Forest Cover Impacts of Chinese Development Projects in Ecologically Sensitive Areas

Ariel BenYishay, Bradley Parks, Daniel Runfola and Rachel Trichler

Abstract:

Abstract: What are the conservation impacts of Chinese development activities in ecological hotspots? We generate and sub-nationally geo-reference a dataset of official Chinese development activities implemented between 2000 and 2014 in the Tropical Andes, the Great Lakes region of Africa, and the Mekong Delta. We then merge these project data with a long series of high-resolution satellite data in order to evaluate their impacts on forest cover. A difference-in-differences estimation strategy is used to identify changes in tree cover that have resulted from exposure to Chinese-funded infrastructure projects in Cambodia and Tanzania. We find that in Cambodia, these projects slowed forest loss, while Tanzania saw faster rates of forest loss in areas near active projects. However, these average results mask heterogeneous treatment effects across different types of forest governance regimes. In Cambodia, where large tracts of forested land – including concessions and plantations – have been granted to natural resource sector investors and the enforcement of environmental laws and regulations is exceptionally weak, we find that standing forests in plantation areas were negatively impacted by nearby Chinese-funded infrastructure projects. In Tanzania, where there is a minimally viable protected areas network, we find that areas under formal protection experienced little or no deforestation from these Chinese-funded projects. These effects hold even after we account for economic development patterns, as proxied by nighttime lights. We conclude that Chinese-funded infrastructure projects need not lead to widespread environmental damage when nearby ecosystems are appropriately protected, and domestic environmental governance plays a crucial role in shaping forest cover outcomes.

Keywords: Chinese Aid, Environment, Cambodia, Tanzania

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AidData is a research and innovation lab located at the College of William & Mary that seeks to make development finance more transparent, accountable, and effective. Users can track over $40 trillion in funding for development including remittances, foreign direct investment, aid, and most recently US private foundation flows all on a publicly accessible data portal on AidData.org. AidData's work is made possible through funding from and partnerships with USAID, the World Bank, the Asian Development Bank, the African Development Bank, the Islamic Development Bank, the Open Aid Partnership, DFATD, the Hewlett Foundation, the Gates Foundation, Humanity United, and 20+ finance and planning ministries in Asia, Africa, and Latin America.

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Contents

1. Introduction

The impacts of major development projects on the surrounding environment are the focus of a longstanding controversy among scholars and policymakers (Rich 1994; Wade 1997, 2016; Pandey and Wheeler 2001; Kareiva et al 2008; Shandra et al. 2011; Buchanan et al. 2016). Foreign donors and their counterparts in developing countries often claim that the development projects they jointly pursue are designed and implemented in environmentally-sensitive ways that minimize the risks of deforestation and biodiversity loss (World Bank 2002; Ledec et al. 2003; Quintero 2007; Dani et al. 2011; Jincheng et al. 2015). However, conservationists and environmental advocacy groups warn that forests continue to shrink at an alarming rate because of development pressures (Laurance et al. 2015).

Development financing from China adds an important wrinkle to this debate. Western aid agencies and development banks have become significantly more risk averse about bankrolling large infrastructure projects due to their environmental and social risks (Nielson and Tierney 2003; Dollar 2008; Hicks et al. 2008; Buntaine 2016). However, since its adoption of a "Going Out" (走出去) strategy in 2000, China has stepped into the breach and parlayed the challenge of a global infrastructure financing gap into an opportunity to establish itself as a go-to supplier of the "hardware" of economic development – the highways, railroads, dams, bridges, ports, and electricity grids that facilitate domestic and international commerce (Foster et al. 2008; French 2010; Sachs 2010; Mwase and Yang 2012; Greenhill 2013; Mustapha and Greenhill 2016; Soulé-Kohndou 2016; Gutman et al. 2015).

In response, Western donors, environmental activists, journalists, and scholars have raised concerns about the nature, pace, and scale of China's overseas activities and the potential for unintended environmental consequences (Kurlantzick 2006; Bosshard 2007; Kynge 2016). Some have questioned whether China is sufficiently prudent in its design and implementation of large-scale infrastructure projects that are proximate to or even located within protected areas and other areas of high biodiversity importance (Taylor 2007). Others have argued that increased competition in the international development finance market encourages developing country governments to shop their riskiest infrastructure proposals to Chinese donors and lenders to ensure that projects without strong environmental safeguards are green-lit (Bosshard 2008; Van Dijk 2009; Laurance et al. 2015).[1] However, the evidence for these claims remains limited; some Chinese financiers and contractors may in fact

[1] Laurance et al. (2015: R261-R262) cite the example of the German Development Bank (KfW), which "is proposing to pave and upgrade a number of low-grade roads through Cambodia's greatest biodiversity hotspot, the Seima Protection Forest, to service indigenous villages there. [KFW] recognizes the large potential for environmental problems from the road upgrades, such as increased poaching and illegal logging. It has asked conservation scientists working in the area to advise them on potential mitigation measures. Although they are greatly concerned about the project, the scientists see no alternative but to support it, because otherwise they believe that Chinese proponents would do it more cheaply and without environmental mitigation, leading to a greater level of illegal logging and forest encroachment than would occur under a KfW-supported project."

behave in a more environmentally responsible manner than critics allege (Van Vliet et al. 2011; Van Vliet and Magrin 2012a, 2012b; Sanborn and Dammert 2013; Irwin and Gallagher 2013; Jincheng et al. 2015; Farrell 2016).

These debates persist because it has proven difficult to subject the claim that Chinese-funded developments projects cause large-scale environmental damage to rigorous empirical scrutiny (Peh and Eyal 2010; Strange et al. 2013). We make several contributions in this paper. First, we collect and publish a new dataset on the nature and locations of Chinese development projects between 2000 and 2014 in three ecologically sensitive regions, using an innovative methodology that synthesizes structured and unstructured information from official, academic, and media-based sources. Second, we spatially join this dataset with remotely sensed forest cover measures and quasi-experimentally test the extent to which proximity to active Chinese projects has led to changes in forest loss. Our panel framework covers 26,716 initially forested grid cells in Cambodia and Tanzania observed over 1982-2014, allowing us to control for district fixed effects and pre-trends at the individual cell level. Finally, we decompose the observed effects based on the forest governance regimes in surrounding areas to understand how Chinese-funded development projects interact with domestic institutions.

The investments that we study consist mostly of infrastructural activities financed by Chinese public sector institutions (e.g. China Exim Bank, China Development Bank). Prior studies on the impacts of individual types of infrastructural investments arrive at a mixed set of conclusions. On one hand, major infrastructural investments — such as road-building, dam-building, electrification, and natural resource extraction projects — can directly contribute to forest loss. Dams that impound water for urban water supply purposes can flood forested areas in upstream areas (McCully 2001; Singh 2002; Finer et al. 2012). Irrigation dams that divert water to downstream area can intensify the conversion of forested land into land that is suitable for agricultural production (Strobl and Strobl 2011).[2] Hydroelectric dams can affect land cover and vegetation outcomes by altering a river's hydrological cycle and thereby changing the ecology of the floodplain and the spatial distribution of flora and fauna (World Commission on Dams 2000; Grumbine et al. 2012; Benchimol and Peres 2015).[3] These ecological changes can, in turn, alter human settlement patterns and the local geography of economic production — for example, individuals

[2] This type of land conversion can result in the destruction of forested wetlands, which provide a wide range of critical ecosystem services (Stavins and Jaffe 1990). However, the irrigation systems that accompany dams often require land-clearing, they can also increase agricultural productivity which could in turn reduce the incentive for farmers to encroach upon forested areas (Ersado 2005).

[3] Dams generally alter the timing and magnitude of water flow, intensify the frequency of non-natural floods, and increase river and reservoir sedimentation (World Commission on Dams 2000; Magilligan and Nislow 2005; Wang et al. 2005).

and agricultural enterprises may move away from previously fertile areas and towards new (and potentially forested) areas that can now be easily converted into cropland (Stavins and Jaffe 1990).[4]

Like dams, roads can accelerate deforestation by reducing the costs of logging and converting forested land into cropland. Road investments can also facilitate household collection of fuelwood for cooking and heating, and there is some evidence that this relationship is particularly strong when new roads are constructed in or near (previously remote) forested areas (Pfaff 2007; Laurance et al. 2015; Damania et al. 2016).[5] Relatedly, oil, mining, and gas investments can encourage migration (Lucas 1985; Laurance et al. 2009; Corno and De Walque 2012; Wilson 2012), the creation of new human settlements (Babigumira et al. 2014), and economic agglomeration (Shah and Baylis 2015; Fafchamps et al. 2016), which may in turn make it easier for individuals and firms to access and clear previously inaccessible land for agricultural, logging, and energy consumption purposes (Pauli 2006; Hund and Megevand 2013; Weng et al. 2013; Barni et al. 2015).

On the other hand, major infrastructural projects can produce significant development gains (Calderón and Servén 2010a, 2010b; Deininger and Okidi 2003; Khandker et al. 2013, 2014), which can, in turn, lead to ambiguous net impacts on nearby forests.[6] The first-order impacts of such projects on economic activity can set in motion a set of processes that indirectly *reduce* pressure on forests. By way of illustration, consider electrification programs. Such programs can help farmers to more efficiently irrigate through the introduction of electricity-powered sprinkler systems (Assunção et al. 2015). If an increase in agricultural productivity shifts farming away from land-intensive activities (e.g. cattle grazing) and toward capital-intensive activities (e.g. mechanized agriculture), deforestation pressures may decline. Assunção et al. (2015) provide evidence from Brazil that the *net* impacts of electrification on forest cover are in fact positive. Likewise, a number of studies suggest that roads can actually improve reduce forest encroachment pressures by improving local development outcomes (Deininger and Minten 1997; Qiao and Rozelle 1998; Andersen et al. 2002; Deng et al. 2011).

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[4] It is also not unusual for dams to require new roads and electricity transmission lines, which can accelerate deforestation (Barreto et al. 2014; Finer et al. 2012).

[5] Barber et al. (2014) provide evidence that each kilometer of a legal road in the Brazilian Amazon is typically associated with three kilometers of illegal roads.

