved (laterite or gravel) roads (40), and dirt roads (12). People also travel by boat across the lake (10) or on foot (3). See Appx. Section E for details.

where t_{ij} is the travel time between locations i and j , and δ converts travel time into trade costs. To estimate δ , we use price data on: (i) imported goods across 48 Cameroonian cities in 1965; and (ii) imported oil in 19 Nigerien cities over four semesters in 1962. Since goods are relatively homogeneous and enter each country through the same port, local price differences mainly reflect trade costs (Atkin and Donaldson, 2015). Regressing local prices on travel times yields an estimate of $\delta \approx 0.08$ (see Appendix Table F.29 for the results and details on the sources). Allen and Arkolakis (2022) also find 0.08.

In the second step, we invert the model under the no-deficit condition in the cross-section to recover productivity and trade flow values and compute the initial trade shares, π^{ijs} , and initial expenditure shares, α^{nj} , that we use to solve the sequential equilibrium.⁵⁶

E. Elasticities: For the rural trade elasticity (i.e., substitutability between rural varieties), we use 4 (Donaldson, 2018). We use 1 for the urban sector based on Boehm et al. (2023) who focuses on manufacturing. Cities thus exist to provide non-homogenous local goods and services. For the agglomeration force, we use 0.05 (Ahlfeldt and Pietrostefani, 2019).

F. Annual Discount Factor: We use 0.95 as Rodriguez-Clare et al. (forthcoming).

G. Calibration of the Sectoral Shocks: To link the model to the reduced-form results, we adopt an indirect inference approach inspired by Caliendo et al. (2019) and Rodriguez-Clare et al. (forthcoming). We test several values for the migration elasticity and calibrate productivity shocks for the rural and urban sectors over the periods 1960-1970, 1970-1980, and 1980-1990, when the lake was drying. We choose the evolution of local productivities that allows us to match the model-implied and reduced-form coefficients in 2010.

More precisely, let $\dot{A}_{s,b} \equiv A_{t+1,s,b}/A_{t,s,b}$ denote the productivity shock for each sector s , treated country-distance bin b (0-150, 150-300 and 300-450 km), and decade $t \in \{1960, 1970, 1980\}$. This means that between 1960 and 1990 the productivity evolves as follows: $A_{s,b}^{1990} = \dot{A}_{s,b}^3 A_{s,b}^{1960}$. For instance, an estimated 50 percent productivity shock here implies that $A_{s,b}^{1990} = 0.5^3 A_{s,b}^{1960}$. The inference procedure then selects the combination of distance bin-specific rural (r) and urban (u) productivity shocks, $(\dot{A}_{r,b}, \dot{A}_{u,b})$, such that

$$(\dot{A}_{r,b}, \dot{A}_{u,b}) = \arg \min \Gamma(\dot{A}_{r,b}, \dot{A}_{u,b})' \mathbf{W} \Gamma(\dot{A}_{r,b}, \dot{A}_{u,b}), \quad (15)$$

where $\Gamma = \beta^{\text{Model}} - \beta^{\text{RF}}$ is the difference between the model-implied and reduced-form estimates in 2010. The weighting matrix $\mathbf{W}$ here consists of the inverse of the SE in the reduced-form regressions to privilege more precise reduced-form estimates.⁵⁷

Lastly, to keep the calibration tractable, we specify only two baseline shocks—one rural shock and one urban shock—and use a scaling matrix to adjust these shocks across

⁵⁶We invert the model to recover the initial trade flows (see the [web model appendix](#) for details).

⁵⁷We test many finite combinations of the sectoral shocks and migration elasticity, selecting the one minimizing the loss function as our starting point to implement Newton's method. Our objective is to minimize the total sum of the weighted rural SSE and the weighted urban SSE. The five positive urban coefficients are set to 0 to avoid estimating positive urban shocks. The SSE is logically smaller for rural areas, and is as low as 0.08 (hence, a maximum total difference of 8% is observed across rural impacts).

all countries and distance bins based on the magnitude of the 2010 reduced-form effects.⁵⁸

The loss function is minimized for a migration elasticity of 5 and rural productivity declines that are large. Appx. Table F.30 reports the implied rural and urban productivity shocks for each country and distance bin in our baseline calibration. The mean cumulative rural (urban) shock for the Lake Chad region over the 1960-90 period is -77% (-10%). Remember that we call them *productivity* shocks because they enter in the model as changes in productivity; however, since we match the reduced-form coefficients, they also capture broader adverse effects, such as reductions in amenities from local climate change, deteriorating environmental conditions, infrastructure disruptions, and conflict.

A migration elasticity of 5 is slightly on the higher side of what the literature has found.⁵⁹ There are reasons that explain this finding: (i) Our elasticity is estimated over multiple decades; (ii) Our shock was large and localized, and people likely migrate more for disproportionately large shocks; and (iii) Our countries had low migration flows pre-shock, implying high bilateral migration costs. Migration frictions in Africa are large due to ethnic factors. The population responses can only be rationalized by a high migration elasticity, and it is precisely because of ethnic divisions that the elasticity is high.

H. Validation: For each pre-2010 decade, we find that the model-implied effects never significantly differ from the reduced-form (RF) effects (test for 48 country-sector-distance bin-decades). Since the sum of squared errors does not distinguish whether the difference between the model and RF effects is positive or negative, we also verify that there are no systematic patterns where the sum of errors (between the model-implied and RF effects) is systematically more positive or negative (test for 14 country-sector-decades). Therefore, the model does not under- or over-estimate the “speed” of the shocks in either sector.

Next, the resulting rural and urban expenditure shares are 62% and 38%, respectively. Using region- and city-specific budget surveys from the 1950s-1960s (Appx. Section E), we reconstruct the corresponding national shares for each country c. 1963. We obtain mean (pop.-weighted) rural and urban expenditure shares of ~60% and ~40%, respectively.

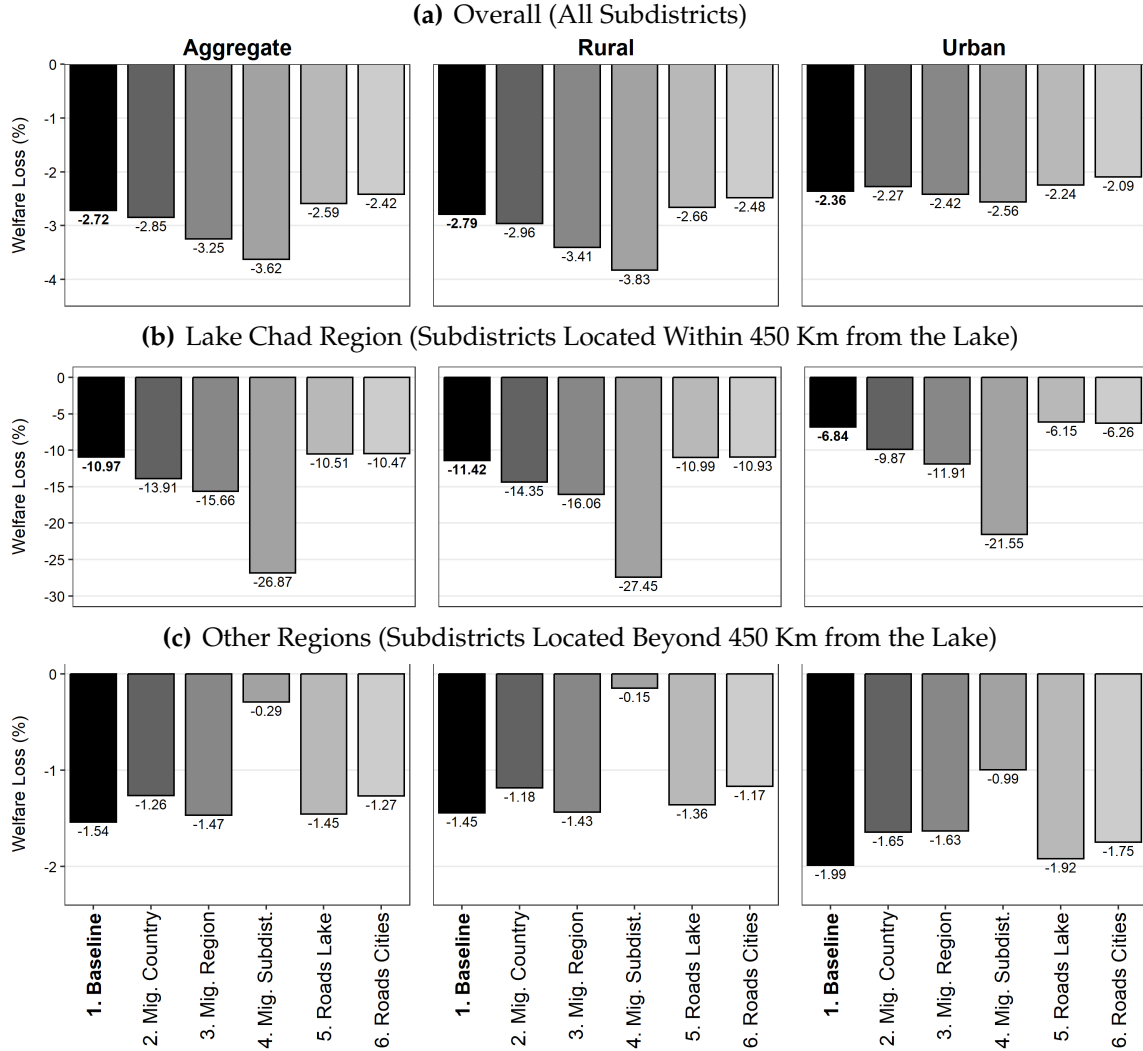
We also compare the model-implied bilateral trade flows to the ones observed in the data c. 1963 (source: Hausmann et al. (2014), who use various methods to improve the COMTRADE database, especially in earlier years). We have four countries and two sectors (N=16). The coefficient of correlation between the predicted and actual (logged) flows is 0.60, which is high considering that: (i) COMTRADE has a lot of unlikely zero or tiny values, and probably omitted informal trade at a time when borders were porous or

⁵⁸For example, the 0-150 km rural shock in Niger (coeff. = -0.80, or -55%) is set to 72% of the 0-150 km rural shock in Nigeria (-1.44, or -76%). This mapping reduces the dimensionality of the calibration problem from 4 (countries)*3 (bins)*2 (sectors) = 24 coefficients to 2. Considering other decades prior to 2010 also makes the calibration intractable. We solve the model for 90 periods to reach the steady state. The intractability is due to the 453*2 possible locations-sectors and the dynamic decisions that agents make over 90 periods.

⁵⁹Bryan and Morten (2019) and Morten and Oliveira (2024) found 3.2 and 4.5, respectively. Conversely, Allen and Donaldson (2018) found values of 8.4, 6.8, and 5.6 for the U.S. in 1850, 1900, and 1950, respectively.

non-existent (e.g., Cameroon, Chad, and Niger were part of the French colonial empire until independence in 1960); and (ii) We likely misclassified some products as “rural” or “urban” despite our best efforts to identify products as belonging to the fishing, livestock, farming, or urban subsector. There are many products for which choices are ambiguous.⁶⁰

Figure 4: Welfare Loss Implied by the Shock, by Sector and Region



Notes: (2) Mig. Country: Migration flows across countries are set to 0. (3) Mig. Region: Migration flows across first-level administrative regions (as of 1960) are set to 0. (4) Mig. Subdist.: Migration flows across subdistricts are set to 0. (5) Roads Lake: We pave the (as of 1963) unpaved ring road around the lake. 83 cells are paved in total (45 in Chad, 19 in Nigeria, 10 in Niger, and 9 in Cameroon). (6) Roads Cities: We use the same budget of 83 cells to be paved, but instead, we pave the unpaved cells of the fastest road from the country's largest city to the lake. We use the following parameters: agglomeration elasticity of 0.05 (γ), urban trade elasticity of 1 (θ^u), rural trade elasticity of 4 (θ^r), migration elasticity of 5 ($1/\nu$), land share in the rural sector of 0.6 ($\phi^r \cdot (1 - \beta)^r$), land share in the urban sector of 0.2 ($\phi^u \cdot (1 - \beta)^u$), labor share in the rural sector of 0.3 ($\phi^r \cdot \beta^r$), labor share in the urban sector of 0.53 ($\phi^u \cdot \beta^u$), rural intermediate inputs share in the urban sector of 0.08 ($\phi^{u,r}$), urban intermediate inputs share in the urban sector of 0.19 ($\phi^{u,u}$), rural intermediate inputs share in the rural sector of 0.07 ($\phi^{r,r}$), and urban intermediate inputs share in the rural sector of 0.03 ($\phi^{r,u}$).

4.3. Baseline Results

Panel A of Figure 4 shows the baseline results across all sectors (left), and for the rural (middle) and urban (right) sectors. Focusing on the 1. Baseline column, we find that the

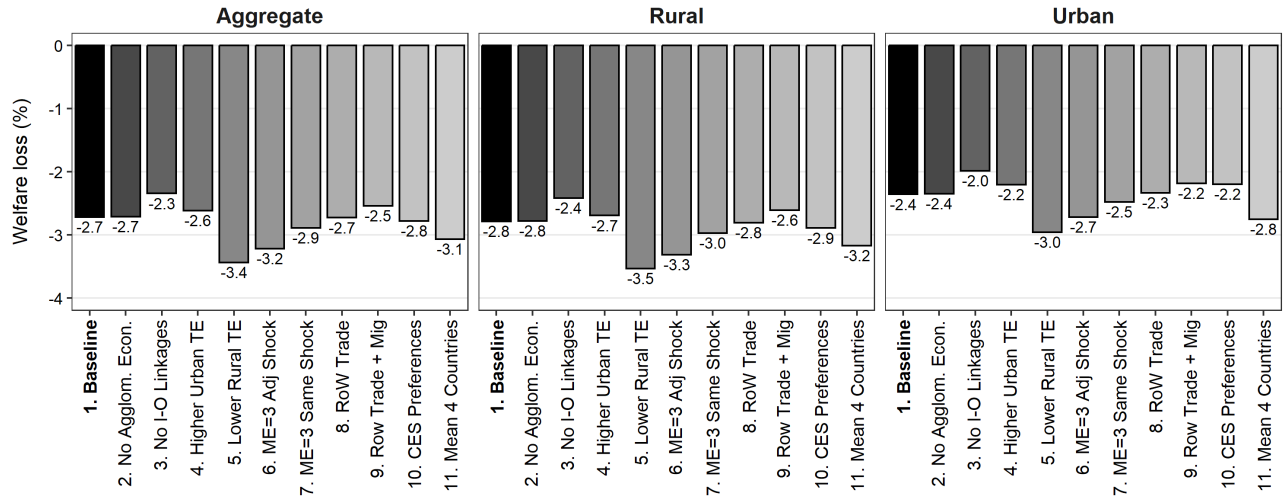
⁶⁰We do not have localized data on wages, prices or trade over time to do the validation at a lower level.

shock led to losses of 2.72%, driven by both rural (2.79%) and urban losses (2.36%). Since the typical 1960 resident (across lake and non-lake areas) experienced a model-implied productivity shock of 2.94%, the adaptation factor was $1 - 2.72/2.94 = 0.07$ (7%) only. This back-of-the-envelope calculation suggests low adaptation capacity in our context.

Panels B and C show the losses for the Lake Chad Region (LCR) (i.e., within 450 km from the lake) and other regions (i.e., beyond 450 km). Overall losses are much larger for the LCR than elsewhere, reaching 10.97% vs. 1.54%. The fact that the LCR accounted for 13% of population c. 1963 explains why the aggregate impact is not larger in Panel A.⁶¹

Figure 5 shows that the baseline overall results remain similar for the whole sample, the LCR, and other regions, when implementing various robustness checks.⁶²

Figure 5: Welfare Loss Implied by the Shock, Robustness Checks



Notes: (2) We lower the agglomeration elasticity from 0.05 to 0. (3) We exclude intermediate inputs in the sectoral production functions. (4) We increase the urban trade elasticity (TE) from 1 to 4. (5) We lower the rural trade elasticity (TE) from 4 to 3. (6) We use the estimated shocks that minimize the loss function when the migration elasticity (ME) is 3. (7) We use the shocks estimated with a ME of 5, but set the ME to 3. (8) We allow for trade with the rest of the world (RoW). (9) We allow for trade and migration with the RoW. (10) We consider CES preferences with $\sigma = 1.7$. (11) We report the simple average of the four country-specific losses.

2. Agglomeration Economies. Results are unchanged if we lower the agglomeration elasticity from 0.05 to 0, due to the urban share changing little in the aggregate.⁶³

3. Input-Output (IO) Linkages. Losses slightly decrease if we exclude intermediate inputs in the sectoral production functions, since it leads to less diffusion of the shock.⁶⁴

4.-5. Trade Elasticities (TE). Losses are only slightly lower when increasing the urban trade elasticity (TE) from 1 to 4. More substitutability between urban varieties reduces urban losses, but the urban sector contributes less to welfare than the rural sector. Lowering the rural trade elasticity from 4 to 3 increases losses to 3.4%. We do not test

⁶¹ Appx. Fig. F8 shows each country's loss (Cameroon: 4.7%; Chad: 3.0%; Niger: 2.1%; Nigeria: 2.6%).

⁶² Appx. Fig. F9 shows the robustness checks for the Lake Chad and other regions. Results hold.

⁶³ Increasing it to 0.10 makes the model more intractable, due to the possibility of multiple equilibria.

⁶⁴ We adjust the output elasticities accordingly so that the exponents still sum to one. The urban sector is for example less exposed to the large rural shocks since it does not use rural intermediate inputs anymore.

a lower elasticity than 3, as this would assume a low degree of substitutability between rural varieties, i.e., foodstuffs. If anything, losses would be even higher in that case.

6.-7. Migration Elasticity (ME). The loss is only slightly higher if we: (i) use the productivity shocks that make our model match the reduced-form effects the most when using a ME of 3; and (ii) keep the same shocks as for ME=5 but lower the ME to 3.

8.-9. Rest of World (RoW). The loss is only slightly lower if we add trade with the RoW (added as a 454th location), or also add migration to/from the RoW.⁶⁵

10. Preferences. Cobb-Douglas preferences ($\sigma = 1$) lead to fixed expenditure shares, whereas CES preferences allow expenditure shares to vary depending on the relative price indices of rural and urban varieties. We use $\sigma = 1.7$ (Edmond et al., 2015). The rural expenditure share decreases, but only marginally.⁶⁶ Losses remain high.⁶⁷

11. Weights. In dynamic QSMs, most studies assume a utilitarian welfare function and use employment weights in the initial period to aggregate welfare (Desmet et al., 2018; Rodriguez-Clare et al., forthcoming). Doing so gives more weight to the largest country, Nigeria. If we use country-specific loss estimates and then take the average of them to give each country the same weight, then the overall loss barely changes.

12. Optimistic Expectations. We follow Fan et al. (2023) to study the role of expectations.⁶⁸ Appx. Fig. F.11 depicts the expected path of rural productivity under such scenarios. Expectations vary depending on the year in which they are formed. In 1960, agents observe the shock, but expect the lake to fully recover the following decade. In 1970, they observe that the lake declines further; nevertheless, they again expect the lake to fully recover next decade. This pattern repeats in 1980 and 1990, with agents forecasting recovery. After 1990, they finally accept reality and do not expect the lake to recover.

⁶⁵Migration is calibrated using region-level data on the number of residents from the RoW c. 1963 (sources provided in the notes of Appx. Fig. F.7) as well as data on the number of residents from each country in major developed economies c. 1963 (Appx. Section E). We model trade using the distance between each subdistrict and Europe's largest port, Rotterdam. We assume a vessel speed of 50 kph. We then impose that shipping goods by sea is four times cheaper than transporting them by road. When computing trade costs based on distance, we thus set $\delta = 0.02$. To calculate total revenue, we use the *World Development Indicators* database of the World Bank to obtain sectoral GDP and employment c. 1963.

⁶⁶The rural share is 61.9% with Cobb-Douglas preferences. With CES preferences, it is 60.7% in the long run. The aggregate structural change impact is also small (the urbanization rate goes from 16.2% to 16.4%).

⁶⁷Introducing non-homothetic preferences would require solving for time-varying price indices within an additional inner loop at each iteration, increasing computational complexity. As in Comin et al. (2021), this could be captured by a parameter governing the responsiveness of expenditure shares to income. However, there is no closed-form solution for expenditure shares; instead, the shares and the aggregate price index are determined implicitly via a fixed-point system, requiring an additional contraction mapping to compute. Introducing non-homothetic preferences would, if anything, amplify losses. Since households in impacted locations become poorer, they rely more on the rural good, which becomes more expensive with the shock.

⁶⁸Fan et al. (2023) examine the role of learning and expectations in dynamic spatial models, developing a second-order approximation method to study how shocks to fundamentals affect the spatial economy in a general stochastic dynamic framework. We follow Ulate et al. (2025) and analyze the role of expectations by solving the full model under the assumption that agents are forward-looking, comparing outcomes based on agents' optimistic expectations with those based on the realized shocks.

Under the setting where beliefs do not match the actual shocks, we can follow Fan et al. (2023) and define three notions of welfare. The first is the *expected welfare* based on agents' beliefs at each point in time. The second is the *perfect foresight* welfare, which assumes that agents know the actual shocks in advance at each period. The third is the *realized welfare*, where agents make decisions based on their beliefs, and outcomes are determined by the actual shocks. Our analysis here focuses on this third measure.

Losses increase from 2.72% in the baseline to 3.97% in the optimistic scenario. Rural losses increase from 2.79% to 4.50% whereas urban losses decrease from 2.36% to 1.21%. Since agents continue to expect the lake to recover, fewer workers relocate from directly affected rural areas to other regions or the urban sector. More workers remain exposed to the shock in each decade until 1990, earning lower real incomes, which amplifies losses.