[6] Studies of the welfare benefits of specific infrastructure investments abound. Roads make it easier for individuals and firms to get products to markets, improve access to public services, increase the expected returns on private investment, and facilitate economic agglomeration processes (Glewwe et al. 2000; Jalan and Ravallion 2002; Kwon 2005; Agénor and Moreno-Dobson 2006; Fan 2008; Fan and Chan-Kang 2008). Mines create employment opportunities, increase income and asset wealth, reduce infant mortality, improve female access to health services, and promote backward linkages to the local economy (Von der Goltz and Barnwal 2014; Aragón and Rud 2013; Fafchamps et al. 2016; Tolonen 2015; Loayza and Rigolini 2016). Dams increase irrigated land for agricultural production and hydroelectricity production, thereby reducing rural poverty in downstream districts (Duflo and Pande 2007). When households have access to reliable electricity, it reduces the time that households spend collecting firewood for cooking and lighting and thus increases employment — in particular, female employment (Winkelman 2011). Electrification also reduces indoor air pollution (Barron and Torero 2014), gives children more time to study at home (Khandker et al. 2014), improves educational outcomes by increasing school attendance (Khandker et al. 2013), and hastens the fertility transition (Potter et al. 2002; Peters and Vance 2011; Grimm et al. 2015).

Whether prior studies on the impacts of infrastructure projects undertaken by traditional donors and domestic governments can be extrapolated to the impacts of Chinese-funded infrastructure projects remains unclear. Many environmental NGOs and conservationists have criticized Chinese development finance institutions for financing and implementing projects with weak environmental safeguards that facilitate legal and illegal logging, agricultural frontier expansion, and human settlements in previously remote or pristine areas (Laurance et al. 2015). It is also possible that even though Chinese-funded infrastructure projects themselves do not induce environmental damage, they may be bundled and geographically clustered with other economic activities that do lead to deforestation (e.g. foreign direct investment activities that seek to extract and export natural resources). Indeed, this may be a unique feature of Chinese development finance: interviews with government and company officials in Tanzania suggest that Chinese development projects are often used strategically by the authorities in Beijing to ease the entry of extractive sector investors into local markets (Li et al. 2013).[7]

At the same time, China Development Bank and China Ex-Im Bank — the two largest sources of Chinese development finance for infrastructure projects overseas — have adopted many of the same environmental safeguards that are used by the major multilateral development banks, including ex ante environmental impact assessments (EIA), project reviews, compliance with host country environmental laws and regulations, and ex-post EIAs (Friends of the Earth 2016).[8]Beyond limiting the potentially negative environmental impacts of infrastructure projects, the environmental safeguards of the CDB and China Ex-IM Bank purportedly encourage Chinese contractors to take measures that *improve* conservation outcomes. These measures typically involve *in-situ* conservation activities that protect flora and fauna in a defined terrestrial or aquatic space, such as the creation of a nature reserves.[9] It is also important to note that many of the Chinese contractors that implement projects for China Exim Bank,

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[7] Li et al. (2013: 310) provides an example from Tanzania, where Chinese aid projects have been used to facilitate the entry of Chinese iron and steel exports into the broader East African market: "to support [a Chinese SOE's] initiative to explore iron and steel opportunities, the Chinese government provided funds for an improvement in the central Tanzanian railway to ensure uninterrupted year-round shipments for [the SOE's] products in Tanzania and its landlocked neighbors of Uganda, Burundi, and Rwanda."

[8] Gallagher (2013: 9) points to the following rationale for that the adoption of these environmental safeguards: "[t]o the extent that local skepticism and protests result in delays or even loss of projects, environment-related political risk can severely affect the bottom line of the major Chinese policy banks." Compagnon and Alejandro (2013) also note that these policy banks understand the success of China's "Going Out" strategy is increasingly dependent on their ability to disabuse critics and important market actors of the notion that they (and their contractors) are not interested in protecting the environment. The Chinese Government has itself been quite explicit about its intentions and its expectations for Chinese firms that are operating overseas; in a 2015 report entitled Report on the Sustainable Development of Chinese Enterprises Overseas, China's State Council (the country's highest policymaking body), the Ministry of Commerce (the country's lead foreign aid agency), and UNDP China offer the following counsel: "Chinese enterprises need to integrate sustainability into every aspect of production and operations. They need to understand that improving sustainability could safeguard their overseas operations…. Regarding the environment, they need to understand and observe related local laws and regulations, and strengthen [environmental impact assessment] in all projects" (Jincheng et al. 2015).

[9] Indeed, in a recent survey of 254 (private and state-owned) Chinese enterprises that operate overseas, Jincheng et al. (2015) find that 67% of Chinese companies in working in the mining and energy sector participate in in-situ conservation systems; 58% of Chinese companies in working in the agriculture, forestry, fishery and animal husbandry sector participate in in-situ conservation systems; and 39% of Chinese companies in working in construction sector participate in in-situ conservation systems. Additionally, Chinese contractors that conduct work on behalf of the CDB and China Ex-IM Bank are also encouraged to engage in *ex-situ* conservation activities to provide special protection for species outside of their natural habitats (Jincheng et al. 2015).

CDB, and MOFCOM also do so for multilateral development banks and bilateral aid agencies, such as the World Bank and the Millennium Challenge Corporation (Office of Inspector General for the Millennium Challenge Corporation 2011; Farrell 2016). Competitive pressures may therefore push these firms to comply with the “gold-plated" environmental standards of these multilateral and bilateral development institutions (Dollar 2016), thereby improving environmental performance on Chinese-funded infrastructure activities.[10] A new study by Farrell (2016: 7) reviews the performance of Chinese and OECD contractors that implement World Bank project and finds that "World Bank [project completion reports] noted environmental and social problems caused by Chinese firms in only two out of the 72 contracts analyzed.”

Of course, Chinese-funded and -implemented activities do not take place in a vacuum but within the context of forest governance regimes instituted by host governments. Prior work points to a relatively clear set of predictions about the ways in which these forest protection regimes mediate the forest cover impacts of large-scale development projects (Brooks et al. 2012; Miller 2015). When domestic environmental regulations are strong, development financiers and their contractors should have incentives to comply with the rules; otherwise, they risk being edged out from the local market for large-scale development projects (van Vliet and Magrin 2012b; Hensengerth 2013). Chinese-financed development projects — the focus of our study —should not be exceptional in this regard. Existing qualitative studies suggest that Chinese contractors with overseas operations usually comply with the legal and regulatory frameworks of their host governments. Wang and Buckley (2016: 5), for example, present survey and interview evidence from private and state-owned Chinese company personnel in Mozambique, Kenya and Uganda, and conclude that "host-country laws and regulations … [stand] out as the most important factor guiding [Chinese] company operations in interviews across all company types and in all three countries."

We therefore expect that prevailing domestic forest governance regimes will condition the impacts that development projects have on forest cover loss. More specifically, in settings where the forest protection regime is strong (such as in protected areas that are local government officials with the resources and authorities necessary to enforce the rules) we expect that development projects will be designed and implemented in ways that minimize deforestation risks (Parrotta 1997; World Commission on Dams 2000;

[10] Buchanan et al. (2016) compare Important Bird and Biodiversity Areas (IBAs) that were exposed to World Bank project activities (between 2000 and 2011) to a matched sample of IBAs that were not exposed to World Bank project activities. They recover evidence that IBAs that were physically proximate to World Bank project activities (<10 km from World Bank project site locations) experience fewer conservation pressures than the matched set of control group IBAs (>100 km from World Bank project site locations). They also demonstrate that World Bank projects within their treatment group are predominantly focused on transport, energy, agriculture, forestry, fishing, and various forms of infrastructure and subjected to significantly more stringent environmental safeguards (i.e. projects that classified as environmental category “A” or “B”) than other World Bank projects. They interpret this subsample analysis as corroborating evidence that introduction and enforcement of World Bank environmental safeguards has facilitated conservation improvements in ecologically sensitive areas (i.e. near IBAs).

Pfaff 2007; Laurance et al. 2015; Damania et al. 2016).[11] Conversely, in settings where large tracts of forested land (e.g. concessions, plantations) are granted to investors or other economic actors to engage in timber extraction, agricultural production, or nonrenewable resource extraction, nearby development projects will likely amplify the deforestation effects of such activities (above and beyond any direct effects that these agricultural and forestry production activities might have on the loss of tree cover).[12]

This paper is organized as follows: In Section II, we describe the study context and the interventions that we will evaluate. Section III describes our data collection efforts. We then describe our empirical methodology in Section IV, and present our results for Cambodia and Tanzania in Sections V and VI, respectively. We provide robustness checks in Section VII and conclude in Section VIII.

2. Study Context

We limit the scope of our study to Cambodia and Tanzania. In both of these countries our data collection efforts (described in detail in Section III) yielded a sufficiently large number of high-precision project locations in the infrastructure sectors. Likewise, in these two countries, there are sufficient numbers of project locations that vary in the timing of their "rollout" to support a difference-in-differences estimation strategy, which relies on variation in the exposure of forested areas to Chinese-funded projects over space (geographical distance) and time (as new project-funded interventions come into effect).

These two country cases shared a common set of characteristics during the period of analysis that made them similarly vulnerable to deforestation pressures. Both countries experienced rapid economic growth and deforestation over this period: average per capita income rose from $300 to $920 in Tanzania (annual growth of 6.5%) and from $300 to $1020 in Cambodia (annual growth of 7.8%). Tanzania's large standing forests covered approximately 26 million hectares in 2000, but fell by 1.7 million hectares over the 15-year period (with the share of total area forested falling from 58.6% to 52.4%). The leading drivers of deforestation during this period of time included population growth, agricultural expansion, commercial logging, charcoal production, and household collection of firewood (Milledge et al. 2007; Burgess et al.

[11] Protected areas generally slow deforestation by strengthening the tenure security of households and constraining access to agricultural land, thereby making it more difficult for the agriculture frontier to advance (Clements and Milner-Gullan 2014; Andam et al. 2008; Shah and Bayliss 2015). Sims (2010) finds that integrated conservation and development projects (ICDPs) are often sited near protected areas, which suggests that more conservation-friendly projects are disproportionately sited in areas where forest protection regimes are stronger. More generally, development projects that follow the so-called "avoid, minimize, mitigate, compensate for, or offset" hierarchy will typically require environmental impact assessments and environmental management plans; the use of environmentally-friendly technologies and biodiversity offsets; the implementation of rehabilitation or offset measures, such as revegetation and reforestation efforts; and sustainable harvesting of forest products when they are sited within or near protected areas (Hund et al. 2013; Buchanan et al. 2016).

[12] Concession and plantation areas are generally areas where deforestation levels are high and local actors are subjected to low levels of regulatory oversight and law enforcement (Forest Trends 2015; Butsic et al. 2015; Davis et al. 2015). Therefore, for those who finance and implement major development projects, it may be easier and less costly to engage in environmentally risk behaviors in these geographical areas (Linkie et al. 2008).

2010; Fisher et al. 2011). Over the same time period, Cambodia lost 1.58 million hectares of its initial 9 million hectares of forest (with the share of land forested falling from 65.4% to 54.3% by 2014).[13] Leading drivers of deforestation in Cambodia during this period of time included land clearance for rubber plantations and cash crops (including sugar, palm oil, cassava), legal and illegal logging, and hydropower development (Clements et al. 2014; Grogan et al. 2015; Forest Trends 2015).

However, these two countries had substantially different forest protection regimes in place during our period of study (2000-2014). There are nearly 800 protected areas in Tanzania, making up approximately 40% of the country's land (Stellmacher et al. 2012; Kideghesho et al. 2013). This network of national parks, game reserves, biosphere reserves, wetlands, community-based forest and wildlife areas, community conservation areas (CCAs), joint forest areas, and game-controlled areas is reasonably effective (Pfeifer et al. 2012; Treue et al. 2014). Since 2004, Tanzanian law has required that all development projects with likely adverse environmental impacts be subjected to environmental impact assessment (EIA). Mwakaje (2013: 121) note that "[t]he mandatory EIA list includes all large-scale development projects and those in ecologically/socially sensitive areas, such as protected areas, wetlands, forests and densely populated areas."[14] However, even before our period of study began, EIAs were "applied routinely to aid-funded development projects" in Tanzania (Mwalyosi et al. 1999: i).

In Cambodia, a 1993 royal decree initially established 23 protected areas. However, a 1999 assessment found Cambodia to have one of the least well-resourced protected areas networks in the entire world (James et al. 1999), and at the beginning of our study period (2000), the Ministry of Environment lacked the legal authority to enforce the country's protected area boundaries (ICEM 2003). A 2008 law subsequently increased the number and diversity of protected areas and granted the Ministry of Environment (MOE) more law enforcement authorities.[15] However, enforcement of gazetted protected areas remained extremely weak even after the passage of this law. In fact, during our period of study, the Cambodian authorities granted a large number of land concessions to timber and agro-industrial companies that were sited *inside* the formal boundaries of protected areas (Forest Trends 2015;

[13] These summary statistics were drawn from the online edition of the World Bank's World Development Indicators (at http://data.worldbank.org/data-catalog/world-development-indicators) on 31 August 2016.
[14] According to a 2012 study, protected area experts in Tanzania consider deforestation to be the single most important environmental issue facing the country and consider "sound land-use planning [to be the] most important ... [determinant of] effective management of [protected areas] in Tanzania" (Stellmacher et al. 2012: 7). Elaborating on this point, the authors of the same study note that from the perspectives of 25 protected areas experts who they interviewed in Tanzania "[sound land-use planning] ... includes balancing conservation and development efforts at national, regional, district and local levels. It also includes the proper and participatory delineation of [protected area] boundaries, development of zoning concepts within [protected areas] and integrated landscape planning around them. Optimal land-use planning [also] reduces spillover effects and conflicts between conservation and development processes, and can increase ecosystem service provisions" (Stellmacher et al. 2012: 7).
[15] There are now 53 protected areas — including national parks, wildlife sanctuaries, protected landscape areas, multi-use protected areas, multi-purpose-use management areas, biosphere reserves, natural heritage sites, marine parks, and Ramsar sites — in Cambodia and roughly 26% of the country's land is formally protected (World Bank 2016).

Clements et al. 2014). In some of these cases, protected areas were formally degazetted to allow investors to engage in commercial activities (Clements et al. 2014). In other cases, no such formal degazetting process took place and concessionaires were simply allowed to engage in commercial activities within protected areas (Forest Trends 2015). Cambodia also has a particularly weak legal and regulatory system in place to minimize and mitigate the negative environmental impacts of development projects (Schulte and Stetser 2014). A 1996 law and 1999 sub-decree both contain some EIA provisions. However, compliance with these official requirements was virtually non-existent during our period of study (Schulte and Stetser 2014). Cambodia's Ministry of Environment indicated in 2012 that "only five percent of major development projects undertake an [EIA]" (Forest Trends 2015: iv). It also noted that "from 1999 to 2003 essentially no [development] projects conducted required EIAs, and from 2004 to 2011 only 110 out of nearly 2,000 [development] projects conducted an EIA" (Schulte and Stetser 2014: 100).

These different protection regimes suggest that the impacts of development projects within these countries may vary based on the nature and effectiveness of the regimes governing nearby forests.

3. Data

3.1 Geographic Unit of Observation

As noted above, we focus our analysis on Cambodia and Tanzania because in both countries a sufficient number of Chinese-funded development project activities were undertaken between 2000 and 2014, and the location and timing of these activities were measured with sufficiently high levels of precision. In each country, we obtain data for the universe of all 5 km square grid cells (the unit observation of the NASA Land Long Term Data Record, which we discuss at greater length below). We then prune these data to only include cells with at least 10% coverage of standing forest in 2000 (prior to the earliest Chinese-funded project in our dataset), using forest status designations from the Hansen et al. (2013) data. This procedure yields an initial dataset of 4,261 forested cells in Cambodia and 22,502 cells in Tanzania, which represents the *universe* of all initially forested cells in our study.

3.2 Outcome Data

Our primary outcome measure reflects the extent of forest loss in each initially forested cell. We use the Hansen et al. (2013) dataset, which characterizes forest cover and loss at a spatial resolution of 30 meters (30m). In addition to limiting our analysis to initially forested cells, we also use the Hansen data to construct an annual outcome measure that captures cumulative forest loss in each 5km square grid cell since 2000. To do this, we aggregate the 30m resolution Hansen data to the 5km resolution level to match the unit of observation in the NASA Land Long Term Data Record (LTDR), which we use to establish trends in vegetation prior to 2000.[16] Thus, while the Hansen data itself contains binary forest status and loss outcomes, our data measure the mean values of the 30m cells nested within each LTDR cell. Our primary outcome measure, $ForestLoss_{it}$, varies from 0 to 1 and reflects the cumulative share of underlying cells experiencing forest loss from 2000 to year t. Higher values thus reflect more extensive deforestation.

We use the LTDR data to establish the pre-treatment deforestation trends in each cell between 1990-1999. Deforestation in the LTDR data is proxied by the Normalized Difference Vegetation Index (NDVI), a measure of the greenness of the composited satellite imagery for the cell. The NDVI ranges from 0 (barren, rocky terrain) to 1 (heavily forested). We construct a linear fit of the 10 year period to produce a pre-trend estimate. As described in the methodology section, we use this estimate to account for potential selection effects in the locations of Chinese-funded project activities relative to preceding deforestation.

3.3 Treatment Data

China does not participate in the international reporting mechanisms that Western governments and multilateral institutions have put in place (the OECD's Creditor Reporting System, the International Aid Transparency Initiative) to track global development finance flows (Xu and Carey 2014; Muchapondwa et al. 2016). In order to overcome this challenge, we use AidData's Tracking Underreported Financial Flows (TUFF) methodology to collect detailed financial, operational, and locational information about Chinese development projects in three ecological hotspots (the lower Mekong Delta, the Great Lakes region of Africa, and the Tropical Andes) from 2000-2014 (Strange et al. 2017). The TUFF methodology provides a set of data collection protocols for standardizing and synthesizing structured and unstructured information from the aid and debt information management systems of developing countries, grant and loan data published by recipient governments, Chinese Ministry of Commerce (MOFCOM) and Chinese embassy websites, case studies undertaken by researchers and non-governmental organizations, and media reports.[17] Our application of this methodology to 19 countries over the period 2000-2014 resulted in a dataset of 1,158 Chinese development projects (collectively worth $161 billion).[18]

[16] http://ltdr.nascom.nasa.gov/cgi-bin/ltdr/ltdrPage.cgi

17 Prior to this study, the TUFF methodology had been codified, peer-reviewed, and successfully employed to identify 2,647 Chinese development projects in 50 recipient countries in Africa over the 2000-2013 period (Dreher et al. 2015; Strange et al. 2017). Data generated through the application of the TUFF methodology have also been widely used in the economics and political science literatures (Hendrix and Noland 2014; Dreher et al. 2015; Dreher et al 2016; Dreher and Fuchs 2015; Hsiang and Sekar 2016; Kilama 2016; Isaksson and Kotsadam 2016; Strange et al. 2017). Muchapondwa et al. (2016) used a "ground-truthing" methodology in Uganda and South Africa to test the reliability of the TUFF methodology and found a generally high level of correspondence

We then geocode all of these projects with a double-blind coding methodology (Strandow et al. 2011), whereby two trained experts independently employ a defined hierarchy of geographic terms and independently assign uniform latitude and longitude coordinates and standardized place names to each geographic feature. These two code rounds are checked against each other. If the two sets of geographic codes are identical, they become the "master" geocodes. In cases when the two independent rounds of geocoding do not result in a perfect match, projects are subjected to a third "arbitration round" where a senior researcher identifies the underlying source of the discrepancy or discrepancies and assigns a master set of geocodes for all of the locations described in the project documentation. This process is designed to minimize the risk of missed or incorrect locations. Coders also specify a precision code for each geocoded project that varied from 1 (exact point) to 9 (national-level project or program). The application of this methodology resulted in the identification of 2,224 Chinese-funded project sites across 19 countries in the Tropical Andes, the Great Lakes region of Africa, and the Mekong Delta over the 2000-2014 period. However, in addition to limiting the scope of our analysis to Cambodia and Tanzania, we include only “high-precision” (projects with precision codes 1 and 2) in our analysis. These are projects with latitude and longitude coordinates within 25 km of the exact intervention sites. We exclude all suspended and cancelled programs as well as projects that reached the (non-binding) pledge stage. We include projects that reached the official commitment, implementation, or completion stage during the period of analysis (2000-2014).[19]

In both countries, we focus our main analysis on infrastructure projects – specifically, those in the Communications, Energy Generation and Supply, Transport and Storage, and Industry, Mining, and Construction sectors.[20] Chinese-funded infrastructure activities in Cambodia consisted of 20 unique projects in 36 project locations. All but two of these projects focused on building roads and bridges; the other two focused on hydropower dam construction and the installation of a fiber-optic cable network. In Tanzania, we identified 16 Chinese-funded infrastructure projects in 53 project locations. These projects support seaport and airport construction, railway rehabilitation, ICT infrastructure, and the construction of a natural gas pipeline. In Tanzania, a sufficient number of geographically precise social sector projects also exist to support a secondary analysis of Chinese-funded development projects in the following sector: Health, Education, and Population Policies/Programs and Reproductive Health. We identified 29

between the Chinese development project data collected through the TUFF methodology and Chinese development project data collected through the systematic application of field-based data collection protocols by local enumerators.