Of course, the data used for the calibration is not as complete as for other contexts like the U.S.. For the sake of simplicity, some dimensions (e.g., unemployment) are also ignored in the model. Some of the model-based results should thus be taken with caution.

4.4. Mechanisms

The model allows us to further examine mechanisms. For each of the 453 subdistricts, we obtain the implied long-run (1960-2010) changes in population, output, prices, land use, wages, and welfare. In Table 7 below, we regress each variable on the lake bin dummies. Since the model offers a controlled environment, the effects are causal by construction, and we do not need country FE. This makes it possible to estimate the constant, which captures the average effect in the rest of each country, so beyond 450 km from the lake. As such, the model permits the triple examination of local, non-local, and GE effects.⁶⁹

(1)-(2) replicate the reduced-form effects on log rural and urban population. The negative rural effects in lake-adjacent locations are offset by a positive average effect of 7% beyond 450 km. Lake-adjacent locations thus lost some of their comparative advantage in rural production. The urban coefficients are then less negative in lake-adjacent locations, suggesting structural change away from the rural sector locally, which we verify using as a dependent variable the change in the urban employment or output share ((3)-(4)). At the national level, we observe structural change away from the urban sector instead (all coefficients are negative in (2)). Indeed, the lake shock was mainly a rural shock, so the lower productivity had to be offset by increased rural employment in the aggregate.⁷⁰

These results are corroborated by (5)-(7), where the dependent variable is the change in (log) total, rural, or urban output. Total output is driven by rural output. Even if rural output increased outside the lake locations, it was not enough to compensate for the rural

⁶⁹We also use Conley SE (100 km). Since the model is calibrated using reduced-form coefficients whose SE we ignore for tractability, we verify that results hold with SE bootstrapped 10,000 times (not shown).

⁷⁰Yet, that aggregate structural change impact is small (the urbanization rate goes from 16.2% to 16.0%). Cobb-Douglas preferences lead to fixed expenditure shares. Since we assume the same expenditure shares across the four countries, the employment shares change little in the aggregate.

productivity shock. Rural prices increased everywhere ((9)), driving aggregate prices up ((8)). Urban prices increased overall, even if they decreased in lake locations ((10)).

Land use adjusts when local specializations change. Rural land use ((11)) follows the patterns of rural production ((6)), declining in lake locations and increasing elsewhere. However, the decline in rural output is mostly occurring through employment losses (coefficients much larger in ((1))). The rural sector being strongly land-intensive, rural decline occurs without a one-for-one decrease in labor and land. Next, we observe no effect on urban production until 300 km from the lake ((7)). Since the sector is strongly labor-intensive and employment decreases ((2)), urban land use has to increase (see (12); the observed percentage changes are high because initial numbers are small).

Table 7: Model-Based Mechanism Results, Long-Run Changes

Dependent Variable = $\Delta \dots$ in 1960-2010 (Logged in all Columns except (3)-(4))								
...	(1) - (2) Population		(3) - (4) Urban Share		(5) - (7) Output			(8) Agg.
	Rural	Urban	Pop.	Output	Total	Rural	Urban	Price
Lake 0-150 Km	-0.70*** (0.15)	-0.04* (0.02)	0.09*** (0.02)	0.02** (0.01)	-0.83*** (0.18)	-0.87*** (0.19)	-0.01 (0.04)	0.02*** (0.00)
Lake 150-300 Km	-0.76*** (0.11)	-0.02 (0.02)	0.09*** (0.02)	0.05*** (0.02)	-0.80*** (0.13)	-0.94*** (0.14)	0.02 (0.03)	0.02*** (0.00)
Lake 300-450 Km	-0.38*** (0.09)	-0.17*** (0.03)	0.03* (0.02)	0.04* (0.02)	-0.37*** (0.07)	-0.47*** (0.12)	-0.20*** (0.04)	0.01*** (0.00)
Constant	0.07*** (0.00)	-0.02*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	0.07*** (0.00)	0.09*** (0.00)	-0.02*** (0.00)	0.06*** (0.00)
...	(9) - (10) Price		(11)-(12) Land Area		(13) Land	(14) - (15) Wage		(16) Welf.
	Rural	Urban	Rural	Urban	Price	Rural	Urban	Index
Lake 0-150 Km	0.03*** (0.00)	-0.00*** (0.00)	-0.02*** (0.00)	0.84*** (0.22)	-0.85*** (0.19)	-0.16*** (0.04)	0.03** (0.02)	-0.08*** (0.02)
Lake 150-300 Km	0.03*** (0.00)	-0.01*** (0.00)	-0.09** (0.04)	0.86*** (0.16)	-0.85*** (0.14)	-0.18*** (0.03)	0.04*** (0.01)	-0.08*** (0.01)
Lake 300-450 Km	0.02*** (0.00)	-0.00 (0.00)	-0.06 (0.04)	0.21** (0.11)	-0.41*** (0.09)	-0.09*** (0.03)	-0.03** (0.01)	-0.05*** (0.01)
Constant	0.08*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	-0.10*** (0.00)	0.08*** (0.00)	0.02*** (0.00)	-0.01*** (0.00)	-0.02*** (0.00)

Notes: Sample: 453 subdistricts in the four countries. We do not include country FE. (5)-(7) Output is expressed in monetary terms. (16) Welfare is the net present value of real income and also captures outside options for workers (Section 4.1.5.). Conley SE 100 Km.

However, land prices strongly decrease in lake locations ((13)), because the absolute effects on rural land use are actually larger than the ones on urban land use, in addition to the fact that land is fixed in space whereas labor is mobile. The wage effects are logically more muted ((14)-(15)). In other words, the labor effects of the shock are mostly occurring through quantities, whereas the land effects are mostly occurring through prices. Given the lower rural productivity and demand for rural labor, rural wages decline locally (but increase elsewhere). Conversely, with local specializations changing, the local demand for urban labor increases, and urban wages increase (at least up to 300 km; see (15)).

Welfare decreases locally (by 8% up to 300 km and 5% between 300 and 450 km; (16))), driven by the lower rural wages ((14)) and higher prices ((8)). Welfare also decreases in non-lake locations, by 2% on average ((16)). Indeed, even if rural wages increase there (+2%; (14)), urban wages decrease (-1%; (15)) and prices increase (+6%; (8)). Outside options also deteriorate, contributing to the welfare losses in all locations.⁷¹

Finally, since the model is dynamic, we can track the evolution of each outcome over time. Appx. Fig. F.10 shows the respective evolution of total population and output for the Lake Chad Region (0-450 Km) and other regions (450+ Km). First, aggregate patterns follow rural patterns. Second, output decreases faster than population. Finally, patterns start stabilizing after 1990 when the lake stops shrinking and are mostly stable post-2010. If anything, population keeps slightly decreasing in the Lake Chad Region after 2010.

4.5. Mitigating Forces: Migration, Trade, and Canal Construction

We have discussed the respective roles of the trade and migration elasticities, and trade and migration with the rest of the world. We now discuss how losses would be impacted with different bilateral migration costs or trade costs. Results are shown in Figure 4 above.

2.-4. Migration costs: Losses increase by one third from 2.72% up to 3.62% when adjusting migration flows so that residents cannot migrate across subdistricts (4. Mig. Subdist.). However, the Lake Chad Region sees its loss almost triple, from 10.97% to 26.87%. The other regions are more protected now, as their loss decreases from 1.54% to 0.29%. Intermediary scenarios where workers can only migrate within the same country or first-level administrative region (c. 1960 boundaries) produce intermediary values (2.-3.).⁷²

5.-6. Trade costs: A policy often implemented in disaster-struck regions is to build roads to increase market access and create local jobs. In the reduced-form analysis, we did not find any effect of the shock on road building. But what if governments had built more roads to cope with the shock? We simulate a policy that paves the (as of 1965) unpaved ring road around the lake, thereby facilitating regional trade.⁷³ 83 cells of $0.1^\circ \times 0.1^\circ$ ($\approx 11 \times 11$ km) are paved (45 in Chad, 19 in Nigeria, 10 in Niger, and 9 in Cameroon), which amounts to 8% of the paved network in 1965. As seen in col. 5. in Fig. 4, the loss decreases from 2.72% to 2.59%, i.e., 0.13 p.p. (for the Lake Chad Region, it decreases by 0.48 p.p.).⁷⁴

⁷¹Appx. Fig. F.6 maps the implied welfare loss for each subdistrict.

⁷²To study the role of migration costs, we adjust the initial migration flows to reflect infinite migration costs across subdistrict pairs and proceed in three different steps. For example, when there is only migration within countries, there are no migration flows between countries. Then, in a first step, we simulate all the transitions from 1960 onwards for 90 periods until the model reaches a new steady state. Second, with the new migration shares, we simulate the economy with productivity shocks resulting from the lake shock. Third, to remove the direct effect of migration costs, we compare the second scenario with the first one.

⁷³To define the ring road, we study the first available Michelin map (1965). The map indicates whether a road is “transcontinental or important.” We use this information to select specific road segments, i.e. cells. For the remaining segments, we select the cells whose paving minimizes the travel time around the lake.

⁷⁴We proceed in three steps. First, we simulate only a trade cost shock between 1960 and 1970 and solve the full path of the model until it reaches a new steady state. Second, we simulate the trade cost shock

Since production reallocates farther away from the lake with the shock, the mitigating effects might be larger if roads are built farther away from the lake. Col. 6 of Fig. 4 uses the same country-specific “road budgets” as above and pave the unpaved cells of the fastest road from each country’s largest city to the lake. Since the largest cities typically already had paved roads around them in 1965, this leads us to pave roads located in more intermediary regions between the largest city and the lake. The loss is reduced further, by 0.30 p.p. (0.54 p.p. in the Lake Chad Region). Roads built farther away likely facilitate the reallocation process that has to take place in other regions due to the shock.

Lake Replenishment Projects: We conduct cost-benefit analyses for two major proposals aimed at replenishing Lake Chad. The first, and most ambitious, is the *Transaqua* project, which proposes the construction of a 2,400-km canal aimed at diverting sufficient water from the Congo River Basin in the Democratic Republic of the Congo (DRC) to replenish Lake Chad (Appx. Fig. F.12 shows the project). Its estimated cost is US\$50 billion (Sayan et al., 2020; The Conversation, 2021), one tenth of the region’s GDP in 2019. To capture this scenario, we implement a counterfactual in which the productivity loss is fully reversed.

The second proposal, known as the *Kotto-Ubangui* project, would use both gravity and pumping to divert water from a new dam at Bria on the Kotto River, a tributary of the Ubangi (Appx. Fig. F.12 shows the location of the dam). Its cost is US\$14.5 billion (or ~30% of the cost of Transaqua) but it would only restore 5,500 sq km, i.e. 25%, of the lost lake area (LCBC, 2011). In this case, the productivity loss is thus only reversed by 25%.⁷⁵

We run two sets of counterfactuals for each project. The first scenario considers the benefits had the projects started in 1990 and been completed by 2010 (the two projects were considered at that time, but funding was the issue). The second scenario evaluates cases in which the projects are approved today (2020s) and finalized during the 2040s.⁷⁶

The aggregate welfare gains from the Transaqua project are estimated to be 3.6–3.8%, while those from the Kotto-Ubangui project are lower, at 1.3–1.5%. These gains correspond to the net present value (NPV) of a compensated variation measure. To translate them into monetary terms, we multiply the NPV gains by the GDP (in USD) of the four countries at the time of the announcement (i.e., either 1990 or the early 2020s).⁷⁷ We find that Transaqua would increase GDP by US\$7-20 billion, below its cost of US\$50 billion.⁷⁸ For the Kotto-Ubangui project, we find equivalent gains of US\$3-7 billion,

between 1960 and 1970 and the productivity shocks between 1960 and 1990 due to the lake shock. Third, to ignore the direct effect of the trade cost shock, we compare the second scenario with the first one.

⁷⁵Given Transaqua is more difficult to implement since the DRC must be involved, the Lake Chad Basin Commission favored the Kotto-Ubangui project up until 2018 when the International Conference on Lake Chad took place. It was then decided that Transaqua should be prioritized to recreate Lake Chad as it was.

⁷⁶See Appx. Fig. F.11 for details. We assume a two-decade construction period. The Suez Canal (193 km) and the Panama Canal (82 km) were built in 10 years more than a century ago. Transaqua is 9 times longer than the combined length of the two. However, construction technologies are likely much better now.

⁷⁷We use 2019 to avoid the undue influence from the COVID pandemic.

⁷⁸The benefit is nominally higher when considering today’s GDP due to post-1990 growth. However, the

compared to a cost of US\$14.5 billion. Both projects thus do not appear to be justified.⁷⁹

5. Conclusion

There is a limited understanding of the role lakes play in economic development, despite lakeshore communities representing 40% of the global population. This knowledge gap is critical as numerous lakes worldwide are shrinking due to climate change. To shed light on the economic effects of climate change through the *global lake recession phenomenon* that it engenders, we focused on Lake Chad which shrunk by 90% between 1963 and 1990. We constructed a novel data set tracking population patterns at a fine spatial level from the 1940s to the 2010s for Cameroon, Chad, Nigeria, and Niger. Regression analyses showed much slower growth close to the lake after it started shrinking. These effects persisted for two decades after it stopped shrinking, implying limited adaptation. The negative water supply effects on fishing, herding, and farming outweighed the growth in land supply and other positive effects. These results were substantiated using historical data on local economic development, environmental change, infrastructure, and conflict. Lastly, we developed a dynamic quantitative spatial model and found aggregate losses of 2.7%, which increased to 10% in Lake Chad areas. Importantly, the model helped study non-local effects, investigate mechanisms, examine the role of aggravating and mitigating forces, and quantify the effects of policy proposals aimed at replenishing Lake Chad.

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cost of US\$50 billion has been advertised since the 2000s. It might be higher now and need to be adjusted.

⁷⁹The cost of Transaqua is likely under-estimated, as it would imply a cost of 20.8 million USD per km. In contrast, the Panama Canal expansion in 2015 and the Suez Canal expansion in 2025 cost 63.4 and 114 million USD per km, respectively. We get 289 million USD per km for the proposed Nicaragua Canal. The DRC and the CAR would also lose water but be compensated by the extra dams generating electricity there.

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ONLINE APPENDIX NOT FOR PUBLICATION

A Lakes and the Global Distribution of Population and Lights

Data. “Large lakes” includes “the 3,067 largest lakes (area $\geq 50 \text{ km}^2$) and 654 largest reservoirs (storage capacity $\geq 0.5 \text{ km}^3$) worldwide” (WWF, 2004). We get 976 natural lakes and 295 reservoirs when we consider lakes larger than Lake Como (146 sq km). Global population data c. 2015 was obtained from Schiavina et al. (2022) (resolution of $1 \text{ km} \times 1 \text{ km}$). Global nighttime lights data in 2010 was obtained from NGDC (2015) ($1 \text{ km} \times 1 \text{ km}$).⁸⁰ Lakes cover 4% of Earth’s non-glaciated land area (Verpoorter et al., 2014).

Global Contribution. L.A. is the coastal city that extends the most from its coastline (by $\sim 90 \text{ km}$).⁸¹ 38% of the world’s population live, and 43% of nighttime lights are located, within 90 km from a coastline. Areas within 90 km from a lake concentrate 43% and 48% of global population and lights. Chicago is the lake shore city that extends the most from its shore (by $\sim 75 \text{ km}$). 36% of the world’s population live, and 40% of nighttime lights are located, within 75 km from a coastline. Areas within 75 km from a lake concentrate 35% and 41% of global population and lights. Using 90 km and lakes larger than Lake Como, areas within 90 km from a lake concentrate 22% and 27% of global population and lights.

Contribution in sub-Saharan Africa (SSA). While 26% of SSA’s population lives within 90 km from the coast, 42% of its population lives close to a lake. Using lakes larger than Lake Como, the latter number is 33.9%, which is still higher than for coastlines.

Drying Lakes. 22% and 17% of global population lives within 90 km and 75 km from a drying lake, respectively. Note that we use all large lakes from WWF (2004) and identify which of these large lakes are drying using the data from Yao et al. (2023).

B Shrinkage of Lakes and Drying of Rivers Across the World

Other examples of drying lakes include: (i) The Dead Sea, that is drying due to CC;⁸² (ii) Qinghai Lake, China’s largest lake, during most of the 20th century (Dong et al., 2018). The lake “is not only a natural barrier preventing the spread of desertification from the west to the east, but also has a significant influence on climate in the Yellow River catchment;” (iii) Poyang Lake in China, due to repeated droughts as well as the Three Gorges Dam upriver on the Yangtze River;⁸³ (iv) Lake Poopo in Bolivia, due to CC;⁸⁴ and (v) Hamun Lake in Afghanistan and Iran, due to extreme droughts;⁸⁵ Other examples

⁸⁰We use the radiance calibrated version of this data to avoid issues related to top-coding.

⁸¹To estimate this distance, we use the geospatialized urban agglomeration boundaries from *Global Human Settlements-Urban Centre Database* (GHS-UCDB) (Florczyk et al., 2019, version 1.2 from 18/04/2020).

⁸²The L.A. Times writes: “The Dead Sea is dying. Drinking water is scarce. Jordan faces a climate crisis [...] the Dead Sea’s level has fallen almost 100 feet.” See www.latimes.com/world-nation/story/2021-04-15/the-dead-sea-is-dying-drinking-water-is-scarce-jordan-faces-a-climate-crisis.

⁸³See <https://www.theguardian.com/environment/2012/jan/31/china-freshwater-lake-dries-up>.

⁸⁴[nytimes.com/interactive/2016/07/07/world/americas/bolivia-climate-change-lake-poopo.html](https://www.nytimes.com/interactive/2016/07/07/world/americas/bolivia-climate-change-lake-poopo.html).

⁸⁵See <https://reliefweb.int/report/iran-islamic-republic/iran-hamun-lake-crisis>.

include Lop Nur in Mongolia, Lake Chapala in Mexico, the Dead Sea, Lake Ebinur in China and Lake Faguibine in Mali, almost always due to global CC.⁸⁶

More US examples include: (i) Pyramid Lake in Nevada; (ii) Owens Lake, another Californian lake that is now a major source of dust pollution; (iii) Walker Lake in Nevada; and (iv) Mono Lake in California.⁸⁷ The shrinkage of Lake Mead in Nevada has alarmed the media.⁸⁸ Similar concerns have been raised for Lake Powell in Arizona and Utah.⁸⁹ California's reservoirs, lakes and rivers are also drying,⁹⁰ for example Lake Tahoe.⁹¹

Other examples of drying lakes and rivers recently highlighted in the media include: (i) The Parana River in Brazil, Paraguay and Argentina;⁹² (ii) Lake Maracaibo, one of South America's largest lakes;⁹³ (iii) Lake Tuz and other lakes in Turkey.⁹⁴; (iv) Sun Moon Lake in Taiwan.⁹⁵; and (v) The Tigris and Euphrates rivers in Iraq.⁹⁶

C Data Appendix - Main Reduced-Form Analysis

Total surface water area. The main source is Olivry et al. (1996).⁹⁷

Chari-Logone River System. Major rivers were obtained from the Landscape Portal. Other streams (i.e., the extended system) were obtained from FAO/GeoNetwork.

Temperature & Rainfall. We use the *Terrestrial Air Temperature and Precipitation: Monthly & Annual Time Series (1900-2017)* V5.01 of Willmott and Matsuura (2001, 2021). The data is reported at a 0.5 by 0.5 degree grid resolution ($\approx 55 \times 55$ km).⁹⁸

⁸⁶See https://en.wikipedia.org/wiki/List_of_drying_lakes for a detailed list.

⁸⁷See https://en.wikipedia.org/wiki/List_of_drying_lakes for a detailed list.

⁸⁸The Washington Post writes: "The reservoir supplying electricity to 350,000 homes as well as irrigation and drinking water to about 25 million people stands at a record low." See www.washingtonpost.com/climate-environment/2022/06/27/lake-mead-reservoir-drought/.

⁸⁹The Guardian writes: "As drought shrivels Lake Powell, millions face power crisis." See www.theguardian.com/us-news/2022/jul/13/lake-powell-drought-electricity.

⁹⁰The Guardian writes: "California's largest reservoirs at critically low levels – signaling a dry summer ahead." See www.theguardian.com/us-news/2022/jun/24/california-drought-reservoirs-water-levels.

⁹¹See www.theguardian.com/us-news/2021/oct/13/lake-tahoe-water-level-drought-climate-change.

⁹²The Guardian writes: "Paraguay on the brink as historic drought depletes river, its life-giving artery." See www.theguardian.com/global-development/2021/sep/27/paraguay-severe-drought-depletes-river.

⁹³The Guardian writes: "Oil slicks and algae blooms marring Venezuela's largest lake are visible from space." See www.washingtonpost.com/world/2021/10/07/oil-pollution-lake-maracaibo-venezuela/.

⁹⁴AP News writes: "Experts say Lake Tuz is a victim of climate change-induced drought." See apnews.com/article/climate-science-business-droughts-environment-137e6f52a8fe14db981a45d19e8907d1.

⁹⁵The Guardian writes: "Parched Taiwan prays for rain as Sun Moon Lake is hit by drought. Taiwan's Sun Moon Lake is so low that parts of it have dried and turned to grass." See <https://www.theguardian.com/environment/2021/may/09/parched-taiwan-prays-for-rain-as-sun-moon-lake-is-hit-by-drought>.