18 We limit the scope of our data collection efforts to Chinese official development assistance (ODA) activities and other official flows. We excluded Chinese military aid and Chinese outward foreign direct investment activities (with or without state involvement).

19 As a robustness check, we also generate models results with a narrower definition of treatment that only includes completed projects and projects that reached the implementation stage.

20 Here we rely upon the sector coding scheme employed in AidData’s TUFF methodology, which is based on the OECD’s three-digit sector classification scheme.

unique projects in 49 project locations. Most of these projects constructed or provided assistance to universities, primary schools, hospitals, and other medical facilities.

Our empirical methodology (described in greater detail below) relies on variation in each forested cell's exposure to Chinese-funded projects. We make use of continuous exposure measures to understand the impacts along the intensive margin rather than relying on purely dichotomous differences. Each 5km forest cell varies in proximity to project locations over space (geographical distance) and over time (as new project sites come into existence). We combine the geographic and temporal variation into a continuous treatment measure of treatment exposure: we construct a weighted sum of proximity to active project locations, where proximity is the inverse of the distance to a project site. The treatment measure for cell *i* in year *t* is thus:

$$(1)\quad Treatment_{it} = \sum_{j=1}^{J} \frac{1}{w(d_{ij})} D_{jt}$$

where d_{ij} is the distance between cell *i* and Chinese activity site *j*, and D_{jt} indicates whether activity site *j* is active in year *t*. Because the effect of treatment is likely non-linear in the proximity to a project site, we weight the distance ($w(d_{ij})$) with historical data on the spatial correlation in forest status, using a Moran's I statistic in forest status in the year 2000 using the LTDR data.

While it is tempting to consider locations very far from any Chinese project sites as a comparison group, we expect selection effects in such a comparison to be quite pronounced, even with the suite of controls we implement. For example, these locations are more likely to occur in different regions/provinces than our treated sites, and thus to be more prone to other unobservables that even location-specific fixed effects may not sufficiently address. We therefore limit our sample to only locations within a maximum distance of any project site, and define this threshold by examining the baseline spatial correlation. We do so by estimating a Moran's I statistic over our cell frame and identifying the distance at which the statistic equals zero. This procedure established a threshold of 121 km in Cambodia and 410 km in Tanzania. We therefore define treatment for each cell based on the status of all active Chinese project sites within this distance threshold, and excluded any forested cells that did not include a Chinese project location within the established threshold. In Cambodia, the dataset includes 4,214 forested cells that we observe for each of the 14 years in our study period, providing 58,996 total cell-year observations. In Tanzania, the dataset includes 22,502 unique cells in sufficient proximity to a Chinese-funded infrastructure project, yielding 315,028 total cell-year observations. There are 21,451 unique cells in sufficient proximity to a Chinese-funded social sector project and 300,314 total cell-year observations.

We thus make comparisons between a subset of more proximate cells that experience at least some potential influence from nearby Chinese projects based on the timing of and their distance to these sites.

Of course, there may be a variety of unobserved features that differ across the timing and distance dimensions. To address selection effects across distance, we implement a time-invariant control that reflects the maximum value of treatment ever received by the cell ($ProximityControl_i$). This captures factors that make the cell more likely to eventually have an active Chinese project site nearby. In subsequent specifications, we also include cell fixed effects which subsume this control and other time-invariant unobservables.

3.4 Forest Governance Data

To capture the forest governance regime in each cell, we use geospatial data from several sources, each reflecting the boundaries of polygons in force in a given year. One such regime is the designation of a Protected Area (PA). We use shapefiles from the World Database of Protected Areas and dates of establishment to identify the share of each cell that falls within the boundaries of an active PA at baseline.[21] We recognize that PA designation does not imply perfect compliance with or enforcement of the forest protection regime, and thus consider our estimates of the effects of the share of the cell within an active PA to be likely lower bounds (on the magnitude) of any effects that we detect. Because preceding deforestation (potentially linked to Chinese project activities) may lead to smaller boundaries for PAs, we construct the baseline extent of PA coverage ($ProtectedArea_i$) for each cell based on the earliest year of Chinese project activity in each country.

Whereas we expect that the establishment of a PA may slow the pace of deforestation, we expect concessions and plantations to have negative or ambiguous effects. For this purpose, we use the boundaries and dates of establishment of concessions issued by the government of Cambodia from Open Development Cambodia.[22] We similarly construct the baseline share of each cell covered by a concession ($Concessions_i$). Concessions data were not available for Tanzania.

For plantations, we obtain data on their geographic extent in Cambodia from Global Forest Watch, reflecting the existing plantations from 2013-2014.[23] Unfortunately, dates of establishment for plantations in our study contexts are not available for many plantations. We therefore use the share of each cell falling within a plantation ($Plantation_i$), recognizing that this measure may be subject to unobserved time-varying selection into plantation status on the basis of characteristics correlated with both proximity to active Chinese sites and forest loss. Plantation data were not available for Tanzania.

21 http://www.protectedplanet.net/
22 https://opendevelopmentcambodia.net/profiles/economic-land-concessions/
23 http://data.globalforestwatch.org/datasets

3.5 Covariate Data

We employ a host of spatial covariates, many of which vary over time, that are known to influence forest cover change (Andam et al. 2008; Joppa and Pfaff 2009; Nelson and Chomitz 2011; BenYishay et al. 2016). Our time-varying covariates include climatic conditions from the University of Delaware (annual maximum, mean, and minimum values of monthly temperature and precipitation)[24], population density from the Gridded Population of the World dataset produced by CIESIN at Columbia University[25], and, in some specifications, nighttime lights from the Defense Meteorological Satellite Program (DMSP) dataset produced by NOAA.[26] Time-invariant characteristics that are available at the cell level include slope and elevation from the NASA Shuttle Radar Topography Mission (SRTM)[27] and urban travel times (a proxy for access to markets) from the European Commission Joint Research Centre.[28] Table Table 2 provides summary statistics for Cambodia and TablesTable 6Table 9 provide summary statistics for these covariates in Tanzania.

4. Empirical Methodology

The most likely source of potential bias in estimating the effects of Chinese projects on nearby forests is the selection of these project sites near areas that had already experienced deforestation or that would have experienced deforestation even in the absence of the Chinese projects. By way of illustration, Figures 1 and 2 show forest loss and Chinese infrastructure activity locations in southeastern Tanzania in both 2005 (prior to any Chinese infrastructure activities) and 2014. The blue Chinese project sites that appear in Figure 2 are co-located with areas that experience forest loss, and in the case of the southeastern tip of Tanzania, with areas already experiencing deforestation prior to Chinese-funded activities. A cross-sectional model examining change in forest cover between 2001 and 2014 would thus detect only this positive correlation between deforestation and a cell's proximity to Chinese infrastructure project sites.

To address these sources of bias, we control for important cell-specific features, including pre-treatment deforestation trends and time-varying climatic conditions that help account for contemporaneous forest loss. Additionally, by controlling for the maximum treatment value of the cell, we account for cross-cell selection into proximity to a Chinese project site. We thus causally identify the effects of Chinese projects on nearby forests using only the spatio-temporal variation in these activities.

24 http://climate.geog.udel.edu/~climate/
25http://sedac.ciesin.columbia.edu/data/collection/gpw-v4
26 http://ngdc.noaa.gov/eog/dmsp.html
27 http://www2.jpl.nasa.gov/srtm/
28 http://forobs.jrc.ec.europa.eu/products/gam/download.php

In a panel model framework, we estimate the following specification for each country:

(2) $$ForestLoss_{it} = \alpha + \beta Treatment_{it} + \gamma ProximityControl_i + \mu NDVI_{i,2000} + \varphi NDVIPreTrend_i + X_i\Lambda + Z_{it}\Omega + D_r + D_t + \epsilon_{it}$$

where $NDVI_{i,2000}$ reflects the baseline greenness of the cell in 2000, $NDVIPreTrend_i$ reflects the linear fit of greenness changes between 1982-1999, X_i includes time-invariant covariates, Z_{it} includes time-varying covariates, D_r captures district-specific fixed effects, and D_t captures year-specific fixed effects. We estimate this specification using OLS and cluster standard errors by both district and year to capture cell-specific and year-specific correlations.

As discussed in the prior section, our $ProximityControl_i$ measure accounts for unobserved time-invariant features correlated with the location's distance to projects that eventually become active. To capture selection effects reflecting preceding dynamics, we include the baseline measure of NDVI and the pre-trend of NDVI. Rather than simply showing that these levels and pre-trends are parallel across proximity to Chinese sites, we proceed directly to including them as controls in our primary specification.

Because we seek to understand the role of forest governance in shaping the impacts of Chinese projects on their surrounding environment, we also estimate models in which we interact our treatment measure with the forest governance regime measures in the cell. That is, we estimate:

(3) $$ForestLoss_{it} = \alpha + \beta Treatment_{it} + \theta Concession_i + \chi Plantation_i + \omega ProtectedArea_i + \delta Treatment_{it} * Concession_i + \pi Treatment_{it} * Plantation_i + \rho Treatment_{it} * ProtectedArea_i + \cdots \quad (3)$$

With the remaining covariates and fixed effects as in Eq. 2.

5. Results: Cambodia

Table 3 presents results for Cambodia. In Column 1, we show the (unconditional) correlation of our treatment measure with forest loss, with no covariates or fixed effects. Proximity to active Chinese project sites is strongly and positively correlated with forest loss. This pattern is consistent with the conventional wisdom that Chinese-funded infrastructure projects bring deforestation, but at the same time it highlights the need for careful estimation of a credible counterfactual: are these losses indeed caused by these projects, are they drivers rather than outcomes of the projects' locations, or are they both driven by some third (or more) set of unobserved factors?

In Column 2, we add our control for the maximal proximity to Chinese project sites ever experienced by each cell. We find that the main treatment variable of interest continues to be positively correlated with forest loss. In Column 3, we further add controls for NDVI at baseline and pre-trends, time-invariant topology, time-varying climatic conditions and population density, and district fixed effects. We continue to find that proximity to Chinese project sites is highly correlated with forest loss.

Importantly, in Column 4, we control for year fixed effects. This control reverses the observed relationship between proximity to Chinese project sites and forest loss. In this, our most rigorous specification, proximity to Chinese project sites actually *reduces* the extent of forest loss in nearby cells. A one standard deviation increase in proximity to active Chinese project sites (0.305) reduces the share of a cell that experienced forest loss by 0.81 percentage points (equal to 15.8% of the mean loss of 5.17 percentage points). It is clear that both Chinese project sites and forest loss are increasing over time over our study time period, thus creating a spurious correlation between these factors absent sufficient time controls in a panel framework. Casual observations about relationship between Chinese-funded infrastructure projects and deforestation that do not account for both changes over time and cross-sectional selection are therefore directly opposite from the true causal relationship.[29]

Are the effects of Chinese project activities shaped by the forest governance regime in which they take place? In Column 5, we estimate Equation 3 using our Cambodia data. The shares of the cell covered by protected areas, concessions, and plantations are all positively correlated with forest loss. This effect is particularly notable for PAs, which are generally intended to *reduce* forest loss. However, as we noted in the study context section of this paper, Cambodia's protected areas are severely under-funded and weakly enforced (Clements et al. 2014; Schulte and Stetser 2014; Forest Trends 2015).

Proximity to active Chinese project sites continues to reduce forest loss in most settings, but in cells covered by plantations, proximity increases forest loss. This pattern is consistent with the notion that intensive forest extraction in plantations is being accelerated by Chinese project activities, which could be the case if these activities increase demand for timber, reduce the costs of extracting timber and other forest products, or are subject to lower levels of environmental regulation and enforcement.

Forest protection regimes may also be correlated with population density and economic activity, as governments may find it easier to create and enforce protected areas in lower-pressure areas where

[29] Many observers have pointed to high levels of deforestation around Chinese-funded projects in Cambodia, and some have interpreted this apparent correlation as evidence that Chinese-funded projects are accelerating deforestation (e.g. Heng 2012; Ciorciari 2015; Milne 2015).

population density is low (Leader-Williams and Harrison 1990).[30] However, Andam et al. (2008) provides evidence that population density is *positively* correlated with forest protection, and there are some reasons to believe that the deforestation impacts of major development projects could be lower in more populated areas.[31] We therefore control for both the level of population density and its interaction with treatment in Column 5. We find no effects of population density on forest cover, either directly or as a factor mediating treatment.

Finally, we consider whether the improvements in forest cover due to treatment in non-plantations and the reductions in plantations are mediated by the impacts of Chinese-funded infrastructure projects on economic growth (Dreher et al. 2016).[32] To do so, we control for the contemporaneous measure of annual mean nighttime lights in the pixel, as nighttime lights have been shown to correlate with growth across a variety of contexts (Chen and Nordhaus 2011; Henderson et al. 2012; Hodler and Raschky 2014; Michalopoulos and Papaioannou 2014).[33] The results, shown in Column 6, indicate that nighttime lights are strongly and positively correlated with forest loss. Controlling for luminosity diminishes the treatment effects of proximity to active Chinese project activities by 21%.[34] Similarly, the treatment effect among cells with plantations is 19% smaller when controlling for nighttime lights. These are relatively small differences in the magnitudes of the treatment effects, suggesting that the effects of Chinese-funded infrastructure project activities on nearby forests are largely not mediated by these activities' impacts on economic growth.

30 Protected areas are, in fact, disproportionately sited in more remote areas (Joppa and Pfaff 2009).
31 One reason why this might be the case is that demand for ecosystem services may be higher in more populated areas and create popular support and pressure for some level of forest protection (Li et al. 2013). A related reason is that land-use planning — for example, zoning that allows for mixed-use areas rather than strict protection that disallows any extractive activity — is more common in areas of higher population density (Nelson and Chomitz 2009). Indeed, Nelson and Chomitz (2011), Pfaff et al. (2014) and Blackman (2015) provide evidence that so-called "mixed-use," "multiple-use," and "sustainable use" forest protection regimes — that do not strictly prohibit extractive activities — are more effective at reducing forest loss than "strict use" forest protection regimes. This is probably the case because hybrid forest governance regimes and land-use planning activities seek to reconcile conservation and development objectives and tend to be more acceptable to local populations and more politically feasible (Nelson and Chomitz 2009). There may also be fewer opportunities for new land clearing in already populated areas (Dasgupta et al. 2014). Additionally, it is possible that in populated areas, people diversify diversify into economic sectors other than agriculture, which tends to be land-intensive (Lewis 1954; Harris and Todaro 1970; Henderson 2005).
32 Dreher et al. (2016) also use georeferenced data on Chinese development projects and nighttime light data (as a proxy for subnational economic activity) to test whether Chinese grants and loans are improving local economic development outcomes in Africa. They find that a 10% increase in Chinese development finance corresponds to a 0.6-1.1% increase in per capita nighttime light output, or a 0.2-0.3% rise in regional GDP.
33 Kiyoyasu and Keola (forthcoming) that nighttime light is a substantially better measure of subnational economic development in Cambodia than official statistics because of the scale of Cambodia's shadow economy. They report that approximately two-thirds of employment in Cambodia is informal and 96% of Cambodian firms exist in the shadow economy.
34 The coefficient on treatment falls in magnitude from -2.95 to -2.32 across Columns 5 and 6.

6. Results: Tanzania

We next turn to an evaluation of the impacts of Chinese-funded infrastructure activities on forest cover outcomes in Tanzania. We find effects that are quite distinct from those in Cambodia when we examine the average treatment effects across all forest governance types, but that reconcile once we account for variation in forest governance regimes. In Columns 1-3 of Table 7, we again find that our treatment measure correlates with forest loss, whether considered unconditionally (Column 1), with our proximity control (Column 2), or a broader set of covariates and district fixed effects (Column 3). Even after we properly account for time variation by including year fixed effects in Column 4, we find that proximity to active Chinese project sites increases the likelihood of forest loss across all Tanzanian cells. This is the opposite effect that we detected in our full set of Cambodian cells, in which proximity to Chinese-funded infrastructure projects slowed forest loss.

These average results mask disparate effects across different types of forest governance regimes. In Tanzania, the only observed differences in forest governance in our data are the shares of the cells in protected areas. In Column 5, we interact this measure with our main treatment and find heterogeneous effects. In cells not covered by any protected areas, proximity to Chinese project sites increases forest loss: a one standard deviation increase in proximity raises forest loss by 0.78 percentage points, which represents a significant increase of 50% relative to the mean loss of 1.58 percentage points. However, these effects are mitigated in protected areas: cells entirely covered by protected areas see treatment effects that are 92% smaller (the main coefficient on treatment of 1.17 is dampened by the coefficient on the interaction term of -1.08). Effects of proximity to Chinese project sites thus diminish in cases when larger proportions of cells are inside protected areas, and in fully protected cells are small and not statistically different from zero. In summary, Chinese-funded infrastructure projects accelerate forest loss in non-protected areas, but forest protection regimes limit these losses. These conditional treatment effects contrast significantly with the conditional effects of Chinese-funded infrastructure projects in Cambodia's protected areas, which is consistent with the cross-country forest governance differences that we describe in the study context section of this paper.

As in Cambodia, we do not find in Tanzania that the effects of these Chinese-funded infrastructure projects on forest loss are mediated by their effects on economic growth, as captured by nighttime lights. In Column 6 of Table 7, we add the contemporaneous annual mean of nighttime lights as a control, finding treatment effects that are nearly identical to those without this control (for both protected and unprotected cells). In fact, the correlation of nighttime lights and forest loss is negative in this sample, indicating that less forest loss is occurring in locations that are newly lit or experiencing luminosity gains than in those that remain stable. We interpret these results as indicating that it is the construction and operation of the infrastructure itself that directly leads to forest losses, rather than the subsequent changes in broader economic activities.

Our data on Chinese development projects in Tanzania also capture a broader set of activities focused on social sectors rather than infrastructure. We use these data to construct an alternative measure of treatment that reflects proximity to these projects rather than to infrastructure projects.[35] Social sector projects on their own are unlikely to directly create large-scale forest loss: when these types of activities involve construction and operation, they are typically undertaken at a smaller scale and can often be done without clearing large existing stands of trees. However, service delivery units, like schools and hospitals, tend to accompany urbanization, economic agglomeration, and deforestation processes (Jedwab 2013; Kazianga et al. 2014). Another reason why social sector projects might negatively impact forests is that they may be bundled with natural resource sector activities as part of a negotiation tactic by Chinese government agencies and firms.[36] As such, it is possible that any social sector project "effects" that we identify may in fact reflect the land cover impacts of a broader bundle of development and investment activities.

In Table 10, we present results repeating the estimations in Table 7 but with this separate treatment measure.[37] Interestingly, we find treatment effects that are quite similar to those observed for infrastructure projects. Proximity to social sector projects is positively correlated with forest loss in both unconditional and conditional contexts (Columns 1-3). After we account for time variation with year fixed effects (Column 4), we still find that these projects lead to increased forest loss, and that these effects are slightly larger than those due to infrastructure projects. In Column 5, we interact the treatment measure with protected area status at baseline. In cells without any protected area coverage, we find evidence of increased forest loss due to proximity to Chinese-funded social sector projects, and at a similar magnitude observed for infrastructure projects. However, cells entirely covered by protected areas experience no increase in forest loss, and even a small decrease, due to proximity to social sector activities. Finally, the addition of nighttime lights as a control (Column 6) does not alter these effects.

35 Again, these social sector projects in Tanzania consist mostly of assistance for hospitals, medical center, universities, and primary schools.