⁹⁶The Washington Post writes that "Where civilization emerged between the Tigris and Euphrates, climate change is poisoning the land and emptying the villages. [...] Years of below-average rainfall have left Iraqi farmers more dependent than ever on the dwindling waters of the Tigris and Euphrates." See https://www.washingtonpost.com/world/interactive/2021/iraq-climate-change-tigris-euphrates/?itid=pr_hybrid_experimentrandom_with_top_mostshared_4_na-ans_4.

⁹⁷Other sources include: (i) Sedick, Ahmed. Le Lac Tchad et ses tributaires; (ii) FAO. 2009. Adapting to future needs, in FAO Water Seminar Proceedings of the World Water Week; (iii) CBLT. 2015. Plan de Developpement et d'Adaptation au Changement Climatique du Lac Tchad. (iv) Okpara, U., L. Stringer, & A. Dougill. 2016. Lake drying and livelihood dynamics in Lake Chad: Unravelling the mechanisms, contexts and responses. Ambio; and (v) Ighobor, Kingsley. 2019. Developper le bassin du lac Tchad.

⁹⁸Source: http://climate.geog.udel.edu/~climate/html_pages/download.html.

D Data Appendix - City Populations

Niger. 166 localities reached 5,000 at least once in 1945-2012. We have available city population estimates for the following years: 1945, 1948, 1951, 1955-1962, 1965-1968, 1977, 1988, 2001, and 2012-2017. For the pre-1968 period, we rely on colonial and post-colonial administrative reports of city population sizes. Post-1968, we rely on population censuses. However, information is patchy. When Niger was still a colony as well as just after independence, administrators would sequentially visit various regions at a time to proceed with administrative counts. As such, for 16 localities with more than 5,000 inhabitants before 1968, population is available for different years for different cities. To create a consistent series, we use exponential interpolations. There are then a few cities for which we know their population before the 1940s and in the late 1950s but not in-between. To better estimate their population c. 1950, we also consider their pre-1950 population.⁹⁹

Cameroon. 186 localities reached 5,000 at any point in 1945-2005. The available years are 1945, 1950, 1953, 1956, 1958-1968, 1970, 1976, 1987 and 2005. For the pre-1976 years, we use colonial and post-colonial administrative counts. After, we use population censuses.

Chad. 100 localities reached 5,000 at any point in the period 1945-2009. The available years are 1945-1951, 1954-1956, 1961, 1964, 1968, 1975, 1993, 2000, and 2009. For the pre-1968 years, we use colonial and post-colonial administrative counts. For the years 1993 and 2009, we use population censuses. For the years 1975 and 2000, we use administrative population count estimates provided by Chad's *Institute of Statistics*.

Nigeria. Data on total urban and rural population at the subdistrict level in 1963 comes from the 1963 census. For the 2006 census, we have population estimates at the ward level from Chi et al (2022)¹⁰⁰ and Smythe and Blumenstock (2022)¹⁰¹. Combining this information with each ward's urban-rural status (provided by the World Bank) allows us to estimate the (census-based) total urban and rural population of each subdistrict c. 2006.

E Data Appendix - Model

A. Input-Output Tables: For each country one by one, we obtain an input-output table in the 1950s or early 1960s, classifying destination and origin sectors as rural or urban.¹⁰²

⁹⁹For later years, there are a few cities for which the first population estimate available exceeds 5,000 by several thousands. These cities might have exceeded 5,000 in the previous years of data but we cannot be sure. To allow for this possibility, and for each city without any early estimate, we assume that their 1945 population was 1 inhabitant and use exponential interpolation to fill the missing years. This increases the likelihood that a city exceeds 5,000 if its value is well above 5,000 the following year of data.

¹⁰⁰Chi, G., Fang, H., Chatterjee, S., & Blumenstock, J. E. (2022). Microestimates of wealth for all low-and middle-income countries. *Proceedings of the National Academy of Sciences*, 119(3), e2113658119.

¹⁰¹Smythe, I. S., & Blumenstock, J. E. (2022). Geographic microtargeting of social assistance with high-resolution poverty maps. *Proceedings of the National Academy of Sciences*, 119(32), e2120025119.

¹⁰²(i) Cameroon (data from 1959): source = Economic Commission for Africa (1967). *Statistical bulletin for Africa, part 2*. Addis Ababa, Ethiopia: Economic Commission for Africa; (ii) Chad (1958): *Republique du Chad (1960). Comptes Economiques*. 1958. N'Djamena, Chad: Secretariat d'Etat aux relations avec les Etats de la Communaute; (iii) Niger (1959): same source as for Cameroon (note that we use the input-output table of Mali as a proxy for the one in Niger, given how similar the two economies were then); and (iv) Nigeria (1959-60): Carter, N. G. (1966). *An input-output analysis of the Nigerian economy, 1959-60*. Hassell Street Press.

B. Migration Flows: According to the model, total population is fixed. We construct the initial mobility matrix across sectors and locations in three different steps:

1. **Migration within a country.** For each ethnic group g , we recover their population in subdistrict n c. 1900 using historical data on the group's homeland area:

$$\text{pop}_{1900}^{ng} = \text{landsh}_{1900}^{ng} \text{Pop}_{1963}^g. \quad (16)$$

Pop_{1963}^g is the total population of group g in 1963. $\text{landsh}_{1900}^{ng}$ is the share of the total homeland area of group g that is contained within subdistrict n c. 1900 (the polygon of the historical homeland area of each group is obtained from Murdock (1967)).¹⁰³ Let $s^n \in [0, 1]$ denote the “staying rate” in subdistrict n , i.e., the share of individuals that stay in their subdistrict of origin.¹⁰⁴ $h_{1963}^{ig} \in [0, 1]$ is the share of group g living in destination location i in 1963.¹⁰⁵ The period- t migrants of group g from n to $i \neq n$ are

$$L^{ni,g} = \text{pop}_{1900}^{ng} \cdot (1 - s^n) \cdot h_{1963}^{ig}, \quad (17)$$

and stayers are

$$L^{nn,g} = s^n \cdot \text{pop}_{1900}^{ng}. \quad (18)$$

Aggregating over groups yields total flows:

$$L^{ni} = \sum_g L^{ni,g}, \quad L^{nn} = \sum_g L^{nn,g}. \quad (19)$$

We then normalize by the total outflow from origin n to obtain internal (domestic) migration shares within each country c :

$$\mu^{ni|c} = \frac{L^{ni}}{\sum_r L^{nr}} \quad \text{for all destinations } i \text{ in country } c. \quad (20)$$

Finally, to obtain the overall (domestic) migration shares that account for external migration from n , we scale them by the non-external fraction:

$$\mu^{ni} = \mu^{ni|c} (1 - \text{ext}^n). \quad (21)$$

2. **Cross-border migration.** We know for each destination subdistrict i in country r the share of residents who are foreigners from other Lake Chad countries, denoted by $f^{i(r)} \in [0, 1]$, and the destination population $\text{Pop}_{1963}^{i(r)}$.¹⁰⁶ Then, using a proportionality assumption, the share of origin n from country c in destination i is:

$$\mu^{i(c),j(r)} = \frac{f^{j(r)} \text{Pop}_{1963}^{j(r)}}{\sum_{c \neq r} \text{Pop}_{1963}^c}. \quad (22)$$

This means that the probability of migrating from a different country to destination j is the same across all origins. We can also define the total external share from i as:

¹⁰³For a group g , this assumes that population density is uniform across all subdistrict areas overlapping with the group's homeland area. This assumption is not unrealistic given construction technologies then.

¹⁰⁴Details on the staying rate used are provided in the notes of Appx. Fig. F.7. Only having national data on the staying rate, we use the same staying rate (70%) for all subdistricts across the four countries.

¹⁰⁵Details on the sources used for each country are provided in the notes of Appx. Figs. F.7.

¹⁰⁶We only have data at the regional level, not the subdistrict level. For each region, we know the share of residents that were born in the other countries of study. We thus apply the same share to all subdistricts of a same region. Details on the sources used for each country are provided in the notes of Appx. Fig. F.7.

$$\text{ext}^i = \sum_{r \neq c, j \in r} \mu^{i(c), j(r)}. \quad (23)$$

3. Sectoral flows. We split flows by destination sector using employment shares. Let s_0^{ik} be the baseline (at $t=0$) employment share of sector $k \in \{\text{rural}, \text{urban}\}$ in destination i . For origin sector j and destination sector k , we get that

$$\mu_{t=0}^{nj, ik} = \mu^{ni} s_0^{ik}. \quad (24)$$

Following these steps, we obtain an initial mobility matrix across locations and sectors to use in the model. Before running the counterfactuals, we adjust this matrix to ensure it is in steady state—meaning that, in the absence of shocks, population remains constant across locations. Formally, the evolution of employment in region n and sector j satisfies:

$$L^{nj} = \sum_{i, k} \mu^{nj, ik} L^{ik},$$

where $\mu^{nj, ik}$ denotes the share of workers moving from location i and sector k to location n and sector j . Finally, we transform the migration shares so that L^{nj} matches the observed total employment in location n and sector j in our data c. 1963.

C. Boat Travel on the Lake: Historically, canoes would travel at a speed of 5 kph in West Africa¹⁰⁷ Motorized pirogues were introduced to the area in the 1950s. Now, most trips in the remaining water areas take place with motorized pirogues.¹⁰⁸ These have an average speed of 20 kph. We thus assume an average (historical) speed of 10 kph for boat travel.

D. Migration to the Rest of the World: Most emigrants from the countries c. 1963 lived in France (which colonized Cameroon, Chad, and Niger), the UK (Nigeria) and Germany (Cameroon). For these countries and the U.S., we use IPUMS census microdata c. 1963.¹⁰⁹

E. Expenditure Shares: For the year 1963, we rely on city-specific surveys as well as region-specific surveys that focused on the regions' rural areas. We use the urban share of each country c. 1965 to obtain the overall expenditure shares for each country.¹¹⁰

¹⁰⁷Sources include: (i) Smith, R., "The Canoe in West African History," *The Journal of African History*, 1970, 11 (4), 515–533; and (ii) Manning, P., "Merchants, Porters, and Canoemen in the Bight of Benin," 1985.

¹⁰⁸Source used for the motorized pirogues: Magrin, Geraud and Marc-Antoine Perouse de Montclos, "Crise et Developpement: La region du Lac Tchad a l'epreuve de Boko Haram," Edition AFD, 2018.

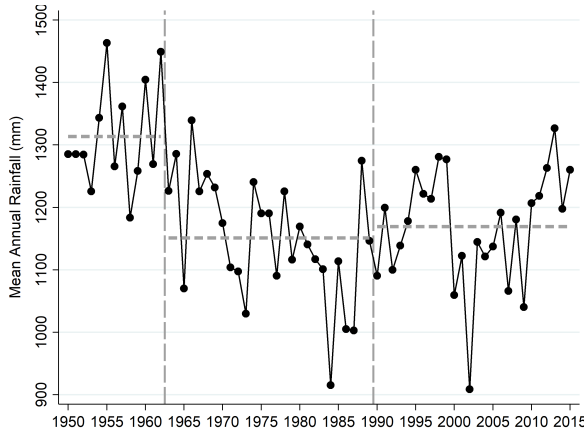
¹⁰⁹We use the following censuses: 1962 for France, 1961 for the UK, and 1970 for Germany and the U.S. (the 1961 Germany census and 1960 U.S. census do not specifically identify residents from the sample countries).

¹¹⁰(A) Cameroon: (i) Winter, G. (1967). *Methodologie des enquetes "niveau de vie" en milieu rural Africain. Bilan des 3 enquetes effectuees de 1961 a 1965 au Cameroun*. Yaounde: ORSTOM; (ii) Gouvernement du Cameroun (1965). *Etudes Socio-Economiques sur le Nord-Cameroun*. Ministere de l'Economie Nationale, Direction de la Statistique; (iii) Gouvernement du Cameroun (1967). *Enquete sur le niveau de vie a Yaounde - Cameroun 1964-1965*. Direction de la Statistique de la Republique Federale du Cameroun; and (iv) Gouvernement du Cameroun (1967). *Le Niveau de vie des populations de l'Adamaoua*. Direction de la Statistique de la Republique Federale du Cameroun. (B) Chad: Ministere du plan et de la cooperation du Tchad (1969). *Enquete socio-economique au Tchad, 1965*. Paris: Republique francaise, Secretariat d'Etat aux affaires etrangeres: INSEE; (C) Niger: (i) Bernus, S. (1964). *Niamey: population et habitat*. Etudes nigériennes: Doc, IFAN. Republique du Niger; and (ii) Gouvernement du Niger (1962). *Etude démographique du Niger (Enquete par sondage, 1960). 1er fascicule : données collectives. Résultats définitifs*. Republique du Niger, Mission économique et pastorale; (D) Nigeria: U.S. Dept of Commerce (1964). *Market for U.S. products in Nigeria*. Bureau of Intl Commerce.

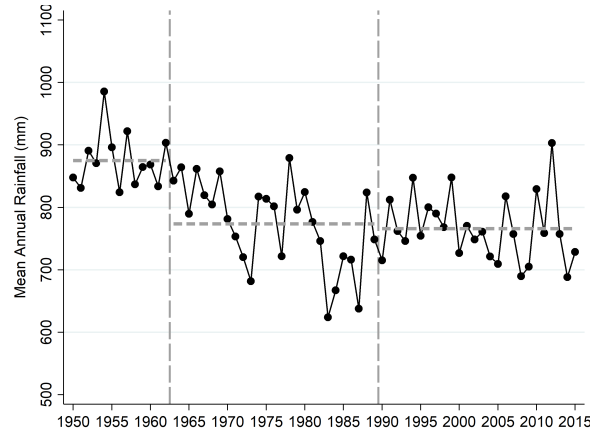
F. Web Appendix Figures and Tables - Not for Publication

Figure F.1: Annual Rainfall in the Central African Republic vs. the Sample Countries

(a) Central African Republic: Areas of the Chari-Logone River System that Feed Lake Chad's Water



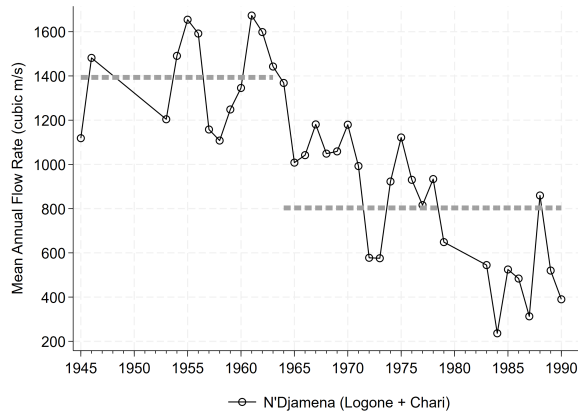
(b) Four Countries of Study: Subdistricts Below the Country-Specific Median Distance to the Lake



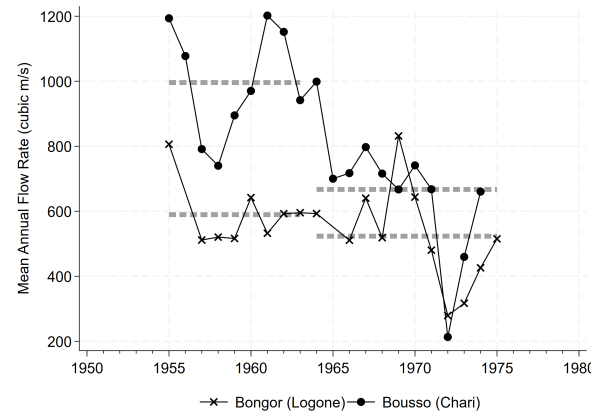
Notes: The figures show mean annual rainfall (mm) in each year t : (a) for the areas (i.e., rainfall pixels) of the Central African Republic located within 10 km of any of the major or minor river of the Chari-Logone river system; and (b) for the subdistricts of Cameroon, Chad, Niger and Nigeria that are "closer" to Lake Chad, i.e. for the subdistricts whose Euclidean distance to the lake is below the median Euclidean distance to the lake in each country. See Appendix Section C for details on the rainfall data used.

Figure F.2: Mean Annual Flow Rate (mm) at Various Sites, 1940s-1980s

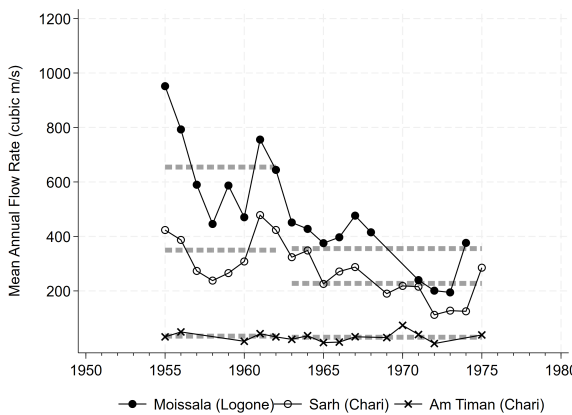
(a) N'Djamena (Chari + Logone)



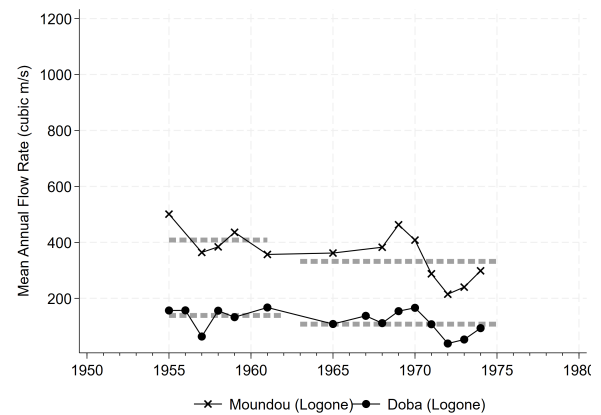
(b) Bongor (Logone) vs. Bousso (Chari)



(c) Upstream Sites of Bousso (Chari)

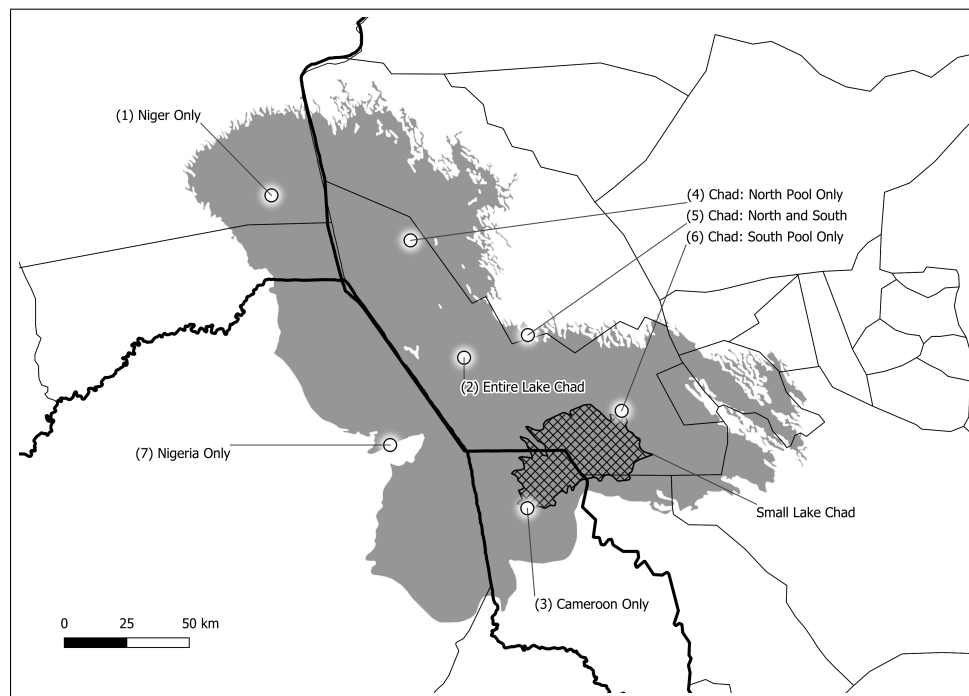


(d) Upstream Sites of Bongor (Logone)



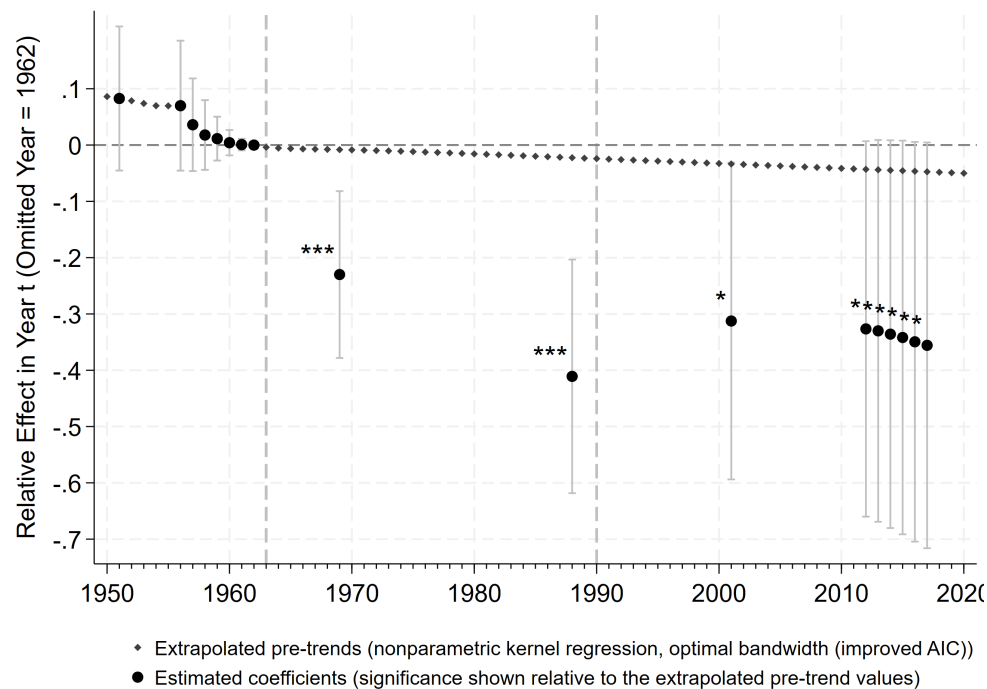
Notes: The figures show the mean flow rate (m^3/s) for selected sites of the Chari-Logone river system and for each year with available data. (a) We report the average of the mean rates for each period 1945-1963 and 1963-1990. (b)-(d) We report the average of the mean rates for each period 1950-1963 and 1963-1975 (data unavailable before 1950). The data on water discharge rates was obtained from: DE/FIH/GRDC & UNESCO/IHP. Center, Global Runoff Data. 1985. Monthly Flow Rates of World Rivers.