36 Drawing upon interviews with government and company officials in Tanzania, Li et al. (2013) argue that this is a unique feature of Chinese aid: Chinese investment projects and development projects are often delivered as part of a "package deal" and geographically clustered to ensure that the local communities hosting Chinese investors also benefit from Chinese development projects. Elaborating on this point, they note that "[t]o obtain [foreign direct investment] deals in the natural resource sector, the Chinese government normally offers a package of multiple-purpose [development] projects in various sectors (e.g., infrastructure, agriculture, manufacturing, healthcare, and education) together with loans to develop these projects. The commitment to [development] projects in different sectors in exchange for investment opportunities in the natural resource sector is a unique approach adopted by the Chinese government. [Some of our interviewees] called this a 'holistic' approach that can lead to opportunities for Chinese firms from diverse sectors. [Another interviewee] considered it 'the best way for China to sell its win-win strategy to work with rural communities where Chinese natural resource firms operate'" (Li et al. 2013: 306-307).

37 The cells used in this analysis are different from those in Table 7 as we limit our frame to only cells that are ever within 410 km of a *social sector* project.

7. Robustness Checks

We conduct a number of robustness checks to confirm that our results are not driven by specifications or parameter values in our data construction. We do so separately for our Cambodia results (Table 4) and Tanzania results (Table 11).

We first consider whether our results are artifacts of our limiting of the cells based on a threshold distance to a project site, where the threshold was estimated based on a measure of spatial autocorrelation in pre-intervention data. We return to the full set of all cells with standing forests in 2000 and limit this set to only cells that are ever within 100km of a project site. Column 1 of Table 4 shows the results for our main estimation on this subset in Cambodia, which are slightly larger in magnitude and now significant at the 5% confidence level. Likewise, when we re-estimate our main specification in Tanzania on a similarly selected set (Column 1 of Table 11), we find treatment effects that are slightly larger and also significant at the 1% level. We then repeat this exercise but limit the threshold to 25 km within a project site for Cambodia in Column 2 of Table 4 (Cambodia's baseline threshold is 121 km, so the 100 km alternative is not substantially different). We find treatment effects that are somewhat smaller on average, while the impacts in cells with plantations remain quite stable. Impacts in cells with protected areas are now statistically significant and negative, indicating that this protection regime further slows the forest loss due to Chinese activities (as it does in our Tanzania data).

We also assess whether our distance-based weighted measure of proximity drives our main results. We employ an alternative measure of treatment: a count of active projects within 100km of the cell in the observation year. Column 3 of Table 4 shows that our average treatment effects in Cambodia are dramatically smaller when using this measure, but that the interaction with plantations continues to show higher forest loss due to Chinese activities near cells covered by plantations. The dampened treatment effects can be explained by the much coarser measure of treatment intensity that equally weights the effects of all projects (i.e., project sites within 5km are similarly counted as those that are 95km away from the cell). When using this alternative measure in our Tanzania data (Column 2 Table 11), we find treatment effects that are roughly one half the size of those using our main measure but that remain statistically different from zero at the 1% level.

We also consider a more strict definition of Chinese activities. In our main models, we include locations for committed, implemented, or completed Chinese projects when we measure our proximity treatment. As a robustness check, we exclude committed projects and limit our sample to only Chinese activities in implementation or completed. While this distinction did not change the number of project locations in Cambodia, the number of infrastructure project locations fell from 53 to 42 in Tanzania. Column 3 of Table

11 shows that the treatment coefficient increases by about 30% (1.662 in Column 3 of Table 11 compared to 1.171 in Column 5 of Table 7) and that we observe a similar dampening of the treatment effect for cells that are covered by protected areas.

Finally, we assess whether our results are driven by our threshold for the share of the cell covered by standing forest in 2000. Recall that forest status for each of our 5km cells is an aggregate of the indicator for standing forest defined by Hansen et al (2013) over each of the underlying 30m cells. Our baseline threshold for inclusion is 10% of the 30m cells indicating standing forest. We vary this threshold to 5% and 15% in Cambodia (Columns 4 and 5 of Table 4), finding that the magnitude of the treatment effects increases in the threshold but remains statistically significant at the 5% level over these alternative thresholds. A similar exercise raising the threshold to 15% in the Tanzania data (Column 4 of Table 11) shows quite similar treatment effects to those under our baseline threshold.

8. Conclusions

Despite the fact that infrastructural investments can deliver a wide range of economic and social benefits to developing countries, there is a large gap between demand and supply in the infrastructure finance market (Fay et al. 2011; OECD 2012). China has emerged as one of few donors and lenders that are willing and able to address these unmet needs, but it has also provoked controversy about the potential environmental consequences of its overseas activities.

To our knowledge, there is no systematic evidence that confronts the causal claim that Chinese-funded development projects have negative environmental impacts. We have attempted to bridge this evidence gap by collecting detailed data on Chinese development projects carried out in three, large ecologically sensitive regions, geo-referencing these activities, and spatially joining them to satellite-based forest cover data and a battery of covariates. Accounting for site selection using both geographic and temporal variation in proximity to active Chinese sites, we rigorously identify the impacts of these projects on the nearby environment. We find that these impacts crucially depend on the forest protection regime: in some cases, Chinese projects actually slow loss in nearby forests, but these effects reverse when the forests are targeted for extraction via plantations. Similarly, in Tanzania, Chinese projects lead to faster losses in unprotected areas, but these losses are effectively mitigated in protected areas. We conclude that China's development activities need not lead to widespread environmental damage when nearby ecosystems are appropriately protected, but domestic environmental governance plays a crucial role in shaping these outcomes.

An important consideration is whether impacts on forests (and the environment, more generally) are correlated with welfare gains or losses to nearby human populations.[38] Our goal in the present paper is not to explicitly estimate the welfare impacts of China's development efforts on these populations; the diverse channels for these impacts offer rich opportunities for future research. However, we do find that these activities' impacts on forests are largely orthogonal to broad economic growth patterns, as proxied by nighttime lights. We consider this good news: welfare gains to human populations (if they exist) need not be traded off against damages to the nearby environment in these contexts.

Finally, there is extensive variation in the types, timing, and spatial distribution of the project portfolio we study. These data offer fertile ground for future studies of both project siting and impacts in targeted subsamples of the data. Its public availability via aiddata.org and china.aiddata.org is meant to spur such research.

[38] In particular, we need to better understand why the unconditional, average treatment effects that we observe in Cambodia and Tanzania cut in opposite directions. As we noted at the beginning of this study, there reasons to believe that infrastructure projects can lead to net negative or net positive impacts on forest cover. However, more research is needed to understand the disparate treatment effects that are observed across countries. One possible explanation is that differences in country conditions or treatment types lead to different impacts on *development* outcomes, which in turn result in different effects on forest cover outcomes. But this is only one of several potential explanations.

Tables and Figures

Figure 1. Southeast Tanzania, 2005

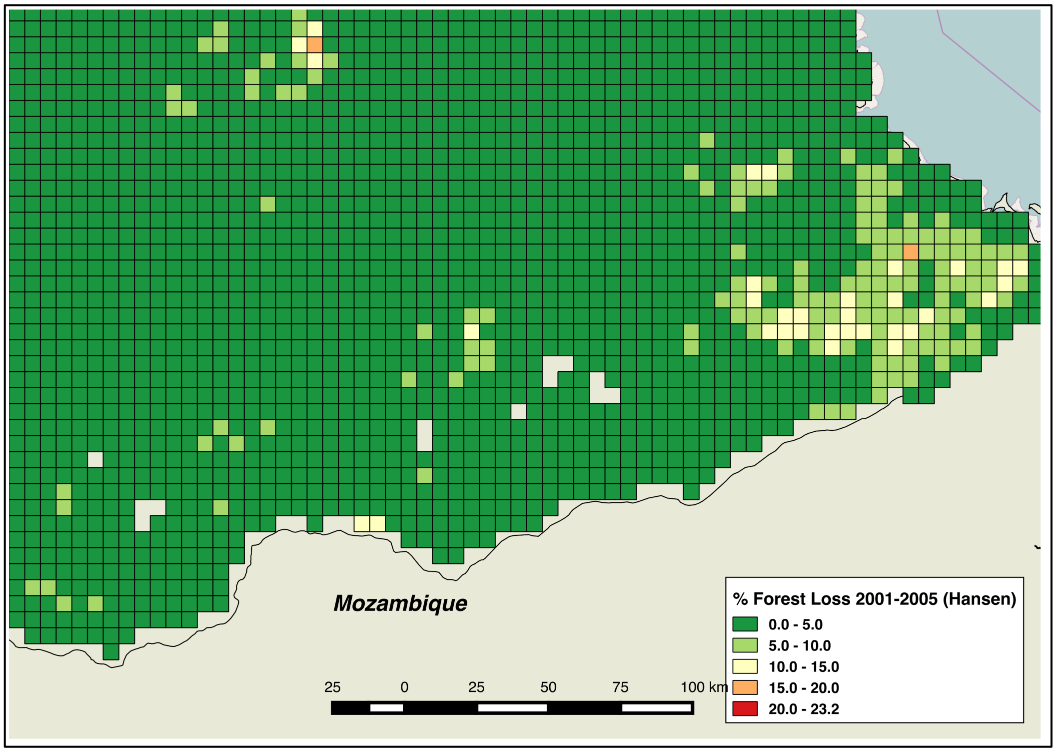

Figure 2. Southeast Tanzania, 2014

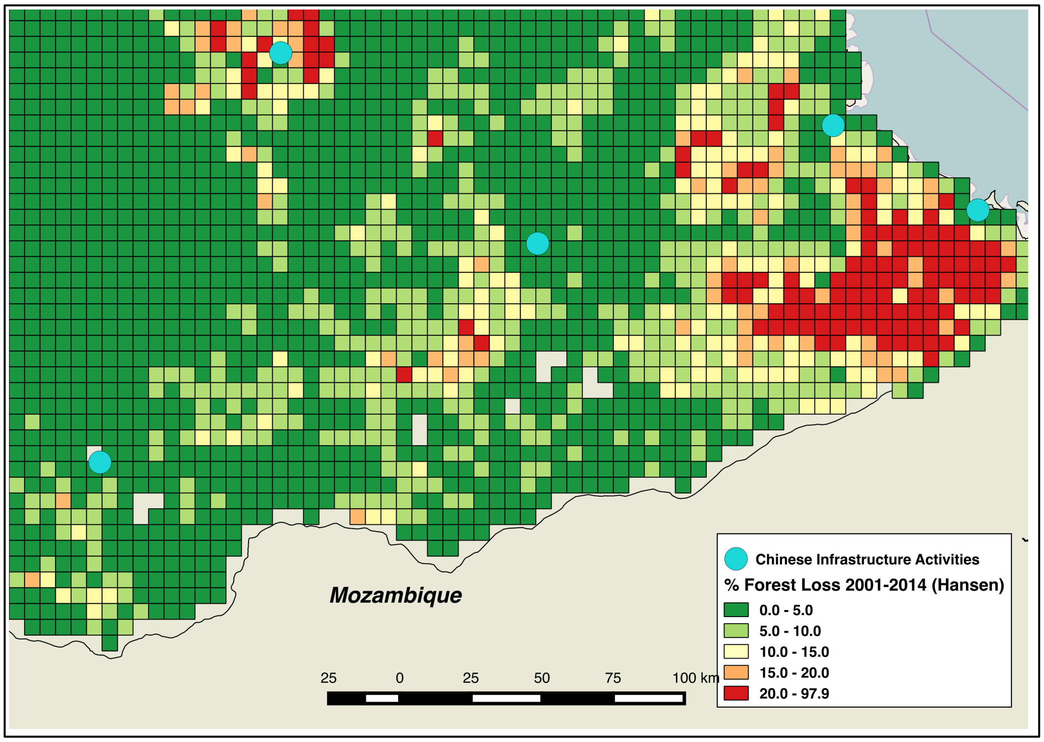

Table 1. Cambodia Treatment Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Proximity	58,996	0.221	0.305	0.000	0.000	0.095	0.347	3.455
Proximity Control	58,996	0.495	0.359	0.000	0.233	0.421	0.704	3.455
Cumulative Forest Loss	58,996	5.168	11.658	0.000	0.080	0.740	4.070	97.850
Proximity, 100km	57,736	0.215	0.301	0.000	0.000	0.094	0.329	3.455
Proximity Control, 100km	57,736	0.482	0.359	0.038	0.209	0.409	0.689	3.455
Proximity, 25km	10,612	0.216	0.292	0.000	0.000	0.000	0.280	2.229
Proximity Control, 25km	10,612	0.479	0.330	0.243	0.243	0.371	0.559	2.229
Project Count, 100km	57,736	1.773	2.256	0	0	1	3	15

Table 2. Cambodia Covariate Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Elevation (m)	58,996	169.971	193.213	0.502	1,313.829
Slope (degree)	58,996	1.840	2.422	0.043	17.241
Urban Travel Time (min)	58,996	475.619	291.466	18.452	1,828.021
Min Temp (C)	58,996	19.924	1.745	16.042	25.832
Max Temp (C)	58,996	25.901	1.235	22.931	30.474
Mean Temp (C)	58,996	23.595	1.286	20.672	27.720
Min Precip (mm)	58,996	15.570	5.675	2.099	41.265
Max Precip (mm)	58,996	373.021	151.645	143.363	1,544.195
Mean Precip (mm)	58,996	144.033	41.342	66.213	409.147
Baseline NDVI	58,996	7,260.244	539.922	2,751.876	8,964.484
NDVI Pre-Trend	58,996	8.268	38.797	-311.492	248.005
Population Density	58,996	27.781	53.051	0.197	847.303
Baseline Protected Area	58,996	0.314	0.426	0.000	1.000
Baseline Concession	58,996	0.040	0.171	0.000	1.000
Plantation	58,996	0.064	0.183	0.000	1.000
Nighttime Lights Pre-Trend	58,996	0.002	0.028	-0.258	0.971
Nighttime Lights	58,996	0.130	0.807	0.000	23.363

Table 3. Cambodia Infrastructure Regression Results

	Dependent variable:					
	Cumulative Forest Loss					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment (Proximity)	7.213***	10.563***	7.496***	-2.671*	-2.949*	-2.322*
	(2.124)	(2.119)	(1.707)	(1.560)	(1.521)	(1.409)
Proximity Control		-5.565***	-2.073	2.084	1.236	0.855
		(1.987)	(2.622)	(2.440)	(1.984)	(1.922)
Baseline NDVI			0.004***	0.004***	0.003***	0.003***
			(0.001)	(0.001)	(0.001)	(0.001)
NDVI Pre-Trend			-0.030***	-0.029***	-0.023***	-0.022***
			(0.010)	(0.009)	(0.008)	(0.007)
Elevation			-0.002	-0.003	-0.004*	-0.003*
			(0.002)	(0.002)	(0.002)	(0.002)
Slope			-0.532***	-0.525***	-0.358**	-0.345**
			(0.190)	(0.186)	(0.148)	(0.143)
Urban Travel Time			-0.001	-0.001	-0.002	-0.002*
			(0.001)	(0.001)	(0.001)	(0.001)
Nighttime Lights Pre-Trend			3.952	5.295	7.720	-20.274***
			(6.110)	(5.701)	(4.759)	(6.479)
Population			0.015	0.011	0.008	0.004
			(0.013)	(0.012)	(0.010)	(0.010)
Baseline Protected Areas					1.066*	1.018*
					(0.624)	(0.617)
Baseline Concessions					1.656	1.634
					(1.092)	(1.104)
Plantations					6.261*	5.794**
					(3.258)	(2.905)
Nighttime Lights						3.280***
						(0.392)
Population*Treatment					-0.009	-0.013**
					(0.006)	(0.006)
Protected Area*Treatment					-1.941	-2.074
					(2.235)	(2.200)
Concession*Treatment					-1.061	0.164
					(3.632)	(3.556)
Plantation*Treatment					45.188***	36.498***
					(12.080)	(10.758)
Constant	3.575***	5.588***	-68.039***	-14.209	-6.659	-14.905
	(1.061)	(1.541)	(21.389)	(17.486)	(17.428)	(18.386)
Observations	58,996	58,996	58,996	58,996	58,996	58,996
Climate Controls?	No	No	Yes	Yes	Yes	Yes
District Fixed Effects?	No	No	Yes	Yes	Yes	Yes
Year Fixed Effects?	No	No	No	Yes	Yes	Yes
Note:				*p<0.1; **p<0.05; ***p<0.01		

Notes: Regression results from a panel dataset of 4,214 cells with standing forest in 2000 over 14 years. Column 1 displays the correlation of our treatment measure of proximity to Chinese infrastructure activities in Cambodia with forest loss, with no covariates or fixed effects. In Column 2, we add a control for the maximal proximity to Chinese activities for each cell. In Column 3, we add covariates and district fixed effects, while in column 4 we also include year fixed effects. Column 5 presents our main specification, which adds interaction terms with measures of the forest governance regime (protected areas, concessions, plantations). In Column 6 we include a continuous yearly measure of nighttime lights. Two-way clustering of standard errors by district and year in all columns.

Table 4. Cambodia Infrastructure Regression Results: Robustness Checks

	Dependent variable:				
	Cumulative Forest Loss				
	(1)	(2)	(3)	(4)	(5)
Treatment (Proximity, 100km)	-3.333**				
	(1.603)				
100km Proximity Control	1.410				
	(1.985)				
Treatment (Proximity, 25km)		-2.318			
		(1.460)			
25km Proximity Control		1.666			
		(1.458)			
Treatment (100km Project Count)			-0.283		
			(0.229)		
Treatment (Proximity)				-2.634**	-4.008**
				(1.136)	(1.864)
Proximity Control				0.712	2.071
				(1.687)	(2.262)
Population*Treatment (100km Proximity)	-0.008				
	(0.006)				
Protected Area*Treatment (100km Proximity)	-1.685				
	(2.254)				
Concession*Treatment (100km Proximity)	-1.012				
	(3.549)				
Plantation*Treatment (100km Proximity)	44.788***				
	(12.057)				
Population*Treatment (25km Proximity)		-0.009			
		(0.007)			
Protected Area*Treatment (25km Proximity)		-6.547***			
		(2.492)			
Concession*Treatment (25km Proximity)		-3.812			
		(3.128)			
Plantation*Treatment (25km Proximity)		48.591***			
		(14.225)			
Population*Treatment (100km Count)			-0.002*		
			(0.001)		
Protected Area*Treatment (100km Count)			-0.137		
			(0.384)		
Concession*Treatment (100km Count)			-0.195		
			(0.467)		
Plantation*Treatment (100km Count)			5.559***		
			(1.622)		
Population*Treatment (Proximity)				-0.004	-0.007
				(0.003)	(0.007)
Protected Area*Treatment (Proximity)				-0.979	-2.388
				(2.021)	(2.544)
Concession*Treatment (Proximity)				-1.447	0.322
				(2.707)	(4.072)
Plantation*Treatment (Proximity)				37.317***	53.656***
				(10.499)	(13.634)
Observations	57,736	10,612	57,736	64,106	54,740
Standing Forest Threshold	10%	10%	10%	5%	15%
Note:			*p<0.1; **p<0.05; ***p<0.01		

Notes: Columns 1-5 replicate Column 5 of Table 3 with alternate treatment measures and/or varying sets of cells. In Col 1, we limit the set of cells to those ever within 100km of a project site. In Col 2, we limit the set of cells to those ever within 25km of a project site. In Col 3, we limit the threshold to 100km of a project site and measure treatment as the project count within 100km. In Col 4, we lower the threshold for standing forests in 2000 from 10% to 5% (thus enlarging the panel dataset), while in Col 5 we increase it to 15% (thus shrinking the panel dataset). All models include the full set of covariates, district and year fixed effects, and two-way clustering of standard errors by district and year.