Figure F.3: Location of the Selected Country-Specific Centroids of Lake Chad



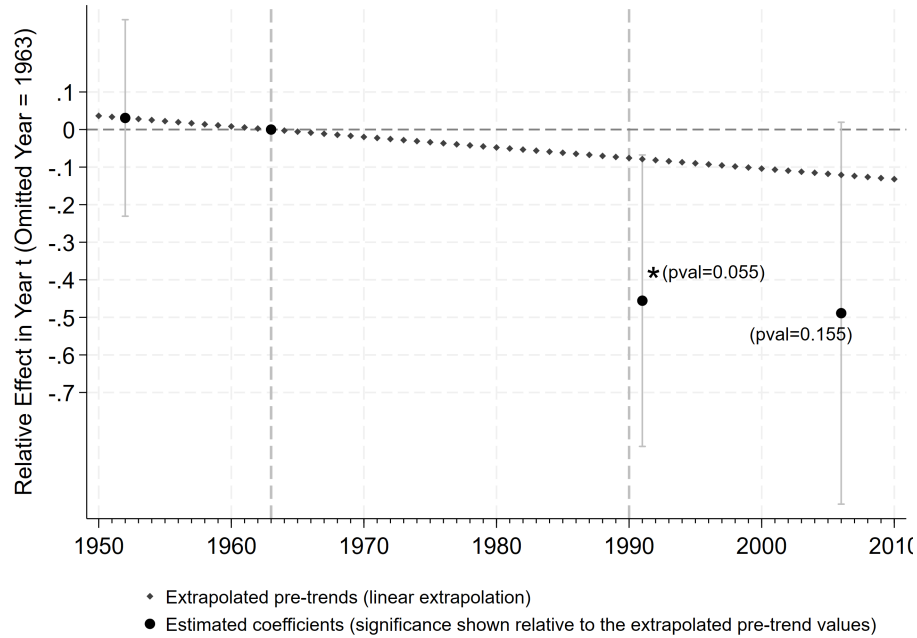
Notes: This figure shows the full (pre-1963) and small (c. 1990 and c. 2020) Lake Chad as well as the “centroids” of Lake Chad that we consider for each of the four countries of study.

Figure F.4: Estimated Coefficients vs. Extrapolated Pre-Trends in Niger, 1950-2020



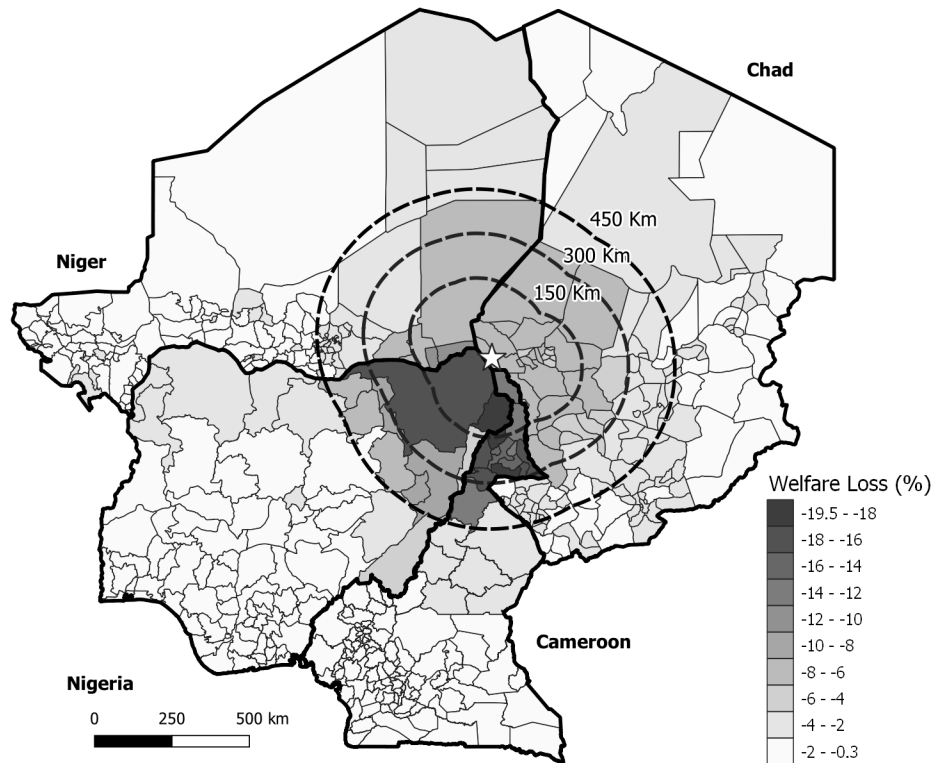
Notes: The figure shows for Niger the relative total population effects of proximity to Lake Chad (relative to the omitted year shown at left). The sample consists of 119 subdistricts $\times$ 17 years, hence 2,023 observations. We include subdistrict FE and year FE, district-specific linear trends, and time-invariant controls interacted with year FE (see text for details). The extrapolated pre-trends are constructed using non-parametric kernel regressions based on a Gaussian kernel function and a bandwidth that is optimally computed using the improved AIC. The stars indicate the level of significance of the estimated post-1963 baseline coefficients when they are compared to the extrapolated pre-trend value of the same year. 90% confidence intervals (Conley SEs 100 Km). The dashed vertical lines show the years the lake started to decline (c. 1963) and stopped shrinking (c. 1990). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Figure F.5: Estimated Coefficients vs. Extrapolated Pre-Trends in Nigeria, 1950-2020



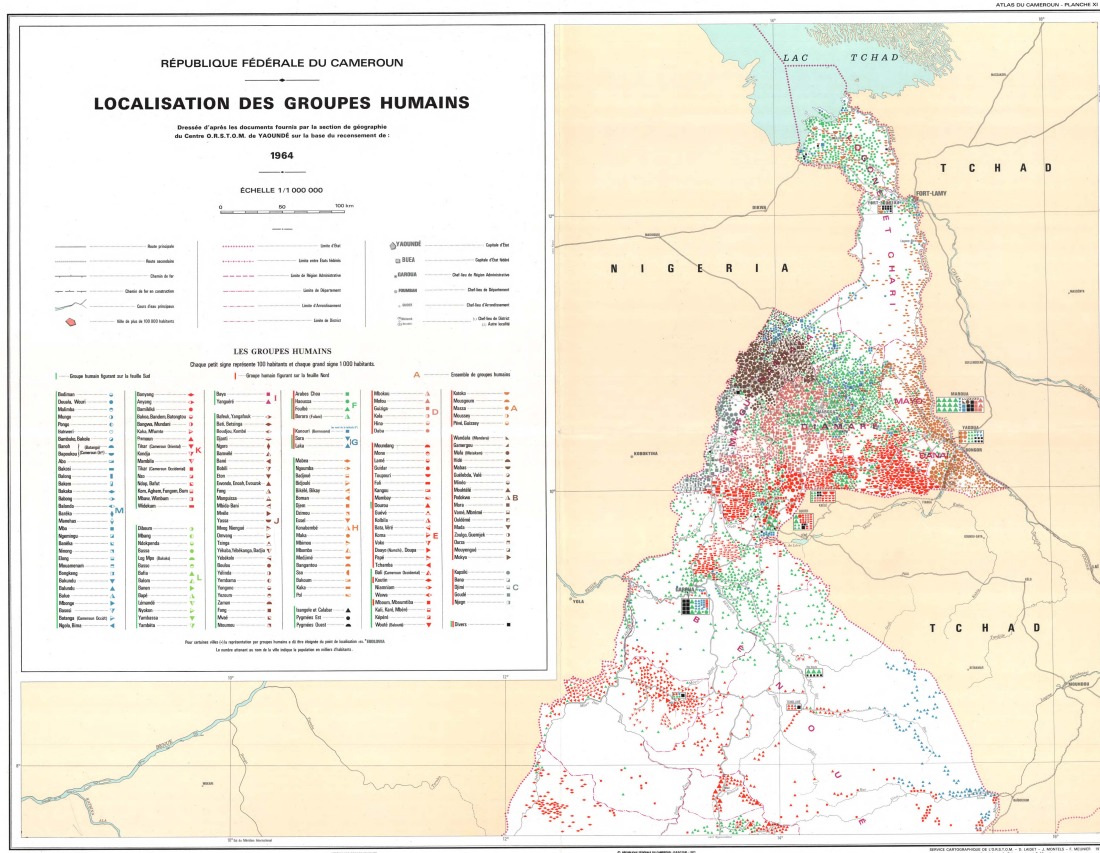
Notes: The figure shows the relative total population effects of proximity to Lake Chad (relative to the omitted year 1963). The sample consists of 83 subdist. $\times$ 4 years = 332 obs. We include subdistrict FE, year FE, district-specific linear trends, and time-invariant controls interacted with year FE (see text for details). The extrapolated pre-trends are constructed using linear extrapolation, as there is only one available year of data before the year 1963. The stars indicate the level of significance of the estimated post-1963 baseline coefficients when they are compared to the extrapolated pre-trend value of the same year. 90% confidence intervals (Conley SEs 100 Km). The dashed lines show the years the lake started to decline (c. 1963) and stopped shrinking (c. 1990).

Figure F.6: Lake Chad Region and Selected Distance Bins for the Bin Specification



Notes: This figure shows the three distance bins used in the flexible bin specification: 0-150 km, 150-300 km, and 300-450 km (based on the Euclidean distance from the subdistrict's centroid to the selected Lake Chad centroid). We define the "Lake Chad Region" as subdistricts within 450 km from Lake Chad. The figure also shows the implied welfare loss for each subdistrict.

Figure F.7: Raw Ethnic Composition Data from Cameroon c. 1963: Northern Section



Notes: (A) **Source for the Cameroon ethnic data** (201 ethnic groups matched to 176 ethnic groups in Murdock (1967)): Government of Cameroon (1975). *Atlas du Cameroun. Localisation des Groupes Humains*, 1964. Yaounde: Institut de Recherches Scientifiques du Cameroun. (B) **Sources for the Chad ethnic data** (152 ethnic groups matched to 45 ethnic groups in Murdock (1967)): (B1) AEF (1955). *Dénombrement de la Population Autochtone au 31 Décembre 1954*. Source: Rapports des Régions et Districts. (B2) Ministère de la Coopération (1964). *Recensement démographique de Fort-Lamy, mars-juillet 1962: résultats*. N'Djamena: Bureau de la Statistique. The Chad data is available for 39 subdistricts in 1954. We recreate the ethnic composition of each subdistrict using a simple probabilistic approach based on population and area. (C) **Source for the Nigeria ethnic data** (208 ethnic groups matched to 117 ethnic groups in Murdock (1967)): Government of Nigeria (1964). Table 3: *Population by Nationality and Ethnic Group, 1963 Population Census, Volume 2. "Lagos", "Western", "Midwestern", "Eastern" and "Northern"*. (D) **Source for the Niger ethnic data** (34 ethnic groups matched to 26 ethnic groups in Murdock (1967)): Poncet, Y. (1973). *Cartes ethno-démographiques du Niger, au 1/1 000 000*. Niamey, Centre Nigérien de Recherches en Sciences humaines. The information was collected in the 1950s-early 1960s according to the source. (E) **Staying share used**: We use a staying share of 70%. Indeed, we find that 75% of Cameroon's residents aged 15 or above still live in their arrondissement of birth in 1962-65 (see below for details on the sources used). There were 60 arrondissements then whereas we use 113 subdistricts in our analysis. Arrondissements being larger than subdistricts, the true number is likely smaller as the current number does not reflect the fact that people could have migrated to another subdistrict within the same arrondissement. See below for details on the sources used. For Niger, we find 78% for individuals aged 15 or above in 1960 but the sample is disproportionately rural and also misses one nomadic region (see below for the main sources used). The true number is likely smaller. Based on the Cameroon and Niger, we decide to use 70%. (F) **Staying share data for Cameroon**: We use the demographic surveys of 8 regions in order to get a complete picture for the whole country in 1962-65. (i) Bamileke regions: Mirivel, Jacques and Jean Chaumont (1966). *La population du pays Bamileké et des départements limitrophes. Principaux résultats de l'enquête démographique de 1965*. Paris: Ministère des Affaires Economiques et du Plan; Société d'Etudes pour le Développement Economique et Social; (ii) Nord-Benoue and Sud-Benoue: INSEE (1964). *Enquête Démographique au Cameroun : Résultats Définitifs pour la Région Nord*. 1962-1964. Service de la statistique. Publisher, I.N.S.E.E.; (iii) Sud-Est: République du Cameroun (1964). *Enquête démographique au Cameroun, 1962-1964 : résultats définitifs pour la Région Sud-Est*. République du Cameroun, Service de la Statistique, République Française Secrétariat d'Etat aux Affaires Etrangères Chargé de la Coopération; I. N. S. E. E., Service de Coopération; (iv) Occidental: République du Cameroun (1964). "La population du Cameroun occidental : resultat de l'enquête démographique de 1964." République Federale du Cameroun, Ministère des Affaires Economiques et du Plan, Service de Statistique Generale; (v) Cameroon Service de la statistique (1963). *Recensement de la ville de Yaoundé en 1962. Résultats principaux*. Ministère de l'économie nationale, Service de la statistique et de le mécanographie, Section des enquêtes; and (vi) République du Cameroun (1965). "Recensement de la ville de Douala - Cameroun 1964." Direction de la Statistique et de la Comptabilité nationale de la République Unie du Cameroun. (G) **Staying share data for Niger**: Sources for Niger in 1960: (i) République du Niger (1963). *Etude Démographique du Niger: Données Individuelles*. INSEE, service de coopération; (ii) République du Niger (1966). *Etude Démographique et Economique en Milieu Nomade*. INSEE, service de coopération; and (iii) République du Niger (1960). *Premiers Resultats Provisoires du Recensement de la Ville de Niamey Avril-Juin 1960*. Niger, Ministère du Plan, Bulletin trimestriel de statistique (NE), Num. 7. (H) **Foreign residents data for Cameroon**: We use the same sources as for the staying share ((F) above). (I) **Foreign residents data for Chad**: (B2) above as well as INSEE (1966). "Enquête démographique au Tchad, 1964. Résultats définitifs." Institut national de la statistique et des études économiques. (J) **Foreign residents data for Niger**: We use the same sources as for the staying share ((G) above). (K) **Foreign residents data for Nigeria**: We use the same sources as for the ethnic data ((C) above).

Figure F.8: Country-Specific Welfare Losses, Aggregate, Rural, and Urban

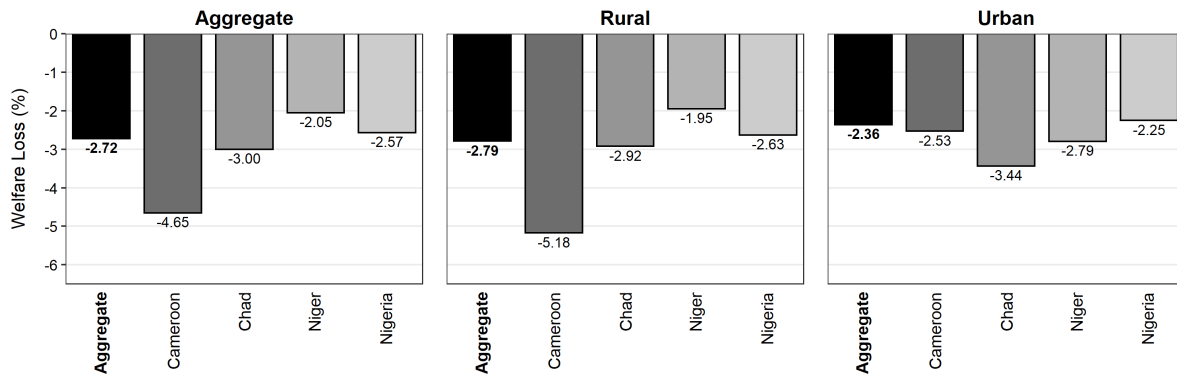
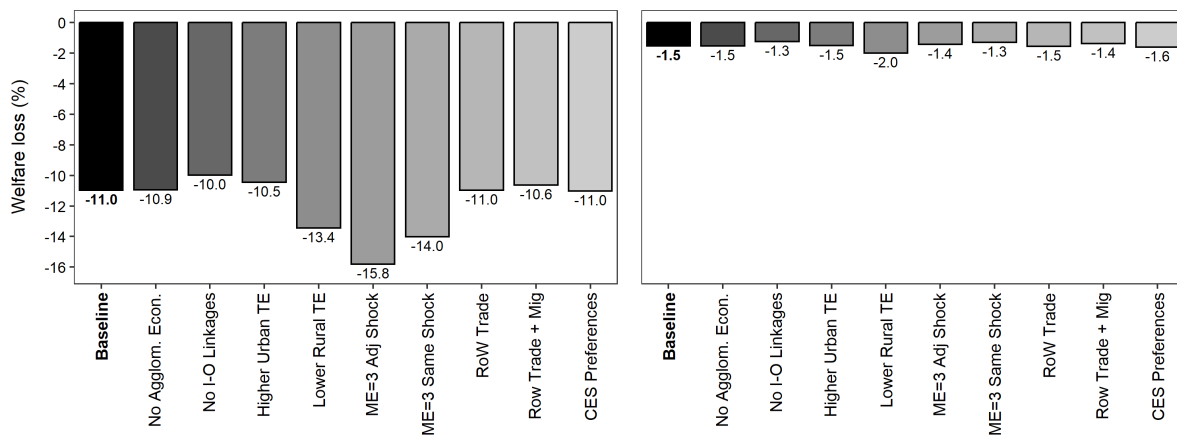


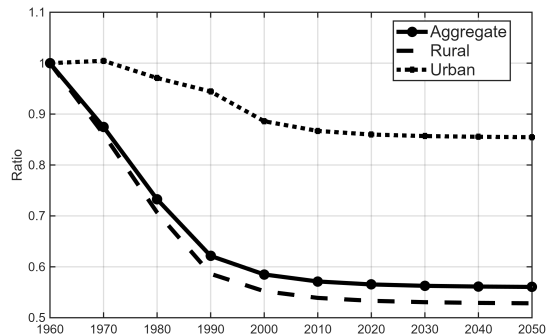
Figure F.9: Lake Chad Region (0-450 Km) vs. Other Regions (450+ Km), Robustness



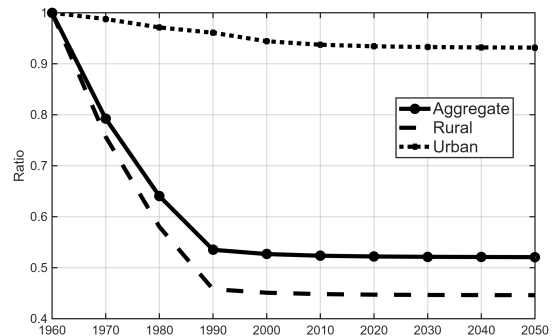
Notes: See the notes of Figure 5 for details on each robustness check. Lake Chad Region = subdistricts within 450 km from the lake.

Figure F.10: Dynamic Population and Output Impacts of the Lake Shock, 1960-2050

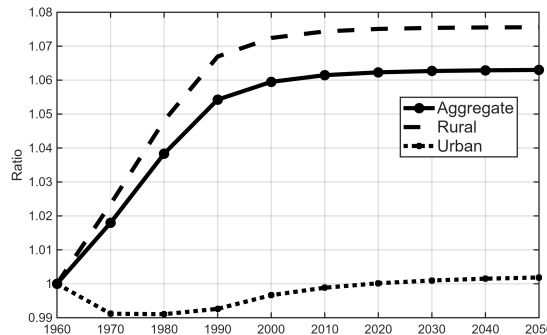
(a) Population, Lake Chad Region (0-450 Km)



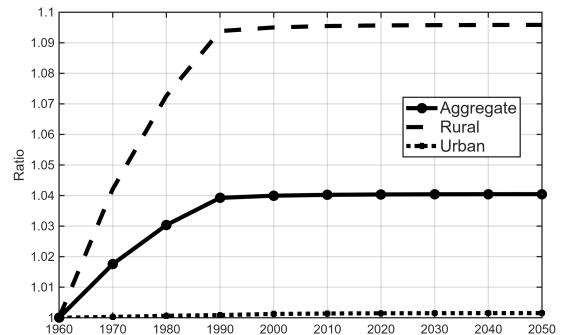
(b) Output, Lake Chad Region (0-450 Km)



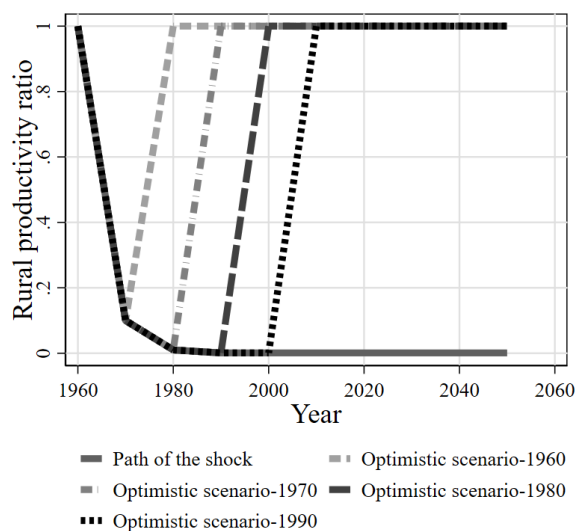
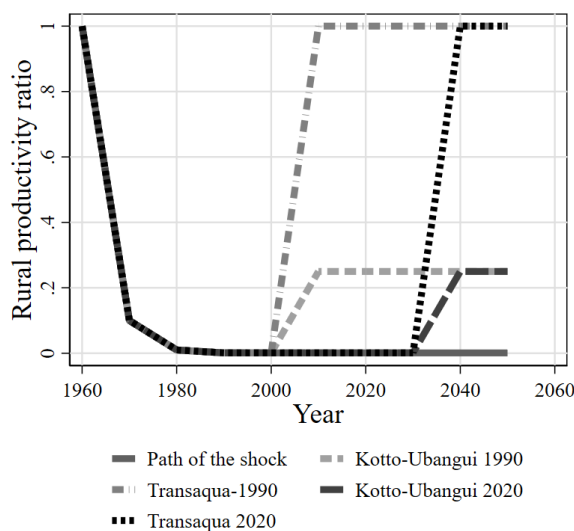
(c) Population, Other Regions (450+ km)



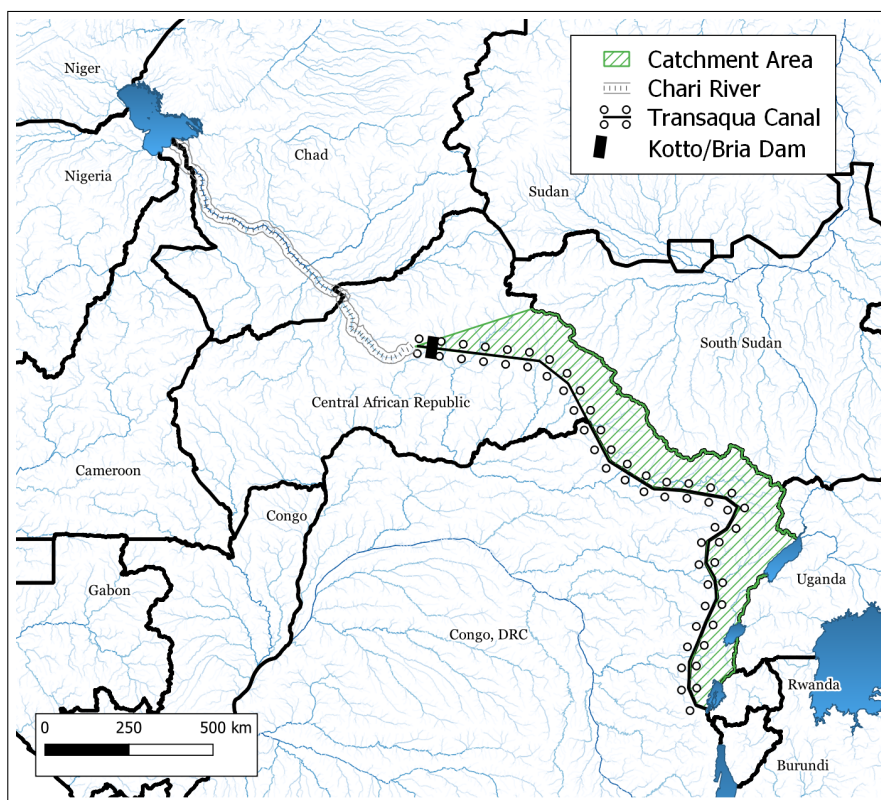
(d) Output, Other Regions (450+ km)



Notes: The figures show for two regions the model-implied aggregate and sectoral population and output patterns from 1960 to 2020.

Figure F.11: Path of the Shock, Optimistic Scenario & Lake Replenishment Projects**(a) Path of the Shock and Optimistic Scenario****(b) Lake Replenishment Projects**

Notes: This figure plots the realized path of the shock as well as the expected path of the shock for the optimistic scenario (Panel A) and in cases where the Government implements projects to replenish Lake Chad (Panel B). The number on the y-axis is a scaling factor that is applied to both the rural and urban productivity shocks (e.g., 0.5 means that we consider 50% of each country-bin-sector-specific shock). In the optimistic scenarios, residents expect the lake to fully recover in just one period. They are fully optimistic in each period until 2000, by which time they accept the new reality and take the path of the shock as the new normal. Panel B plots the expected path for two projects that policy makers have been discussing to replenish the lake. The Transaqua line assumes that the Transaqua canal is announced in 1990 or 2020, and finished 20 years later. The lines for the Kotto-Ubangui project can be similarly interpreted.

Figure F.12: Map of the Transaqua and Kotto-Ubangui Projects

Notes: The *Transaqua* project proposes the construction of a 2,400-km canal aimed at diverting enough water from the Congo River Basin in the Democratic Republic of the Congo to replenish Lake Chad. The second proposal, known as the *Kotto-Ubangui* project, would use both gravity and pumping to divert water from a new dam at Bria on the Kotto River, a tributary of the Ubangi. The map shows the Kotto/Bria dam.

Table F.1: Initial Characteristics, Lake Locations vs. Non-Lake Locations, c. 1963

CAMEROON	(1) Lake Chad Region (0-450 Km)	(2) Rest of the Country (450+ Km)	Diff. (1) - (2)	sign.
Per Capita Output (cst 2010 US\$)	1046	981	64	n.s.
Population Density (inh. per sq km)	29	37	-8	n.s.
Urbanization Rate (%)	5.3	10.0	-4.6	n.s.
Urban Share of Total Output (%)	13.7	15.9	-2.1	n.s.
Mean Temperature (°C)	27.2	23.8	3.4	***
Mean Annual Precipitations (mm)	900	2,131	-1,231	***
CHAD	(1) Lake Chad Region (0-450 Km)	(2) Rest of the Country (450+ Km)	Diff. (1) - (2)	sign.
Per Capita Output (cst 2010 US\$)	635	676	-42	n.s.
Population Density (inh. per sq km)	14	10	4	n.s.
Urbanization Rate (%)	3.7	3.2	0.4	n.s.
Urban Share of Total Output (%)	4.2	5.2	-1.0	n.s.
Mean Temperature (°C)	28.2	27.4	0.8	***
Mean Annual Precipitations (mm)	577	832	-255	***
NIGER	(1) Lake Chad Region (0-450 Km)	(2) Rest of the Country (450+ Km)	Diff. (1) - (2)	sign.
Per Capita Output (cst 2010 US\$)	1760	1133	627	n.s.
Population Density (inh. per sq km)	9	19	-9	***
Urbanization Rate (%)	4.7	3.5	1.2	n.s.
Urban Share of Total Output (%)	5.1	8.3	-3.2	n.s.
Mean Temperature (°C)	27.8	28.2	-0.4	***
Mean Annual Precipitations (mm)	472	577	-105	***
NIGERIA	(1) Lake Chad Region (0-450 Km)	(2) Rest of the Country (450+ Km)	Diff. (1) - (2)	sign.
Per Capita Output (cst 2010 US\$)	967	1774	-807	***
Population Density (inh. per sq km)	45	153	-108	***
Urbanization Rate (%)	9.9	16.5	-6.5	***
Urban Share of Total Output (%)	1.5	14.9	-13.4	**
Mean Temperature (°C)	26.5	26.7	-0.2	n.s.
Mean Annual Precipitations (mm)	846.3	1773.8	-928	***

Notes: We consider per capita output, population density, the urbanization rate, and the urban share of total output c. 1963. We report the mean temperature and mean annual rainfall for the period 1950-1964, in order to be consistent with Table 5. Note that the Lake Chad Region includes all subdistricts located within 450 km from the lake. No controls or FE are included. Conley SE 100 Km.

Table F.2: Reduced-Form Effects, Robustness, Chari-Logone (CL) River System

Dependent Variable:	Log Total Subdistrict Population in Year t					
Chari-Logone (CL) Rivers Related Test:	Baseline	No River Controls	Control(s) for Log Euclidean Distance(s):			No River Subdistrict
			Main Rivers	All Rivers	CAR Origin	
<u>CHAD</u>	(1)	(2)	(3)	(4)	(5)	(6)
Proximity to Lake*c.1990	-0.54*** [0.20]	-0.56*** [0.21]	-0.55*** [0.21]	-0.55*** [0.21]	-0.58*** [0.21]	-0.60** [0.26]
Proximity to Lake*c.2010	-0.62*** [0.16]	-0.66*** [0.17]	-0.59*** [0.16]	-0.60*** [0.16]	-0.64*** [0.17]	-0.43*** [0.14]
Obs.	690	690	690	690	690	340
<u>NIGERIA</u>	(1)	(2)	(3)	(4)	(5)	(6)
Proximity to Lake*c.1990	-0.46** [0.20]	-0.45** [0.19]	-0.35* [0.21]	-0.26 [0.25]	-0.33 [0.25]	-0.46** [0.20]
Proximity to Lake*c.2010	-0.49* [0.26]	-0.51** [0.26]	-0.52* [0.30]	-0.33 [0.30]	-0.31 [0.28]	-0.49* [0.26]
Obs.	332	332	332	332	332	328
<u>CAMEROON</u>	(1)	(2)	(3)	(4)	(5)	(6)
Proximity to Lake*c.1970	-0.19** [0.08]	-0.14 [0.09]	-0.18** [0.09]	-0.18** [0.09]	-0.19* [0.11]	-0.92** [0.38]
Proximity to Lake*c.1990	-0.40*** [0.12]	-0.35** [0.15]	-0.43*** [0.11]	-0.44* [0.25]	-0.45*** [0.14]	-2.18* [1.23]
Proximity to Lake*c.2010	-0.36** [0.14]	-0.34** [0.14]	-0.45*** [0.11]	-0.46 [0.43]	-0.40*** [0.13]	-1.82 [2.09]
Obs.	565	565	565	565	565	495
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y
District Linear Trends	Y	Y	Y	Y	Y	Y
Main CL Dummy*Year FE	Y	N	N	N	N	N
Main CL Dist.*Year FE	N	N	Y	Y	N	N
Extensive CL Dummy*Year FE	Y	N	Y	N	N	N
Extensive CL Dist.*Year FE	N	N	N	Y	N	N
Main CL Dist. (CAR)*Year FE	N	N	N	N	Y	N
Other Baseline Controls	Y	Y	Y	Y	Y	Y

Notes: Proximity to Lake is the negative of the log Euclidean distance to the centroid of Lake Chad within the country's territory. Samples: Chad: 138 subdist. x 5 years (1948-2009) = 690 obs. c.1990 = 1993. c.2010 = 2009. Nigeria: 83 subdist. x 4 years (1948-2009) = 332 obs. c.1990 = 1991. c.2010 = 2006. Cameroon: 113 subdist. x 5 years (1963-2005) = 563 obs. c.1970 = 1967. c.1990 = 1987. c.2010 = 2005. (2) We do not include the interactions of the year FE with two dummies for whether the subdistrict is crossed by a river that belongs to the "main" or "extensive" Chari-Logone (CL) river system. (3) We interact the year FE with the log of the Euclidean distance to any river of the main CL river system (and drop the interactions of the year FE with a dummy for whether the subdistrict is crossed by a main river). (4) We use specification (3) and also interact the year FE with the log of the Euclidean distance to any minor river of the extensive CL river system (and drop the interactions of the year FE with a dummy for whether the subdistrict is crossed by a river of the extensive system). (5) We interact the year FE with the log of the Euclidean distance to any river of the main CL river system that originates from the Central African Republic's territory (CAR) (and drop the interactions of the year FE with the two dummies for whether the subdistrict is crossed by a river that belongs to the main or extensive CL river system). (6) We drop all subdistricts crossed by a river of the main or extensive CL river system. For Cameroon, we replace district-specific linear trends by region(10)-specific linear trends as district boundaries fully overlap with subdistrict boundaries close to the Lake Chad when river subdistricts are dropped (district trends then mechanically capture the effects of proximity to Lake Chad). Conley SE 100 Km.

Table F.3: Reduced-Form Effect, Robustness, Niger 1950s-2010s

Dependent Variable:	Log Total Subdistrict Population in Year t					
Test:	Baseline	Full Lake Centroid	Lake Shore	Alt Inflow River Ctrl	Climate Controls	Conley SE 250 Km
(Relative to Omitted Year 1962)	(1)	(2)	(3)	(4)	(5)	(6)
Proxi. to Lake (log)*c.1970 ($t = 1969$)	-0.23*** [0.08]	-0.29*** [0.11]	-0.19*** [0.06]	-0.13 [0.10]	-0.22** [0.09]	-0.23*** [0.09]
Proxi. to Lake (log)*c.1990 ($t = 1988$)	-0.41*** [0.11]	-0.59*** [0.16]	-0.34*** [0.09]	-0.48** [0.19]	-0.41*** [0.13]	-0.41*** [0.10]
Proxi. to Lake (log)*c.2000 ($t = 2001$)	-0.31** [0.17]	-0.48** [0.26]	-0.25** [0.12]	-0.48* [0.33]	-0.31* [0.16]	-0.31** [0.18]
Proxi. to Lake (log)*c.2010 ($t = 2012$)	-0.33* [0.17]	-0.52** [0.26]	-0.25* [0.14]	-0.38 [0.33]	-0.32* [0.18]	-0.33** [0.18]
Standardized effect c. 1990	-0.16	-0.22	-0.14	-0.25	-0.16	-0.16
Standardized effect c. 2010	-0.16	-0.22	-0.14	-0.18	-0.16	-0.16
Subdistrict (119) FE, Year (17) FE	Y	Y	Y	Y	Y	Y
District (31) Trends, Controls	Y	Y	Y	Y	Y	Y

Notes: 119 subdist. x 17 years (1951-2017) = 2,023 obs. *Proxi. to Lake* is the negative of the log Euclidean dist. to the lake. We report the coefficients for the closest years to the year 1970, 1990, 2000 and 2010. We also report the effect of a one-standard-deviation increase in proximity to the lake in 1990 and 2010. Except in (2)-(3), we use the centroid of Lake Chad within Niger's territory. (2): Centroid of the full lake. (3) We use the log distance to the lake shore in 1963. (4): We add a dummy if the subdistrict contains the Komadugu-Yobe river, interacted with year FE. (5): We also control for mean temperature and the log of mean annual rainfall in $[t-5; t]$. Controls (interacted with year FE): log Euclidean distance to the largest/capital city and its square, and latitude. Conley SE 100 Km ((6): 250 km).

Table F.4: Reduced-Form Effect, Robustness, Nigeria 1950s-2010s

Dependent Variable:	Log Total Subdistrict Population in Year t								
Test:	Baseline	Full Lake Centroid	Lake Shore	Alt Inflow River Ctrl	Climate Ctrls	Conley 250 Km	Region-Year FE	Correct 1963 Pop	Drop 1963
(We omit 1963. (9) 1952)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Proxi. to Lake (log)*1990	-0.46** [0.20]	-0.52** [0.22]	-0.45** [0.19]	-0.66*** [0.24]	-0.45** [0.20]	-0.46** [0.18]	-0.38** [0.19]	-0.44** [0.20]	-0.43* [0.22]
Proxi. to Lake (log)*2010	-0.49* [0.26]	-0.56* [0.29]	-0.48** [0.24]	-0.63** [0.27]	-0.48* [0.27]	-0.49** [0.26]	-0.43* [0.26]	-0.47* [0.26]	-0.44 [†] [0.29]
Std. effect c. 1990	-0.26	-0.27	-0.28	-0.37	-0.25	-0.26	-0.21	-0.24	-0.24
Std. effect c. 2010	-0.28	-0.30	-0.31	-0.38	-0.29	-0.30	-0.26	-0.27	-0.25
Observations	332	332	332	332	332	332	332	332	249
Subdist (83) FE, Yr (4) FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District (24) Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: 83 subdist. x 4 years (1952-2006) = 332 obs. For each subdistrict, *Proxi. to Lake (log)* is the negative of the log Euclidean dist. to the lake centroid. We report the coefficients for the closest years to the years 1990 and 2010. We also report the effect of a one-standard-deviation increase in proximity to the lake in 1990 and 2010. Except in (2)-(3), the centroid used is the centroid of Lake Chad within Nigeria's territory. (2): We use the centroid of the full lake. (3): We use the log distance to the lake shore in 1963. (4): We add a dummy if the subdistrict contains the Komadugu-Yobe river, interacted with year FE. (5): We control for mean temperature and the log of mean annual rainfall in the period $[t-5; t]$. (7): We include 1963 region-year FE (the 4 regions are Northern, Eastern, Mid-Western, and Western). (8): We correct the 1963 population of each subdistrict using the region-level census estimates that were first published in 1962 (source: Ahonsi, Babatunde A. "Deliberate falsification and census data in Nigeria" *African affairs* 87.349 (1988): 553-562.). The correction gives smaller populations in the Northern and Eastern regions, and larger populations in the Western region (incl. Lagos). The population of the Mid-Western region is unchanged. (9): We drop 1963. Conley SE 100 Km ((6): 250 km). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, † $p < 0.15$.

Table F.5: Reduced-Form Effect, Robustness, Chad 1940s-2010s

Dependent Variable:		Log Total Subdistrict Population in Year t							
	Test:	Baseline	Full Lake In All	Centroid In Chad	Lake Shore	Varying Shore	Outflow Control	Climate Controls	Conley 250 Km
(Omitted Year = 1965)		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Proxi. to Lake (log)*c.1990		-0.54*** [0.20]	-0.44** [0.22]	-0.33* [0.18]	-0.09** [0.05]		-0.50** [0.20]	-0.49** [0.21]	-0.54*** [0.13]
Proxi. to Lake (log)*c.2010		-0.62*** [0.16]	-0.61*** [0.18]	-0.48*** [0.15]	-0.16*** [0.05]		-0.54*** [0.14]	-0.62*** [0.14]	-0.62*** [0.16]
Distance to Lake (log) in Year t						-0.09*** [0.02]			
Std. effect c. 1990		-0.22	-0.19	-0.16	-0.08		-0.20	-0.20	-0.22
Std. effect c. 2010		-0.27	-0.29	-0.25	-0.15		-0.24	-0.27	-0.27
Std. effect in Year t						-0.17			
Subdist (138) FE, Yr (5) FE		Y	Y	Y	Y	Y	Y	Y	Y
District (36) Trends, Ctrls		Y	Y	Y	Y	Y	Y	Y	Y

Notes: 138 subdistricts $\times$ 5 years (1948-2009) = 690 obs. For each subdistrict centroid, *Proxi. to Lake (log)* is the negative of the log Euclidean distance to the lake. We report the effect of a one-standard-deviation increase in proximity to the lake in 1990 and 2010. (1): We use the centroid of the Northern section of the lake that belongs to Chad's territory only. (2)-(3): We use the centroid of the full lake area, whether across all countries or within Chad's territory. (4) We use the distance to the lake shore in 1963. (5) We use the log Euclidean distance to the shore in year t . (6): We add a dummy if the subdistrict contains the Bahr el-Ghazal, which we interact with year FE. (7): We control for mean temperature and the log of mean annual rainfall in $[t-5; t]$. Conley SEs 100 Km (8): 250.

Table F.6: Reduced-Form Effect, Robustness, Cameroon 1960s-2010s

Dependent Variable:		Log Total Subdistrict Population in Year t				
	Test:	Baseline	Full Lake Centroid	Lake Shore	Climate Controls	Conley SE 250 Km
(Relative to the Omitted Year = 1963)		(1)	(2)	(3)	(4)	(5)
Proximity to Lake (log)*c.1970 ($t = 1967$)		-0.19** [0.08]	-0.36** [0.15]	-0.11** [0.05]	-0.21** [0.08]	-0.19** [0.09]
Proximity to Lake (log)*c.1980 ($t = 1976$)		-0.27** [0.11]	-0.55*** [0.21]	-0.15** [0.06]	-0.31*** [0.11]	-0.27** [0.12]
Proximity to Lake (log)*c.1990 ($t = 1987$)		-0.40*** [0.12]	-0.80*** [0.24]	-0.23*** [0.07]	-0.49*** [0.14]	-0.40*** [0.15]
Proximity to Lake (log)*c.2010 ($t = 2005$)		-0.36** [0.14]	-0.72** [0.30]	-0.20** [0.08]	-0.36** [0.14]	-0.36** [0.16]
Standardized effect c. 1990		-0.19	-0.32	-0.13	-0.23	-0.19
Standardized effect c. 2010		-0.16	-0.26	-0.10	-0.16	-0.16
Subdistrict (113) FE, Year (5) FE		Y	Y	Y	Y	Y
District (47) Trends, Controls		Y	Y	Y	Y	Y

Notes: 113 subdist. $\times$ 5 yrs (1963-2005) = 563 obs. For each centroid, *Proximity to Lake (log)* is the negative of the log Euclidean dist. to the lake. We only report the coefficients for the closest years to the years 1970, 1980, 1990 and 2010. We also report the effect of a one-standard-deviation increase in proximity to the lake in 1990 and 2010. Except in (2)-(3), the lake centroid that we use is the centroid of Lake Chad within Cameroon's territory. (2): We use the centroid of the full lake. (3) We use the log distance to the lake shore in 1963. (4): We control for mean temperature and log mean annual rainfall in the period $[t-5; t]$. Conley SE 100 Km ((5): 250 km).