Table 5. Tanzania Infrastructure Treatment Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Proximity	315,028	0.483	0.670	0.000	0.000	0.140	0.838	7.480
Proximity Control	315,028	1.350	0.900	0.008	0.786	1.101	1.631	7.480
Cumulative Forest Loss	315,028	1.579	3.574	0.000	0.030	0.300	1.430	79.730
Proximity, 100km	197,694	0.218	0.393	0.000	0.000	0.000	0.323	6.711
Proximity Control, 100km	197,694	0.603	0.667	0.184	0.229	0.421	0.672	6.711
Project Count, 100km	197,694	0.819	1.390	0	0	0	1	19

Table 6. Tanzania Infrastructure Covariate Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Elevation (m)	315,028	968.298	505.829	4.319	3,672.095
Slope (degree)	315,028	2.265	2.392	0.004	19.738
Urban Travel Time (min)	315,028	407.499	334.089	3.010	2,608.798
Min Temp (C)	315,028	19.882	1.105	16.406	22.880
Max Temp (C)	315,028	23.139	1.155	20.314	26.655
Mean Temp (C)	315,028	21.608	1.086	18.506	24.290
Min Precip (mm)	315,028	14.894	6.193	2.828	68.603
Max Precip (mm)	315,028	185.170	44.793	71.874	491.477
Mean Precip (mm)	315,028	78.283	13.282	27.870	128.024
Baseline NDVI	315,028	6,948.030	504.202	2,706.404	9,449.060
NDVI Pre-Trend	315,028	27.620	36.132	-335.058	338.750
Baseline Protected Area	315,028	0.349	0.449	0.000	1.000
Population Density	315,028	37.255	113.569	0.081	7,764.935
Nighttime Lights Pre-Trend	315,028	0.002	0.037	-1.086	1.793
Nighttime Lights	315,028	0.062	0.798	0.000	44.081

Table 7. Tanzania Infrastructure Regression Results

	Dependent variable:					
	Cumulative Forest Loss					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment (Proximity)	1.673***	1.638***	1.551***	0.854***	1.143***	1.155***
	(0.156)	(0.164)	(0.155)	(0.233)	(0.253)	(0.253)
Proximity Control		0.064	0.449	0.612*	0.705**	0.714**
		(0.146)	(0.333)	(0.337)	(0.308)	(0.309)
Baseline NDVI			0.001***	0.001***	0.001***	0.001***
			(0.0002)	(0.0002)	(0.0002)	(0.0002)
NDVI Pre-Trend			-0.005***	-0.005***	-0.005***	-0.005***
			(0.002)	(0.002)	(0.002)	(0.002)
Elevation			0.001***	0.001***	0.001***	0.001***
			(0.0003)	(0.0003)	(0.0002)	(0.0002)
Slope			-0.039*	-0.040*	-0.043**	-0.044**
			(0.023)	(0.023)	(0.021)	(0.021)
Urban Travel Time			-0.001***	-0.001***	-0.001***	-0.001***
			(0.0002)	(0.0002)	(0.0002)	(0.0002)
Nighttime Lights Pre-Trend			0.042	0.043	-0.123	0.951
			(0.550)	(0.562)	(0.603)	(0.815)
Population			-0.0001	-0.0001	-0.0003	0.001
			(0.0005)	(0.0005)	(0.0005)	(0.001)
Baseline Protected Areas					-0.598***	-0.585***
					(0.205)	(0.203)
Nighttime Lights						-0.215**
						(0.089)
Population*Treatment					-0.0002	-0.0002
					(0.0001)	(0.0002)
Protected Area*Treatment					-1.090***	-1.098***
					(0.249)	(0.247)
Constant	0.770***	0.701**	-4.419	-9.620***	-8.063***	-7.003**
	(0.174)	(0.283)	(3.048)	(3.215)	(3.017)	(2.974)
Observations	315,028	315,028	315,028	315,028	315,028	315,028
Climate Controls?	No	No	Yes	Yes	Yes	Yes
District Fixed Effects?	No	No	Yes	Yes	Yes	Yes
Year Fixed Effects?	No	No	No	Yes	Yes	Yes
Note:				*p<0.1; **p<0.05; ***p<0.01		

Notes: Regression results from a panel dataset of 22,502 cells with standing forest in 2000 over 14 years. Column 1 displays the correlation of our treatment measure of proximity to Chinese infrastructure activities in Tanzania with forest loss, with no covariates or fixed effects. In Column 2, we add a control for the maximal proximity to Chinese activities for each cell. In Column 3, we add covariates and district fixed effects, while in column 4 we also include year fixed effects. Column 5 presents our main specification, which adds an interaction term with protected area coverage at baseline. In Column 6 we include a continuous yearly measure of nighttime lights. Two-way clustering of standard errors by district and year in all columns.

Table 8. Tanzania Social Sector Treatment Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Proximity	300,314	0.592	0.863	0.000	0.094	0.280	0.724	11.293
Proximity Control	300,314	1.179	1.377	0.000	0.250	0.713	1.597	11.293
Cumulative Forest Loss	300,314	1.491	3.491	0.000	0.030	0.270	1.310	79.730

Table 9. Tanzania Social Sector Covariate Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Elevation (m)	300,314	988.789	500.382	4.319	3,672.095
Slope (degree)	300,314	2.303	2.427	0.004	19.738
Urban Travel Time (min)	300,314	415.092	337.716	3.010	2,608.798
Min Temp (C)	300,314	19.891	1.109	16.406	22.880
Max Temp (C)	300,314	23.128	1.166	20.314	26.655
Mean Temp (C)	300,314	21.601	1.090	18.506	24.290
Min Precip (mm)	300,314	15.008	6.304	2.828	68.603
Max Precip (mm)	300,314	183.444	43.792	71.874	491.477
Mean Precip (mm)	300,314	78.205	13.405	27.870	128.024
Baseline NDVI	300,314	6,940.379	502.485	2,706.404	9,449.060
NDVI Pre-Trend	300,314	27.713	36.311	-335.058	338.750
Baseline Protected Area	300,314	0.283	0.432	0.000	1.000
Population Density	300,314	37.182	115.972	0.081	7,764.935
Nighttime Lights Pre-Trend	300,314	0.003	0.052	-0.866	2.212
Nighttime Lights	300,314	0.070	0.803	0.000	44.081

Table 10. Tanzania Social Sector Regression Results

	Dependent variable:					
	Cumulative Forest Loss					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment (Proximity)	1.276***	1.721***	1.586***	0.992***	1.147***	1.153***
	(0.137)	(0.153)	(0.147)	(0.140)	(0.151)	(0.153)
Proximity Control		-0.367***	-0.113	0.181	0.236	0.241
		(0.100)	(0.276)	(0.265)	(0.197)	(0.198)
Baseline NDVI			0.001***	0.001***	0.001***	0.001***
			(0.0002)	(0.0002)	(0.0002)	(0.0002)
NDVI Pre-Trend			-0.005***	-0.005***	-0.005***	-0.005***
			(0.002)	(0.002)	(0.002)	(0.002)
Elevation			0.001***	0.001***	0.001***	0.001***
			(0.0003)	(0.0003)	(0.0002)	(0.0002)
Slope			-0.021	-0.026	-0.027	-0.028
			(0.021)	(0.021)	(0.020)	(0.020)
Urban Travel Time			-0.001***	-0.001***	-0.001***	-0.001***
			(0.0002)	(0.0002)	(0.0002)	(0.0002)
Nighttime Lights Pre-Trend			-0.908*	-0.879*	-0.844	-0.012
			(0.497)	(0.505)	(0.525)	(0.504)
Population			0.00003	-0.0001	0.0001	0.001
			(0.0005)	(0.0005)	(0.0005)	(0.001)
Baseline Protected Areas					-0.554*	-0.542*
					(0.294)	(0.291)
Nighttime Lights						-0.177**
						(0.089)
Population*Treatment					-0.0002**	-0.0002***
					(0.0001)	(0.0001)
Protected Area*Treatment					-1.218***	-1.223***
					(0.320)	(0.321)
Constant	0.736***	0.904***	-0.852	-6.884**	-6.031**	-5.563**
	(0.219)	(0.232)	(2.989)	(3.050)	(2.775)	(2.776)
Observations	300,314	300,314	300,314	300,314	300,314	300,314
Climate Controls?	No	No	Yes	Yes	Yes	Yes
District Fixed Effects?	No	No	Yes	Yes	Yes	Yes
Year Fixed Effects?	No	No	No	Yes	Yes	Yes
Note:				*p<0.1; **p<0.05; ***p<0.01		

Notes: Regression results from a panel dataset of 21,451 cells with standing forest in 2000 over 14 years. Column 1 displays the correlation of our treatment measure of proximity to Chinese social sector projects in Tanzania with forest loss, with no covariates or fixed effects. In Column 2, we add a control for the maximal proximity to Chinese activities for each cell. In Column 3, we add covariates and district fixed effects, while in column 4 we also include year fixed effects. Column 5 presents our main specification, which adds an interaction term with protected area coverage at baseline. In Column 6 we include a continuous yearly measure of nighttime lights. Two-way clustering of standard errors by district and year in all columns

Table 11. Tanzania Infrastructure Robustness Checks

	Dependent variable:			
	Cumulative Forest Loss			
	(1)	(2)	(3)	(4)
Treatment (Proximity, 100km)	1.457***			
	(0.382)			
100km Proximity Control	0.408			
	(0.273)			
Treatment (100km Project Count)		0.501***		
		(0.118)		
Treatment (Proximity)			1.662***	1.454***
			(0.334)	(0.321)
Proximity Control			0.821*	0.820**
			(0.459)	(0.372)
Population*Treatment (100km Proximity)	-0.0002			
	(0.0003)			
Protected Area*Treatment (100km Proximity)	-0.852			
	(0.532)			
Population*Treatment (100km Count)		-0.0001		
		(0.0001)		
Protected Area*Treatment (100km Count)		-0.324**		
		(0.158)		
Population*Treatment (Proximity)			-0.0003	-0.0003
			(0.0002)	(0.0002)
Protected Area*Treatment (Proximity)			-1.464***	-1.338***
			(0.288)	(0.321)
Observations	197,694	197,694	315,028	261,870
Standing Forest Threshold	10%	10%	10%	15%
Note:		*p<0.1; **p<0.05; ***p<0.01		

Notes: Columns 1-4 replicate Column 5 of Table 7 with alternate treatment measures and/or varying sets of cells. In Column 1, we limit the set of cells to those ever within 100km of a project site and measure treatment as a weighted proximity. In Column 2, we limit the set of cells to those ever within 100km of a project site and measure treatment as the project count within 100km. In Column 3, we restrict the set of Chinese infrastructure activities to those in implementation or completion stages, thus excluding those in the commitment stage. In Column 4, we increase the threshold for standing forest in 2000 from 10% to 15% (thus shrinking the panel dataset). All models include the full set of covariates, district and year fixed effects, and two-way clustering of standard errors by district and year.

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