Table F.7: Reduced-Form Effects, Robustness, Central Afr. Republic (CAR) Shock

Dependent Variable:	Log Total Subdistrict Population in Year t						
Central African Republic (CAR) Related Test: Exponent on Distance:	Baseline	+ Ctrl Distance to CAR Border	+ Ctrl CAR Rainfall Loss (%) CL Rivers	Weights = Area $\alpha = 1$	Weights = 1963 Pop $\alpha = 2$	Weights = Area $\alpha = 1$	Weights = 1963 Pop $\alpha = 2$
<u>CHAD</u>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Proximity to Lake*c.1990	-0.54*** [0.20]	-0.55*** [0.21]	-0.55*** [0.21]	-0.55*** [0.20]	-0.56*** [0.20]	-0.54*** [0.20]	-0.53*** [0.20]
Proximity to Lake*c.2010	-0.62*** [0.16]	-0.58*** [0.17]	-0.57*** [0.17]	-0.63*** [0.16]	-0.64*** [0.16]	-0.62*** [0.16]	-0.61*** [0.16]
<u>NIGERIA</u>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Proximity to Lake*c.1990	-0.46** [0.20]	-0.26 [†] [0.18]	-0.22 [0.18]	-0.36** [0.17]	-0.36** [0.17]	-0.44** [0.18]	-0.44** [0.18]
Proximity to Lake*c.2010	-0.49* [0.26]	-0.43* [0.25]	-0.39 [†] [0.25]	-0.36* [0.22]	-0.35 [†] [0.22]	-0.51** [0.23]	-0.50** [0.23]
<u>CAMEROON</u>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Proximity to Lake*c.1970	-0.19** [0.08]	-0.12** [0.06]	-0.18** [0.08]	-0.15** [0.06]	-0.16*** [0.06]	-0.15** [0.07]	-0.18** [0.07]
Proximity to Lake*c.1990	-0.40*** [0.12]	-0.42*** [0.14]	-0.74** [0.30]	-0.38*** [0.13]	-0.39*** [0.13]	-0.33** [0.13]	-0.38*** [0.13]
Proximity to Lake*c.2010	-0.36** [0.14]	-0.60*** [0.22]	-1.17** [0.50]	-0.38** [0.17]	-0.39** [0.17]	-0.33** [0.16]	-0.35** [0.16]
<u>NIGER</u>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Proximity to Lake*c.1970	-0.23*** [0.08]	-0.39*** [0.10]	-0.44*** [0.11]	-0.24*** [0.08]	-0.24*** [0.08]	-0.27*** [0.08]	-0.27*** [0.08]
Proximity to Lake*c.1990	-0.41*** [0.11]	-0.42** [0.17]	-0.43** [0.19]	-0.43*** [0.10]	-0.43*** [0.10]	-0.46*** [0.11]	-0.45*** [0.11]
Proximity to Lake*c.2000	-0.31** [0.14]	-0.24 [0.24]	-0.25 [0.24]	-0.34*** [0.12]	-0.34*** [0.13]	-0.38*** [0.12]	-0.37*** [0.12]
Proximity to Lake*c.2010	-0.33* [0.17]	-0.16 [0.27]	-0.13 [0.26]	-0.34** [0.16]	-0.35** [0.17]	-0.40*** [0.15]	-0.38** [0.15]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y	Y	Y	Y
Dist. CAR Border*Year FE	N	Y	N	N	N	N	N
Dist. CAR CL River*Year FE	N	N	Y	N	N	N	N
CAR Rain Shock*Year FE	N	N	N	Y	Y	Y	Y

Notes: Proximity to Lake is the negative of the log Euclidean dist. to the selected lake centroid. Samples: Chad: 138 subdist. x 5 years (1948-2009) = 690 obs. Nigeria: 83 subdist. x 4 years (1948-2009) = 332 obs. Cameroon: 113 subdist. x 5 years (1963-2005) = 563 obs. Niger: 119 subdist. x 17 years (1951-2017) = 2,023 obs. (2)-(3) We add interactions of the year FE with the log Euclidean distance to the (2) border of the Central African Republic (CAR) (3) main rivers of the Chari-Logone (CL) river system located within the CAR. (4)-(7) We add interactions of the year FE with the distance-weighted average percentage rainfall loss in the CAR's CL river subdistricts between 1950-62 and 1963-69. More precisely, for each subdistrict of analysis i and each of the 14 CL river subdistricts j in CAR c. 1963 (out of 38 subdistricts in total), we know the Euclidean distance between i and j as well as the average rainfall level (mm) in 1950-62 and 1963-69. For each subdistrict i , we then obtain across all 14 subdistricts j the mean of the distance-weighted average rainfall level, defined as $\text{rainfall}/(\text{distance}^\alpha)$, with α measuring the impact of distance. Additionally, when aggregating the average rainfalls across all 14 CAR subdistricts j , we use as weights the total area or total population c. 1963 (source: Annuaire Statistique de l'AEF, Volume II, Années 1951 a 1955 - Haut Commissariat de l'AEF) of each CAR subdistrict. Finally, we obtain for each subdistrict i the percentage loss in average CAR rainfall between 1950-1962 and 1963-1969. We only report the coefficients for the closest years to the years 1970, 1990 and year 2010. See text for details on the controls. Conley SE 100 Km. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$ † $p < 0.15$.

Table F.8: Reduced-Form Effects, Robustness, Controls for the Local Weather

Dependent Variable:	Log Total Subdistrict Population in Year t						
Climate Controls:	Baseline	[$t-10;t$]	[$t-30;t$]	[$t-50;t$]	1960-69 - 1950-59	1962-69 - 1950-61	1964-69 - 1950-63
NIGER							
Proxi. to Lake (log)*1990	-0.41*** [0.11]	-0.37*** [0.13]	-0.40*** [0.11]	-0.42*** [0.11]	-0.37*** [0.08]	-0.34*** [0.08]	-0.27*** [0.09]
Proxi. to Lake (log)*2010	-0.33* [0.17]	-0.30* [0.17]	-0.31* [0.16]	-0.32* [0.17]	-0.28** [0.14]	-0.27* [0.14]	-0.25 [†] [0.15]
NIGERIA							
Proxi. to Lake (log)*1990	-0.46** [0.20]	-0.47** [0.22]	-0.36* [0.21]	-0.33* [0.18]	-0.63*** [0.24]	-0.57** [0.23]	-0.46** [0.22]
Proxi. to Lake (log)*2010	-0.49* [0.26]	-0.49* [0.26]	-0.38 [†] [0.26]	-0.51* [0.27]	-0.73** [0.32]	-0.64** [0.30]	-0.49* [0.28]
CAMEROON							
Proxi. to Lake (log)*1990	-0.40*** [0.12]	-0.53*** [0.14]	-0.60*** [0.13]	-0.32*** [0.10]	-0.44*** [0.14]	-0.27 [†] [0.17]	-0.26* [0.14]
Proxi. to Lake (log)*2010	-0.36** [0.14]	-0.39*** [0.14]	-0.57*** [0.16]	-0.55*** [0.16]	-0.40** [0.17]	-0.14 [0.24]	-0.17 [0.17]
CHAD							
Proxi. to Lake (log)*1990	-0.54*** [0.20]	-0.47** [0.21]	-0.54*** [0.20]	-0.56*** [0.20]	-0.52*** [0.19]	-0.52*** [0.20]	-0.55*** [0.20]
Proxi. to Lake (log)*2010	-0.62*** [0.16]	-0.62*** [0.15]	-0.63*** [0.14]	-0.65*** [0.16]	-0.56*** [0.14]	-0.55*** [0.16]	-0.56*** [0.15]
Subdistrict FE, Period FE	Y	Y	Y	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y	Y	Y	Y

Notes: (2)-(4) We control for mean temperature and log mean annual rainfall in [$t-X; t$]. (5)-(7) We include the absolute changes in mean temperature and log mean annual rainfall between the indicated periods. Conley SE 100 Km. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, [†] $p < 0.15$.

Table F.9: Reduced-Form Effects, Robustness, Irrigation and Dams Controls

Dependent Variable:	Log Total Subdistrict Population in Year t							
Additional Controls:	(1) None	(2) - (3) Irrigation Equipped Actual		(4) Dams	(5) None	(6) - (7) Irrigation Equipped Actual		(8) Dams
Irrigation Control:								
(Omitted = c. 1963)		Niger				Cameroon		
Proxi. to Lake (log)*1990	-0.41*** [0.11]	-0.46*** [0.11]	-0.46*** [0.11]	-0.42*** [0.11]	-0.40*** [0.12]	-0.42*** [0.16]	-0.42*** [0.16]	-0.37*** [0.12]
Proxi. to Lake (log)*2010	-0.33* [0.17]	-0.42*** [0.16]	-0.43*** [0.16]	-0.33* [0.17]	-0.36** [0.14]	-0.40* [0.22]	-0.40* [0.23]	-0.37*** [0.14]
(Omitted = c. 1963)		Chad				Nigeria		
Proxi. to Lake (log)*1990	-0.54*** [0.20]	-0.74*** [0.21]	-0.74*** [0.21]	-0.54*** [0.20]	-0.46** [0.20]	-0.50** [0.21]	-0.51** [0.21]	-0.41** [0.20]
Proxi. to Lake (log)*2010	-0.62*** [0.16]	-0.89*** [0.21]	-0.89*** [0.21]	-0.62*** [0.16]	-0.49* [0.26]	-0.55** [0.27]	-0.55** [0.27]	-0.50* [0.28]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Additional controls: (2)-(3) & (6)-(7) Log of area equipped for irrigation or actually irrigated c. 2005*year FE. Source: AQUASTAT - FAO's Global Information System on Water and Agriculture (v5). (4) & (8) Dummies if the subdistrict has reservoirs or river barriers in t as well as the logged numbers of reservoirs or river barriers in t . Source: Global Dam Watch (v1) consensus global database.

Table F.10: Maximum Contributions of Anthropogenic Activities to Lake Chad's Drying

Subdistricts: Countries:	All Subdistricts of Study (4)	+ CAR (5)	0-150 km + Chari-Logone rivers of Study (4)	+ CAR (5)
(a) Irrigation capacity Δ (%) 1963-1985	4.7	4.8		
(b) Local population Δ (%) c. 1963 - c. 1990			11.1	12.4
(c) Livestock stock Δ (%) 1960-63 vs. 1985-90	1.8	1.9		
Sum (a) + (b) + (c)	18.0	19.5		

Notes: Lake Chad's decreased by 85.5 billions cubic m between 1963 and 1985 (source: Olivry, J-C., Chouret, A., Vuillaume, G., Lemoalle, J., and Bricquet, J-P. 1996. *Hydrologie du lac Tchad*. Paris: ORSTOM). (a) Between 1963 and 1985, irrigation infrastructure increased by 400 km in the four countries of study and 410 km including the Central African Republic (CAR) (FAO, 2025). In the U.S. in 2015, the average irrigation application rate was 1.5 acre feet per acre irrigated (source: USDA. 2025. *Irrigation & Water Use*. USDA Economic Research Service.) We apply the same rate over 22 years. (b) For each subdistrict within 150 or 450 km from the lake or crossed by a river of the Chari-Logone river system, we know by how much population changed between 1963 and 1990. Each U.S. resident uses an average of ≈ 80 gallons of water a day (source: EPA. 2025. *Statistics and Facts* EPA: WaterSense). We apply the same rate over 22 years. (c) From the sources used to compute total livestock output (table notes of Appx. Table F.12), we obtain the number of total livestock units (TLU) of each subdistrict c. 1963. We do not know how TLUs changed for each subdistrict between 1963 and 1990 but we know the percentage increase in the amount of TLUs at the country level between 1960-63 and 1985-90 (source: FAO. 2025. *FAOSTAT*. FAO). We use these rates to obtain local TLU changes. Next, one TLU requires 25 liters of water per day (source: Sileshi, Z., Tegegne, A. and Tsadik, G.T. 2003. *Water resources for livestock in Ethiopia: Implications for research and development*. Mimeo.). We apply the same rate over 22 dry seasons (when pastoral communities move their livestock to the lake's shores and rivers).

Table F.11: Reduced-Form Effects, Robustness, Placebo Lakes

Dependent Variable:	Log Total Subdistrict Population in Year t					
	Niger (2,023 Obs.)			Cameroon (565 Obs.)		
Placebo Lake: Type:	Tabalak Natural	Lassouri Natural	Dan Douchi Natural	Lagdo Reservoir	Maga Reservoir	Bambendjing Reservoir
Proxi. Lake Chad (Log)*1990	-0.42*** [0.11]	-0.37*** [0.12]	-0.42*** [0.11]	-1.93** [0.90]	-1.18*** [0.45]	-0.50* [0.27]
Proxi. Lake Chad (Log)*2010	-0.33* [0.17]	-0.28* [0.16]	-0.35** [0.17]	-1.97 [1.46]	-1.11 [0.71]	-0.31 [0.34]
Proxi. Placebo Lake (Log)*1990	-0.05 [0.07]	0.02 [0.07]	0.07 [0.08]	-0.62 [0.65]	-0.19** [0.09]	0.76*** [0.11]
Proxi. Placebo Lake (Log)*2010	-0.06 [0.13]	-0.02 [0.10]	0.16 [0.12]	-0.84 [1.11]	-0.04 [0.14]	1.19*** [0.19]
	Cameroon		Nigeria (332 Obs.)			
Placebo Lake: Type:	Ossa Natural	Nguru Natural	Maladumba Natural	Kainji Reservoir	Tiga Reservoir	Jebba Reservoir
Proxi. Lake Chad (Log)*1990	-1.11*** [0.34]	-0.51** [0.21]	-0.50*** [0.18]	-0.41** [0.21]	-0.45** [0.20]	-0.49** [0.19]
Proxi. Lake Chad (Log)*2010	-1.08** [0.46]	-0.51** [0.24]	-0.48* [0.25]	-0.50* [0.30]	-0.49* [0.27]	-0.54** [0.26]
Proxi. Placebo Lake (Log)*1990	0.30 [0.20]	0.32** [0.14]	-0.04 [0.13]	0.05 [0.14]	0.03 [0.58]	-0.15 [0.19]
Proxi. Placebo Lake (Log)*2010	0.65** [0.26]	0.42** [0.20]	-0.16 [0.18]	-0.01 [0.18]	0.04 [0.74]	-0.24 [0.28]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y	Y	Y

Notes: This table shows the long-run effects (relative to the omitted pre-1963 year) for other large lakes of at least 20 sq km in each country. We include natural lakes as well as man-made lakes (reservoirs) built before the 1980s. For each country, we only consider the three largest natural lakes and the three largest man-made lakes that meet these conditions. Conley SEs 100 km.

Table F.12: Reduced-Form Effects, Robustness, Controls for Initial Economic Conditions

Dependent Variable:		Log Total Subdistrict Population in Year t							
1963 Control(s) × Year FE	Urban Share in		Log Urb & Rur		1963 Control(s) × Year FE	Urban Share in		Log Urb & Rur	
	Pop.	Output	Pop.	Output		Pop.	Output	Pop.	Output
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
Cameroon					Niger				
Proxi.*c.1970	-0.16** [0.07]	-0.08 [0.17]	-0.15** [0.07]	-0.15* [0.08]	Proxi.*c.1970	-0.25*** [0.08]	-0.24*** [0.08]	-0.19*** [0.07]	-0.10 [0.07]
Proxi.*c.1980	-0.24** [0.10]	-0.37** [0.18]	-0.25** [0.10]	-0.24** [0.12]	Proxi.*c.1990	-0.38*** [0.11]	-0.39*** [0.11]	-0.35*** [0.12]	-0.39*** [0.13]
Proxi.*c.1990	-0.38*** [0.12]	-0.71*** [0.24]	-0.39*** [0.12]	-0.41*** [0.13]	Proxi.*c.2000	-0.33** [0.15]	-0.31** [0.15]	-0.31** [0.15]	-0.34** [0.15]
Proxi.*c.2010	-0.41*** [0.15]	-0.95*** [0.34]	-0.41*** [0.14]	-0.38** [0.17]	Proxi.*c.2010	-0.39** [0.17]	-0.33* [0.17]	-0.30* [0.17]	-0.34** [0.17]
Chad					Nigeria				
Proxi.*c.1990	-0.54*** [0.20]	-0.62** [0.25]	-0.52** [0.21]	-0.53** [0.23]	Proxi.*c.1990	-0.35* [0.21]	-0.53*** [0.19]	-0.52** [0.24]	-0.46** [0.21]
Proxi.*c.2010	-0.62*** [0.16]	-0.64*** [0.19]	-0.62*** [0.18]	-0.61*** [0.20]	Proxi.*c.2010	-0.33 [0.28]	-0.60** [0.25]	-0.57* [0.31]	-0.56** [0.28]
Subdist FE, Yr FE	Y	Y	Y	Y	Subdist FE, Yr FE	Y	Y	Y	Y
Dist Trends, Ctrls	Y	Y	Y	Y	Dist Trends, Ctrls	Y	Y	Y	Y

Notes: Cameroon: 113 subdistricts × 5 yrs (1963-2005) = 563 obs. Niger: 119 subdistricts × 17 years (1951-2017) = 2,023 obs. Nigeria: 83 subdistricts × 4 years (1952-2006) = 332 obs. Chad: 138 subdistricts × 5 years (1948-2009) = 690 obs. (1) We control for the urbanization rate in 1963, i.e., the population share of urban areas, which we interact with year FE. (2) We control for the share of the urban sector in total output circa 1963, which we interact with year FE. (3) We control for log urban population and log rural population circa 1963, which we interact with year FE. (4) We control for log total farming output, log total livestock output, log total fishing output and log total urban output circa 1963, which we interact with year FE. **Sources for each country-sector:** (i) Cameroon - Farming: Dizian (1976), *World Atlas of Agriculture, Africa: Cameroon* and Service Colonial des Statistiques, Ministère de la France d'Outre-Mer (1947), *Annuaire Statistique du Cameroun, Volume I 1938-1945*; (ii) Cameroon - Livestock: Hubert (1966), *L'élevage et le commerce du bétail dans le Nord du Cameroun*; Dizian (1976), *World Atlas of Agriculture, Africa: Cameroon* and; Lunde and Lindtjørn (2013); (iii) Cameroon - Fishing: Couty and Duran (1968), *Le Commerce du Poisson au Tchad*; Chambre d'Agriculture, de l'Élevage et des Forêts du Cameroun (1962), *1962 Cameroun's Economy* and IBRD and IDA (1966), *L'Économie de la République Fédérale du Cameroun*; (iv) Cameroon - Urban: Marguerat (1973), *Atlas du Cameroun, Planche XVII: Les villes et leurs fonctions*; (v) Chad - Farming: Division de la Statistique Agricole, République du Tchad (1972), *L'Agriculture et l'Élevage Tchadiens à Travers les Chiffres 1962-1971* and Secrétariat d'État aux Relations avec les États de la Communauté, République du Tchad (1960), *Comptes Économiques 1958*, (vi) Chad - Livestock: Secrétariat d'État aux Relations avec les États de la Communauté, République du Tchad (1960), *Comptes Économiques 1958* and; Lunde and Lindtjørn (2013); (vii) Chad - Fishing: Couty and Duran (1968), *Le Commerce du Poisson au Tchad*; Cabot (1972), *Atlas Pratique du Tchad* and Secrétariat d'État aux Relations avec les États de la Communauté, République du Tchad (1960), *Comptes Économiques 1958*; (viii) Chad - Urban: Cabot (1972), *Atlas Pratique du Tchad*; (ix) Niger - Agriculture: Service de l'Agriculture, République du Niger (1962), *Rapport Annuel 1962, Statistiques*; (x) Niger - Livestock: Direction de l'Élevage et des Industries Animales, République du Niger (1964), *Rapport Annuel, Statistiques, 1963-64* and; Lunde and Lindtjørn (2013); (xi) Niger - Fishing: Niger (1965), *Plan quadriennal, 1965-68* (xii) Niger - Urban: Mission Démographique du Niger (1963), *Étude Démographique du Niger, Données Individuelles* and; Service de la Statistique et de la Mécanographie, République du Niger, *Annuaire Statistique 1962*. (xiii) Nigeria - Agriculture: Department of Statistics, Nigeria (1952), *Report on the Sample Census of Agriculture 1950-51* (xiv) Nigeria - Livestock: Department of Statistics, Nigeria (1952), *Report on the Sample Census of Agriculture 1950-51* and; Johnson Et al., Consortium for the Study of Nigerian Rural Development (1969), *Strategies and Recommendations for Nigerian Rural Development 1969/85* and; Lunde and Lindtjørn (2013); (xv) Nigeria - Fishing: FAO FishStat; National Council on Marine Resources and Engineering Development (1968), *Marine Science Activities of the Nations of Africa* and; Aminu (1993), *The Past History and Present Trends in the Fisheries of Lake Chad*; (xvi) Nigeria - Urban: Federal Office of Statistics, Nigeria (1966), *Industrial Survey of Nigeria 1963*. Conley SEs 100 Km.

Table F.13: Reduced-Form Effects, Robustness, Excluding Controls

Dependent Variable:	Log Total Subdistrict Population in Year t							
(Relative to Omitted Year)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Niger		Cameroon			Chad		
Excluded Control(s):	Baseline	Baseline	Rivers	Largest	Capital	Baseline	Rivers	Larg/Cap
Proxi. to Lake (log)*1990	-0.41*** [0.11]	-0.40*** [0.12]	-0.35** [0.15]	-0.39*** [0.12]	-0.35*** [0.11]	-0.54*** [0.20]	-0.56*** [0.21]	-0.26** [0.13]
Proxi. to Lake (log)*2010	-0.31** [0.14]	-0.36** [0.14]	-0.34** [0.14]	-0.34** [0.14]	-0.30** [0.12]	-0.62*** [0.16]	-0.66*** [0.17]	-0.56*** [0.15]
	Niger		Nigeria					
Excluded Control(s):	Larg/Cap	Baseline	Rivers	Largest	Capital	Oil Cap	North Cap	Oil
Proxi. to Lake (log)*1990	-0.17* [0.10]	-0.46** [0.20]	-0.45** [0.19]	-0.34* [0.18]	-0.28 [0.26]	-0.58*** [0.18]	-0.52** [0.21]	-0.63*** [0.20]
Proxi. to Lake (log)*2010	-0.19 [0.15]	-0.49* [0.26]	-0.51** [0.26]	-0.39 [0.27]	-0.15 [0.38]	-0.70*** [0.25]	-0.60** [0.28]	-0.75*** [0.27]

Notes: This table shows the long-run effects when excluding specific sets of controls. See text for details on the controls. Larg/Cap: The largest city is also the capital city. Oil Cap: Port Harcourt. North Cap: Kano. Oil: All oil controls. Conley SEs 100 km.

Table F.14: Reduced-Form Effects, Robustness, Removing District-Specific Trends

Dependent Variable:	Log Total Subdistrict Population in Year t						
	(1)	(2)	(3)		(1)	(2)	(3)
	Cameroon				Niger		
Proximity*c.1990	-0.40*** [0.12]	-0.51*** [0.17]	-0.41*** [0.14]	Proximity*c.1990	-0.41*** [0.11]	-0.39*** [0.10]	-0.34*** [0.10]
Proximity*c.2010	-0.36** [0.14]	-0.55** [0.22]	-0.37** [0.18]	Proximity*c.2010	-0.33* [0.17]	-0.29*** [0.11]	-0.19 [0.16]
	Nigeria				Chad		
Proximity*c.1950	0.03 [0.13]	-0.03 [0.11]	-0.02 [0.11]	Proximity*c.1950	-0.28*** [0.10]	-0.46*** [0.14]	-0.31*** [0.10]
Proximity*c.1990	-0.46** [0.20]	-0.29 [†] [0.20]	-0.32* [0.19]	Proximity*c.1990	-0.54*** [0.20]	-0.10 [0.25]	-0.46** [0.23]
Proximity*c.2010	-0.49* [0.26]	-0.24 [0.20]	-0.29 [0.20]	Proximity*c.2010	-0.62*** [0.16]	0.06 [0.14]	-0.50*** [0.12]
Subdist FE, Yr FE, Ctrls	Y	Y	Y	Subdist FE, Yr FE, Ctrls	Y	Y	Y
Included Trends	District	None	Region	Included Trends	District	None	Region

Notes: Cameroon: 113 subdistricts x 5 yrs (1963-2005) = 563 obs. Niger: 119 subdistricts x 17 years (1951-2017) = 2,023 obs. Nigeria: 83 subdistricts x 4 years (1952-2006) = 332 obs. Chad: 138 subdistricts x 5 years (1948-2009) = 690 obs. In the **baseline (1)**, we consider 47, 31, 24 and 36 districts in Cameroon, Niger, Nigeria and Chad, respectively. The districts correspond to 2nd level administrative units in the 1960s. In **col. (2)**, we do not include district-specific linear trends. In **col. (3)**, we instead include region-specific linear trends, with regions corresponding to the first-level administrative units in the 1960s. This includes 10, 15, 6 and 13 regions in Cameroon ("regions"), Niger ("cercles"), Nigeria ("zones") and Chad ("prefectures"), respectively. Conley SEs 100 Km. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$ † $p < 0.15$.

Table F.15: Reduced-Form Effects, Robustness, Controls for Longitude

Dep. Var.:	Log Total Subdistrict Population in Year t									
	Niger		Cameroon		Chad		Nigeria		Nigeria (150 Km Bins)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Proxi* ⁹⁰	-0.41*** [0.11]	-0.49*** [0.11]	-0.40*** [0.12]	-0.50*** [0.16]	-0.54*** [0.08]	-0.44*** [0.14]	-0.46** [0.20]	0.28 [0.38]	150* ¹⁰ [0.43]	-1.03** [0.74]
Proxi* ¹⁰	-0.33* [0.17]	-0.33** [0.17]	-0.36** [0.14]	-0.53** [0.22]	-0.62*** [0.17]	-0.50** [0.22]	-0.49* [0.26]	-0.17 [0.48]	300* ¹⁰	-0.83** [0.35]
									450* ¹⁰	-0.38 [†] [0.24]
Long*Yr FE	N	Y	N	Y	N	Y	N	Y	N	Y
Subdist FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dist Trends	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

(2), (4), (6), (8) & (10): We interact the subdistrict's longitude with year FE. (9)-(10): We consider the specification with three distance bins (e.g., "300" is a dummy if the subdistrict is 150-300 km from Lake Chad). Conley SE 100 Km. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, $\dagger p < 0.15$.

Table F.16: Reduced-Form Effects, Corrected Population Levels in Lake Shore Subdistricts

Dependent Variable:	Log Total Subdistrict Population in Year t							
	(1) (2) (3)			(1) (2) (3)				
	Niger			Cameroon				
Proximity*c.1990	-0.42***	-0.42***	-0.43***	Proximity*c.1990	-0.32**	-0.32**	-0.38***	
	[0.10]	[0.10]	[0.10]		[0.13]	[0.13]	[0.12]	
Proximity*c.2010	-0.36**	-0.35**	-0.37**	Proximity*c.2010	-0.26*	-0.26*	-0.27*	
	[0.17]	[0.17]	[0.17]		[0.14]	[0.14]	[0.14]	
Chad				Nigeria				
Proximity*c.1990	-0.57*	-0.57*	-0.36	Proximity*c.1990	-0.45**	-0.45**	-0.44**	
	[0.32]	[0.31]	[0.31]		[0.20]	[0.20]	[0.20]	
Proximity*c.2010	-0.90***	-0.92***	-0.51***	Proximity*c.2010	-0.48*	-0.48*	-0.46*	
	[0.21]	[0.19]	[0.18]		[0.26]	[0.26]	[0.26]	
Pop correction from Subdist FE, Yr FE, Ctrl	Built Area Y	Volume Y	Lights Y	Pop correction from Subdist FE, Yr FE, Ctrl	Built Area Y	Volume Y	Lights Y	

Notes: Cameroon: 113 subdistricts $\times$ 5 yrs (1963-2005) = 563 obs. Niger: 119 subdistricts $\times$ 17 years (1951-2017) = 2,023 obs. Nigeria: 83 subdistricts $\times$ 4 years (1952-2006) = 332 obs. Chad: 138 subdistricts $\times$ 5 years (1948-2009) = 690 obs. **(1)** We correct the post-1963 population levels of lake shore subdistricts using the ratio of the total built-up area of existing settlements located inside the former lake area to the total built-up area of existing settlements located outside the former lake area. Geospatialized information on built-up area is available from the Global Human Settlement Layer (GHSL) database circa the years 1975, 1990, 2000 and 2015 (GHS-Built-S: resolution of 1 km $\times$ 1 km). For each post-1963 census year used in our analysis, we rely on the correction ratio from the closest year available in GHSL. **(2)** The correction ratios are constructed using total built volumes. Information on built volumes circa the years 1975, 1990, 2000 and 2015 comes from the Global Human Settlement Layer (GHSL) database (GHS-Built-V: resolution of 1 km $\times$ 1 km). **(3)** The correction ratios are constructed using total night lights. Night lights data corresponding to the DMSP satellites are provided by NGDC (2015). The radiance calibrated version of this data, which is available for select years between 1996 and 2011, is used to avoid top-coding complications. The data are available at a 30 arc second ($\approx$ 1 km at the equator) spatial resolution. For each post-1963 census year, we rely on the correction ratio from the closest year available in the night lights data. Conley SEs 100 Km. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$ $\dagger p < 0.15$.

Table F.17: Reduced-Form Effects, Robustness, SUTVA

Dependent Variable:	Log Total Subdistrict Population in Year t						
(Omitted = c. 1963)	(1)	(2)	(3)	(Omitted = c. 1963)	(4)	(5)	(6)
Excluded Control Subdistricts (Km)	None	450-600	450-750	Excluded Control Subdistricts (Km)	None	450-600	450-750
	Niger				Cameroon		
Proximity Lake*1970	-0.23*** [0.08]	-0.16** [0.08]	-0.24*** [0.09]	Proximity Lake*1970	-0.19** [0.08]	-0.20** [0.09]	-0.15** [0.08]
Proximity Lake*1990	-0.41*** [0.11]	-0.33*** [0.09]	-0.34*** [0.11]	Proximity Lake*1980	-0.27** [0.11]	-0.33*** [0.12]	-0.27*** [0.10]
Proximity Lake*2000	-0.31** [0.14]	-0.20* [0.11]	-0.16 [0.11]	Proximity Lake*1990	-0.40*** [0.12]	-0.43*** [0.13]	-0.41*** [0.13]
Proximity Lake*2010	-0.33* [0.17]	-0.21 [†] [0.13]	-0.26** [0.13]	Proximity Lake*2010	-0.36** [0.14]	-0.36** [0.14]	-0.34** [0.14]
Obs.	2,023	1,581	1,309	Obs.	565	555	535
	Chad				Nigeria		
Proximity Lake*1990	-0.54*** [0.20]	-0.57*** [0.20]	-0.52** [0.20]	Proximity Lake*1990	-0.46** [0.20]	-0.48** [0.21]	-0.41** [0.20]
Proximity Lake*2010	-0.62*** [0.16]	-0.65*** [0.15]	-0.55*** [0.16]	Proximity Lake*2010	-0.49* [0.26]	-0.53* [0.29]	-0.41 [0.28]
Obs.	690	475	290		332	316	288
Subdistrict FE, Year FE	Y	Y	Y	Subdistrict FE, Year FE	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	District Trends, Ctrls	Y	Y	Y

Notes: Baseline samples: Niger: 119 subdistricts x 17 years (1951-2017) = 2,023. Cameroon: 113 subdistricts x 5 yrs (1963-2005) = 563. Chad: 138 subdistricts x 5 years (1948-2009) = 690. Nigeria: 83 subdistricts x 4 years (1952-2006) = 332. For each subdistrict centroid, *Proximity to Lake (log)* is the negative of the log Euclidean distance to the selected lake centroid. **Cols. (2) & (5):** We exclude subdistricts located within 450-600 km from the selected lake centroid. **Cols. (3) & (6):** We exclude subdistricts located within 450-750 km from the selected lake centroid. See text for details on the controls. We consider 450-600 km and 450-750 km because the distance bin specification relies on distance bins of 150 km up to 450 km (0-150, 150-300, 300-450). Conley SEs 100 Km. *** p<0.01, ** p<0.05, * p<0.1, † p<0.15.

Table F.18: Urban Extensive Margin Effects, Distance Bins, 1950-2020

Dependent Variable:	Dummy if at least One City (Locality $\geq 5,000$ inh.) in the Subdistrict in Year t							
	Niger		Chad		Cameroon		Nigeria	
Year ...:	c. 1990	c. 2010	c. 1990	c. 2010	c. 1990	c. 2010	c. 1990	c. 2010
0-150 Km*Year ...	0.19 [0.28]	-0.25 [0.25]	0.59** (0.23)	1.12*** (0.32)	-0.00 [0.43]	-0.62 [0.59]	- -	-1.32** [0.58]
150-300 Km*Year ...	0.44 [0.29]	0.42*** [0.11]	0.64*** (0.21)	1.44*** (0.26)	0.09 [0.35]	-0.00 [0.46]	- -	-1.00** [0.42]
300-450 Km*Year ...	-0.12 [0.10]	-0.21** [0.10]	0.08 (0.15)	0.44** (0.19)	-0.32 [0.34]	-0.69 [0.47]	- -	-0.44** [0.22]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Niger: 119 subdistricts x 17 years (1951-2017) = 2,023 obs. c.1990 = 1988. c.2010 = 2012. Cameroon: 113 subdistricts x 5 years (1963-2005) = 563 obs. c.1990 = 1987. c.2010 = 2005. Chad: 138 subdistricts x 5 years (1948-2009) = 690 obs. c.1990 = 1993. c.2010 = 2009. Nigeria: 83 subdistricts x 2 years (1963, 2006) = 166 obs. c.2010 = 2006. Urban population data is not available for the census years 1952 and 1991. We only report the coefficients for the closest years to the years 1990 and 2010. See text for details on the controls and details on how urban and rural populations are constructed. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10.

Table F.19: Heterogeneity wrt Historical Urbanization, Distance Bins, 1950-2020

Dependent Variable:	Log Rural Population in the Subdistrict in Year t							
	Niger		Chad		Cameroon		Nigeria	
...	City Dummy 1963	Urban Share 1963	City Dummy 1963	Urban Share 1963	City Dummy 1963	Urban Share 1963	City Dummy 1963	Urban Share 1963
Lake 150 km*1990*...	0.00 [0.00]	0.00 [0.00]	0.00 (0.00)	0.00 (0.00)	0.00 [0.00]	0.00 [0.00]	- -	- -
Lake 300 km*1990*...	0.00 [0.00]	0.00 [0.00]	-0.30 (0.39)	0.01 (0.01)	0.26 [0.29]	0.02 [0.02]	- -	- -
Lake 450 km*1990*...	0.68*** [0.14]	0.01*** [0.00]	0.60 (0.42)	0.01 (0.02)	0.17 [0.25]	0.04*** [0.02]	- -	- -
Lake 150 km*2010*...	0.00 [0.00]	0.00 [0.00]	0.00 (0.00)	0.00 (0.00)	0.00 [0.00]	0.00 [0.00]	0.00 [0.00]	-0.15** [0.06]
Lake 300 km*2010*...	0.00 [0.00]	0.00 [0.00]	0.40 (0.34)	0.01* (0.01)	0.08 [0.20]	0.00 [0.01]	0.00 [0.00]	-0.10*** [0.04]
Lake 450 km*2010*...	0.59*** [0.19]	0.01*** [0.00]	0.46 (0.57)	-0.00 (0.04)	0.27 [0.19]	0.03* [0.02]	0.00 [0.00]	0.04** [0.02]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: 119 subdistricts x 17 years (1951-2017) = 2,023 obs. c.1990 = 1988. c.2010 = 2012. Cameroon: 113 subdistricts x 5 years (1963-2005) = 563 obs. c.1990 = 1987. c.2010 = 2005. Chad: 138 subdistricts x 5 years (1948-2009) = 690 obs. c.1990 = 1993. c.2010 = 2009. Nigeria: 83 subdistricts x 2 years (1963, 2006) = 166 obs. c.2010 = 2006 (rural pop. data not available for the census year 1991). **City Dummy** is a dummy if the subdistrict had at least one city in 1963. **Urban Share** is the urban population share c. 1963. See text for details on the controls and details on how urban and rural pop. are constructed. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10.

Table F.20: Rural Population and Urban Population, Distance Bins Specification, Test for Pre-Trends, 1950s

Dependent Variable:	Dummy at Least One City	Log Urban Pop.	Log Rural Pop.	Dependent Variable:	Dummy at Least One City	Log Urban Pop.	Log Rural Pop.	Dependent Variable:	Dummy at Least One City	Log Urban Pop.	Log Rural Pop.
(1) Niger				(2) Chad				(3) Cameroon			
1960 x 0-150 km	0.01 [0.01]	0.01 [0.01]	-0.01 [0.01]	1957 x 0-150 km	0.04 [0.04]	0.05 [0.03]	-0.01 [0.03]	1953 x 0-150 km	0.02 (0.12)	-0.15 [0.13]	0.01 [0.17]
1960 x 150-300 km	0.00 [0.00]	0.01 [0.01]	-0.00 [0.01]	1957 x 150-300 km	0.06 [0.04]	0.05 [0.03]	0.00 [0.03]	1953 x 150-300 km	-0.04 (0.11)	-0.17 [0.13]	0.09 [0.16]
1960 x 300-450 km	0.00 [0.00]	0.01 [0.00]	-0.00 [0.01]	1957 x 300-450 km	0.04 [0.03]	0.04* [0.02]	0.01 [0.02]	1953 x 300-450 km	0.09 (0.13)	0.07 [0.13]	0.19 [0.14]
1959 x 0-150 km	0.01 [0.01]	0.02 [0.02]	-0.01 [0.02]	1956 x 0-150 km	0.01 [0.05]	0.03 [0.04]	0.01 [0.04]	Subdistrict FE, Year FE District Trends, Ctrls	Y, Y Y, Y	Y, Y Y, Y	Y, Y Y, Y
1959 x 150-300 km	0.00 [0.01]	0.01 [0.01]	0.00 [0.02]	1956 x 150-300 km	0.03 [0.04]	0.03 [0.04]	0.02 [0.04]	(3) Cameroon			
1959 x 300-450 km	0.00 [0.00]	0.01 [0.00]	0.00 [0.01]	1956 x 300-450 km	0.03 [0.03]	0.03 [0.03]	0.02 [0.03]	1954 x 0-150 km	0.12 [0.18]	0.19 [0.19]	- -
1958 x 0-150 km	0.01 [0.01]	0.03 [0.01]	-0.02 [0.02]	1951 x 0-150 km	0.02 [0.06]	0.06 [0.06]	0.05 [0.05]	1954 x 150-300 km	-0.20 [0.34]	-0.10 [0.33]	- -
1958 x 150-300 km	0.01 [0.01]	0.02 [0.01]	-0.00 [0.02]	1951 x 150-300 km	0.03 [0.05]	0.04 [0.05]	0.03 [0.08]	1954 x 300-450 km	-0.30 [0.31]	-0.24 [0.29]	- -
1958 x 300-450 km	0.01 [0.01]	0.02 [0.01]	0.01 [0.01]	1951 x 300-450 km	0.03 [0.03]	0.05* [0.03]	0.05** [0.03]	Subdistrict FE, Year FE District Trends, Ctrls	Y, Y Y, Y	Y, Y Y, Y	Y, Y Y, Y
Subdistrict FE, Year FE District Trends, Ctrls				Y, Y Y, Y	Y, Y Y, Y	Y, Y Y, Y	Y, Y Y, Y	Subdistrict FE, Year FE District Trends, Ctrls	Y, Y Y, Y	Y, Y Y, Y	Y, Y Y, Y

Notes: Niger: 117 subdist. x 17 years (1951-2017) = 1,989 obs. We exclude two subdistricts whose urban (and thus rural) population c. 1963 was interpolated using post-1963 population data. This is not an issue for the extensive margin regression. We thus use the full sample of 119 subdist. x 17 years = 2023 obs. for the first column. Chad: 138 subdist. x 5 years (1948-2009) = 690 obs. Cameroon: 96 subdist. x 2 years ("1954", which captures the mean population in 1953-56, and "1962", which captures the mean population in 1959-64) = 192 obs (we omit 17 subdistricts containing cities with missing population information for "1962"). Having only two years of data, we do not include district-specific trends. Since the extensive margin effects are mostly small and not significant, we use log (urban pop. + 1) as the dependent variable capturing urban population change. We then use log(rural pop. + 1). We only report the coefficients for the 1950s. We do not have consistent urban population data for Nigeria before 1963. See text for more details on the specifications. Conley SE 100 Km.

Table F.21: Reduced-Form Effects, Other Economic Outcomes, Cross-Section

Dependent Variable defined circa 2010:	Log (Lights / Area)	Log (Built Area/ Area)	Log (Volume / Area)	Log (Lights / Area)	Log (Built Area/ Area)	Log (Volume / Area)
(Omitted = c. 1963)	Cameroon			Niger		
Lake 150 km*c. 2010	-0.42* [0.25]	-0.40 [†] [0.25]	-0.47* [0.26]	-0.25* [0.14]	-0.01 [0.17]	0.04 [0.20]
Lake 300 km*c. 2010	-0.29** [0.14]	-0.24** [0.12]	-0.22* [0.13]	-0.22*** [0.07]	-0.42*** [0.14]	-0.34** [0.15]
Lake 450 km*c. 2010	-0.27* [0.15]	-0.07 [0.20]	-0.08 [0.20]	-0.08** [0.04]	-0.10 [0.08]	-0.06 [0.08]
Observations	113	113	113	119	119	119
(Omitted = c. 1963)	Chad			Nigeria		
Lake 150 km*c. 2010	-0.08 [0.05]	0.07 [0.19]	0.18 [0.20]	0.19 [0.33]	-0.72*** [0.16]	-0.66*** [0.17]
Lake 300 km*c. 2010	-0.01 [0.02]	-0.05 [0.19]	0.00 [0.20]	-0.20 [0.29]	-0.40** [0.17]	-0.27 [0.18]
Lake 450 km*c. 2010	0.03 [0.02]	-0.09 [0.14]	-0.04 [0.15]	0.10 [0.24]	-0.09 [0.11]	-0.05 [0.12]
Baseline Controls	Y	Y	Y	Y	Y	Y
1963 Econ Conditions Ctrl	Y	Y	Y	Y	Y	Y
1963 Electricity Controls	Y	N	N	Y	N	N
1975 Built Area or Volume Ctrl	N	Y	Y	N	Y	Y

Notes: These are cross-sectional regressions where the dependent variable is defined circa the year 2010 and we control as much as possible for initial conditions circa the year 1963. Night lights data corresponding to the DMSP satellites are provided by NGDC (2015). The radiance calibrated version of this data, which is available for select years between 1996 and 2011, is used to avoid top-coding complications. The data are available at a 30 arc second (≈ 1 km at the equator) spatial resolution. Geospatialized information on built-up area and volume is available from the Global Human Settlement Layer (GHSL) database circa the years 1975, 1990, 2000 and 2015 (GHS-Built-S: resolution of 1 km*1 km). In both cases, we aggregate information at the subdistrict level and rely on information for the closest year to the year 2010. 1963 conditions controls: urban population share, log urban population, log rural population, and output shares and log total output levels of the farming, livestock, fishing and urban sectors, all defined c. 1963. 1963 electricity controls: (i) Cameroon: We control for whether the subdistrict has access to electricity as well as the log of the total electrical capacity, total length of the electrical network, total electrical consumption and the number of subscribers of each subdistrict in 1957 (we include information from both existing stations and stations under construction); (ii) Niger: We control for whether the subdistrict has access to electricity as well as the log of the total electrical capacity and total electrical production of each subdistrict in 1963; (iii) Chad: We control for whether the subdistrict has access to electricity as well as the log of the total electrical capacity of each subdistrict circa 1963 (we include information from both 1959 and 1970); (iv) Nigeria: We control for whether the subdistrict has access to electricity as well as the log of the total electrical production of each subdistrict circa 1963 (we include information from both existing stations and stations under construction). 1963 GHSL controls: We control for the value of the dependent variable in 1975. Cross-sectional controls: log distance to the country's largest city and its square, log distance to the country's capital city and its square, and latitude (for oil-rich Nigeria, we also control for log distance to Port Harcourt and log distance to Kano and their square, as well as the share of the subdistrict's area that is covered by oil and gas fields and its square). Conley SEs 100 Km. *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$ [†] $p < 0.15$.

Table F.22: Reduced-Form Effects, Vegetation Health and Density, Distance Bins, Panel

Dependent Variable:	Mean Normalized Difference Vegetation Index (NDVI) (0-1) in Period t			
Benchmark = 1982-1994	(1) Cameroon	(2) Chad	(3) Niger	(4) Nigeria
Lake Bin 150 km*(2000-2014)	-0.06*** [0.00]	-0.02*** [0.00]	-0.01*** [0.00]	-0.00 [0.01]
Lake Bin 300 km*(2000-2014)	-0.02*** [0.00]	-0.01*** [0.00]	-0.02*** [0.00]	-0.00 [0.01]
Lake Bin 450 km*(2000-2014)	-0.02*** [0.00]	-0.00 [0.00]	-0.01*** [0.00]	-0.00 [0.00]
Mean NDVI in 1982-1994	0.67	0.33	0.20	0.55
Subdist FE, (5-Year) Period FE	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y

Notes: Obs.: (1) Niger: 119 subdist. x 8 five-year periods (1982-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, 2005-2009, 2010-2014, 2015-2019) = 952. (2) Cameroon: 113 subdist. x 8 five-year periods = 904. (3) Chad: 138 subdist. x 8 five-year periods = 1,104. (4) Nigeria: 83 subdist. x 8 five-year periods = 664. We report the difference between the avg. effect for (2000-05 + 2005-09 + 2010-14) and the avg. effect for (1982-84 + 1985-89 + 1990-94) (omitted = 2015-2019). Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10.

Table F.23: Reduced-Form Effects, Crop Production, Distance Bins, Cross-Section

Dependent Variable:	Log (Value of Crop Production / Area) circa 2010			
	(1) Cameroon	(2) Chad	(3) Niger	(4) Nigeria
Lake Bin 150 km	-2.98*** [0.65]	-0.06 [0.59]	-2.38*** [0.75]	-0.11 [0.28]
Lake Bin 300 km	-1.44*** [0.50]	-1.90*** [0.63]	-1.06* [0.55]	-0.44* [0.25]
Lake Bin 450 km	-0.98** [0.45]	0.42 [0.65]	-0.37 [0.31]	0.06 [0.20]
Controls (Incl. 1963 Agriculture)	Y	Y	Y	Y

Notes: Obs.: Cameroon: 113 subdistricts. Chad: 138 subdistricts. Niger: 119 subdistricts. Nigeria: 83 subdistricts. In addition to the baseline controls, we control for the following controls defined circa the year 1963: log total farming output, log rural population and log area, as well as the GDP share of farming. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10, † p<0.15.

Table F.24: Reduced-Form Effects, Livestock Production, Distance Bins, Cross-Section

Dependent Variable:	Log (Number of Total Livestock Units (TLUs) / Area) circa 2010			
	(1) Cameroon	(2) Chad	(3) Niger	(4) Nigeria
Lake Bin 150 km	-1.50*** [0.36]	-0.71† [0.50]	0.18 [0.14]	-0.30 [0.39]
Lake Bin 300 km	-1.11*** [0.28]	-1.70*** [0.36]	-0.78*** [0.17]	-0.39† [0.27]
Lake Bin 450 km	-1.02*** [0.27]	-0.45* [0.25]	-0.08 [0.19]	-0.02 [0.33]
Controls (Incl. for 1963 Livestock)	Y	Y	Y	Y

Notes: Obs.: Cameroon: 113 subdistricts. Chad: 138 subdistricts. Niger: 119 subdistricts. Nigeria: 83 subdistricts. We use the following total livestock units (TLU) weights to construct the TLUs of each subdistrict in 2010 (source: FAO, weights specifically designed for Africa; see Data Appendix for details): 0.5 for cattle, 0.1 for goats and sheep, and 0.8 for horses. In addition to the baseline controls, we control for the log of (total livestock output circa 1963 / area). Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10, † p<0.15.

Table F.25: Proximity to Lake Chad and Conflict, Cross-Sectional Analysis, 1997-2019

Conflict Event Type:	(1) - (3) Non-Organized Violence			(4) - (6) Organized Violence		
	All	Protests	Riots	All	Battles	on Civilians
Dependent Variable:	Number of Conflict Events in 1997-2019, Poisson Model					
Lake 0-150 Km Dummy	2.26** (1.12)	1.76 [†] (1.34)	2.19*** (0.80)	1.85*** (0.46)	1.89*** (0.40)	1.86*** (0.55)
Lake 150-300 Km Dummy	1.44** (0.65)	1.75** (0.88)	1.02** (0.43)	1.26*** (0.24)	1.22*** (0.25)	1.18*** (0.29)
Lake 300-450 Km Dummy	0.36 (0.48)	0.57 (0.64)	0.14 (0.32)	-0.52 (0.38)	-0.60* (0.33)	-0.50 (0.48)
Mean	13.69	9.25	4.45	29.79	12.78	14.32
Country FE & Controls, Obs.	Y, 453	Y, 453	Y, 453	Y, 453	Y, 453	Y, 453

Notes: Controls: We use the baseline controls (see text for details). Unfortunately, historical localized conflict data does not exist for the 1950s-1960s in our context. "on Civilians": violence against civilians. Conley SE 100 km *** p<0.01, ** p<0.05, * p<0.10.

Table F.26: Reduced-Form Effects, Roads, Distance Bins, Cross-Section

Dependent Variable:	(1) - (2) Cameroon (N = 113)		(3) - (4) Chad (N = 138)	
	Paved Roads	Improved Roads	Paved Roads	Improved Roads
Lake 0-150 Km Dummy	-0.02 [0.02]	-0.01 [0.01]	0.00 [0.00]	-0.00 [0.00]
Lake 150-300 Km Dummy	-0.00 [0.01]	0.01 [0.01]	0.00 [0.00]	-0.00 [0.00]
Lake 300-450 Km Dummy	0.01 [0.01]	-0.01 [0.01]	0.00 [0.00]	-0.00 [0.00]
Dependent Variable:	(5) - (6) Niger (N = 119)		(7) - (8) Nigeria (N = 83)	
	Paved Roads	Improved Roads	Paved Roads	Improved Roads
Lake 0-150 Km Dummy	-0.02* [0.01]	-0.01 [0.01]	0.01 [0.01]	-0.00 [0.01]
Lake 150-300 Km Dummy	-0.02** [0.01]	-0.01 [0.01]	-0.00 [0.01]	-0.00 [0.00]
Lake 300-450 Km Dummy	-0.01 [0.01]	0.00 [0.01]	0.01*** [0.00]	0.00 [0.00]
Controls (Incl. for c. 1963 Roads)	Y	Y	Y	Y

Notes: Obs. (subdistricts): Cameroon: 113. Chad: 138. Niger: 119. Nigeria: 83. The dependent variable is the log of the total length (km) of paved roads or improved roads (gravel, laterite, etc.) per area in 2008. We control for the value of the dependent variable in 1965, the first year with available road data in Jedwab and Storeygard (2021). We also add the baseline controls. Conley SE 100 Km.

Table F.27: Reduced-Form Effects, Health Facilities, Distance Bins, Cross-Section

Dep.Var.: Log (Num of ... / Area) c. 2010	(1)-(4) Cameroon				(5)-(7) Chad		
	Health Centers	Medical Centers	Local Hospitals	Regional Hospitals	Health Centers	Local Hospitals	Regional Hospitals
Lake 150 Km	-0.033*** [0.010]	-0.005** [0.002]	-0.002*** [0.001]	0.000 [0.000]	-0.001 [0.001]	-0.000 [0.000]	0.000 [0.000]
Lake 300 Km	-0.025*** [0.008]	-0.004*** [0.002]	-0.002*** [0.001]	0.000* [0.000]	0.004* [0.002]	0.000 [0.000]	0.000 [0.000]
Lake 450 Km	-0.017** [0.007]	-0.003** [0.001]	-0.001** [0.001]	-0.000 [0.000]	-0.003*** [0.001]	-0.000 [0.000]	0.000 [0.000]
Dep.Var.: Log (Num of ... / Area) c. 2010	(8)-(10) Niger				(11)-(14) Nigeria		
	Health Huts	Medical Centers	All Hospitals	Primary Health	Secondary Local	Health State	Tertiary Health
Lake 150 Km	-0.006* [0.003]	-0.001 [0.001]	0.000 [0.000]	-0.005 [0.008]	0.000 [0.000]	-0.000 [0.001]	-0.000 [0.000]
Lake 300 Km	-0.008*** [0.003]	-0.002* [0.001]	-0.000 [0.000]	-0.007 [0.006]	0.000 [0.000]	-0.000 [0.000]	-0.000 [0.000]
Lake 450 Km	-0.003 [0.002]	-0.002* [0.001]	0.000 [0.000]	-0.003 [0.006]	0.000 [0.000]	0.000 [0.000]	-0.000 [0.000]
Ctrls (Incl. for 63 Health)	Y	Y	Y	Y	Y	Y	Y

Notes: Obs. (subdistricts): Cameroon: 113. Chad: 138. Niger: 119. Nigeria: 83. In addition to the baseline controls, we control for the following variables circa 1963 (expressed as the log of (number of ... / area)): **(1)-(4)** Cameroon: public dispensaries, private dispensaries, departmental centers for preventive medicine, public hospitals, and private hospitals in 1967 (source: *Atlas du Cameroun, Planche IX* (1970)); **(5)-(7)** Chad: dispensaries, infirmaries, medical centers, hospitals, services for the control of the contagious diseases, medics, surgeons, oral surgeons, and pharmacists in 1967 (source: Cabot (1972), *Atlas Pratique du Tchad*); **(8)-(10)** Niger: hospitals, health centers, health pavilions, dispensaries, maternities, medics, and nurses in 1964 (source: République du Niger (1964), *carte administrative: Infrastructure sanitaire*); and **(11)-(14)** Nigeria: dispensaries, health centers, health offices, clinics, maternities, joint maternities and dispensaries, general hospitals, and specialist hospitals in 1967 (source: Nigeria (1967), *health facilities, drawn and printed by Federal Surveys*). We use the following source for the dependent variables circa 2010: Maina, Joseph, Paul O. Ouma, Peter M. Macharia, Victor A. Alegana, Benard Mitto, Ibrahima Socé Fall, Abdisalan M. Noor, Robert W. Snow, and Emelda A. Okiro. "A spatial database of health facilities managed by the public health sector in sub Saharan Africa." Scientific data 6, no. 1 (2019): 134. The dataset was elaborated by the authors between 2012 and 2018 based on available data at the time through sources such as ministries of health, other government agencies or the United Nations Office for the Coordination of Humanitarian Affairs' Humanitarian Data Exchange. Note that the source does not distinguish local, regional and national hospitals for Niger. For Nigeria, there are subtypes of hospitals in the data for which it is unclear whether they are local, regional or national. We thus do not distinguish local, regional and national hospitals for Nigeria. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10, † p<0.15.

Table F.28: Reduced-Form Effects, Education Facilities, Distance Bins, Cross-Section

Dep.Var.: Log (Num of ... / Area) c. 2010	(1)-(3) Cameroon			(4)-(7) Chad			
	Primary Schools	Secondary Schools	Tertiary Schools	Primary Schools	Junior Sec. Schools	Senior Sec. Schools	University
0-150 Km Dummy	-0.119* [0.066]	-0.048** [0.023]	-0.003** [0.001]	-0.015* [0.009]	-0.004* [0.002]	-0.002** [0.001]	-0.000 [0.000]
150-300 Km Dummy	-0.069 [0.055]	-0.032* [0.019]	-0.002** [0.001]	-0.014 [0.011]	-0.005** [0.002]	-0.003*** [0.001]	-0.000 [0.000]
300-450 Km Dummy	-0.031 [0.051]	-0.019 [0.018]	-0.002** [0.001]	-0.024*** [0.008]	-0.004* [0.002]	-0.002** [0.001]	-0.000
Dep.Var.: Log (Num of ... / Area) c. 2010	(8)-(9) Niger		(10)-(11) Nigeria UBEC		(12)-(14) Nigeria GRID		
	Senior Sec. Schools	University	Primary Schools	Junior Sec. Schools	Primary Schools	Secondary Schools	Tertiary Schools
0-150 Km Dummy	0.000 [0.000]	0.000** [0.000]	-0.209*** [0.059]	-0.114*** [0.036]	-0.141*** [0.035]	-0.070*** [0.022]	-0.003*** [0.001]
150-300 Km Dummy	-0.000 [0.000]	0.000 [0.000]	-0.156*** [0.045]	-0.073*** [0.028]	-0.126*** [0.028]	-0.053*** [0.017]	-0.002*** [0.001]
300-450 Km Dummy	-0.000* [0.000]	0.000 [0.000]	-0.023 [0.032]	-0.012 [0.019]	-0.021 [0.023]	-0.005 [0.010]	0.000 [0.001]
Ctrls (Incl. 63 Education)	Y	Y	Y	Y	Y	Y	Y

Notes: Obs. (subdistricts): Cameroon: 113. Chad: 138. Niger: 119. Nigeria: 83. In addition to the baseline controls, we control for the following variables circa 1963 (expressed as the log of (number of ... / area)): (1)-(3) Cameroon: public junior secondary schools ("colleges publics"), private junior secondary schools ("colleges prives"), public secondary schools ("ecoles normales publiques"), private secondary schools ("ecoles normales privees"), public supplementary schools ("cours complementaires publics"), private supplementary schools ("cours complementaires prives"), technical schools, and senior secondary schools ("lycees") in 1961 (source: Ministere des Finances et du Plan, Republique du Cameroun (1961), *Premier Plan Quinquennal de Developpement Economique et Social*); (4)-(7) Chad: public primary schools, private primary schools, junior secondary schools ("colleges d'enseignement general"), secondary schools ("ecoles normales"), senior secondary schools ("lycees publics"), specialized schools, technical schools, training centers for teachers, and private secondary schools (source: Cabot (1972), *Atlas Pratique du Tchad* - note that 1961 is the earliest source listed and 1968 is the oldest source listed); (8)-(9) Niger: primary schools (due to lack of data for this type of education facilities, we use density defined at a higher spatial level, in particular subdivisions instead of subdistricts), secondary schools ("ecoles normales"), senior secondary schools ("lycees"), supplementary schools ("cours complementaires"), technical schools, and private secondary schools in 1962 (source: Service de la Statistique et de la Mecanographie, Republique du Niger, *Annuaire Statistique 1962*); and (10)-(14) Nigeria: primary schools, secondary schools, technical schools, training centers for teachers, and universities in 1968. Due to lack of data at the subdistrict level, we use densities at the province level instead. For East-Central, we use data at the state level (from 1962) as data at the province level is also not available (sources: Federal Ministry of Education, Nigeria (1969), *Statistics of Education in Nigeria, 1969 Series II, Volume II* and Ministry of Education, Eastern Nigeria (1965), *1962 Annual Report*). We use the following sources for the dependent variables circa 2010: (1)-(3) Cameroon (data available for the year 2024): SDG Data Cameroon Hub. (4)-(7) Chad (data available for the year 2024): (i) Wikipedia. 2021. List of universities of Chad (English and French webpages). (ii) Gouvernement du Chad. 2024. Recensement Scolaire. N'Djamena: Gouvernement du Tchad. (8)-(9) Niger - (data available circa the year 2010): (i) Wikipedia. 2021. List of universities of Niger (English and French webpages). (ii) Republique du Niger. 2021. Ministere de l'enseignement technique et de la formation professionnelle. (iii) *Annuaire Statistique, Annee Scolaire 2021-2022*, Liste des etablissements par region. Niamey: Republique du Niger. (10)-(11) Nigeria (UBEC) (data available for the year 2022): Government of Nigeria (2025), Universal Basic Education Commission (UBEC), Lagos: Government of Nigeria. (12)-(14) Nigeria (GRID) (data available for the year 2020): GRID3 (2024). Nigeria Data. GRID3. Conley SE 100 Km. *** p<0.01, ** p<0.05, * p<0.10, † p<0.15.

Table F.29: Estimation of Trade Costs, Cameroon and Niger, c. 1963

	Dependent Variable: Log of the Price in Location j ($\ln p_{oj}$)			
	(1) OLS	(2) IV	(3) OLS	(4) IV
Panel A: <i>“Cost of Imported Goods” for 48 Cameroonian Cities, 1965</i>				
Travel time (t_{oj} ; hours)	0.089*** (0.005)	0.090*** (0.004)	0.088*** (0.005)	0.090*** (0.003)
Log City Pop. $j, c. 1965$			-0.027*** (0.007)	-0.027*** (0.007)
Observations	48	48	48	48
R-squared	0.815	0.815	0.851	0.850
IV F-statistic		487.7		488.3
Panel B: <i>Price of Imported Petroleum Products in 19 Nigerien Cities, 1962</i>				
Travel time (t_{oj} ; hours)	0.061*** (0.007)	0.058*** (0.008)	0.064*** (0.007)	0.061*** (0.007)
Log City Pop. $j, c. 1962$			0.012 (0.009)	0.011 (0.008)
Observations	228	228	228	228
R-squared	0.899	0.898	0.909	0.908
IV F-statistic		228.5		234.5
Product-Trimester FE	Y	Y	Y	Y

Notes: Panel A: We use data on the cost of imported goods for 48 Cameroonian cities in 1965. Source: Orstom (1965). *Atlas du Cameroun, Planche XVII. Les villes et leurs fonctions*. Orstom. The “imported goods” are described as originating from Douala, Cameroon’s only international port. One caveat is that we do not know how the basket of imported goods varies across cities, i.e. how homogenous our price data is. Panel B: We use data on the price of petroleum products for 19 Nigerien cities in 1962. We know the price of gasoline, oil and diesel fuel in each trimester of 1962. Source: Republique du Niger (1962). *Annuaire Statistique*. Commissariat General au Plan. As a result, we have $3 \times 4 \times 19 = 228$ obs. In this case, gasoline/oil/diesel is reported to originate from the border town of Gaya, close to both Benin and Nigeria. Panels A & B: For each country, we estimate the regression: $\ln p_{ojs} = \alpha_s + \delta t_{oj} + \gamma \ln pop_j + \epsilon_{ojs}$, where o is the origin location, t_{oj} is the road-based travel time (hours) between origin o and destination j , and ϵ_{ojs} is the error term (s is the sector). In some specifications, we also control for the population of city j c. 1963 as market size could influence prices locally (whether due to demand or supply factors). Given potential endogeneity concerns regarding the “placement” of transportation networks, we instrument travel times with the Euclidean distance between the origin and destination locations (assuming it does not impact prices through another channel than travel costs). For Niger, since we consider 3 petroleum products $\times$ 4 trimesters, we include 12 product-trimester FE. Lastly, we consider Conley SE (100 km). With the best specification (2SLS + population control; see col. (4)), δ equals = 0.090*** in Cameroon and 0.061*** in Niger. Using as weights the population of each country c. 1963, we find an average value of 0.08.

Table F.30: Calibration of the Shock: Indirect Inference Approach

Panel A: Rural shock	Niger	Cameroon	Chad	Nigeria
0-150 km Lake Dummy	64.69%	69.71%	45.51%	89.64%
150-300 km Lake Dummy	49.70%	78.76%	46.93%	89.08%
300-450 km Lake Dummy	7.94%	78.37%	46.22%	44.78%
Panel B: Urban shock	Niger	Cameroon	Chad	Nigeria
0-150 km Lake Dummy	6.53%	4.12%	0.00%	0.00%
150-300 km Lake Dummy	9.71%	0.00%	0.00%	0.00%
300-450 km Lake Dummy	7.92%	0.00%	0.53%	16.56%

Notes: This table presents the implied rural and urban productivity shocks that minimize the distance between the reduced-form sectoral coefficients and the corresponding model-implied coefficients. We estimate these shocks by running the same regressions using the simulated data generated by the model with a migration elasticity of 5. The productivity shocks are introduced every decade between 1960 and 1990. The reported values correspond to the solution of the minimization problem in equation 15.