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Environmental Impacts of Chinese Government-Funded Infrastructure Projects: Evidence from Road Building in Cambodia

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Abstract

China’s international development finance commitments now average $85 billion annually, roughly double those of the U.S. Much of this funding is spent on infrastructure upgrades, yet very little is known about the environmental risks posed by these projects. We study the impacts of Chinese government-funded road improvements in Cambodia, where over the past two decades China’s state-owned banks have supplied more than $4 billion for 30 projects building, rehabilitating or upgrading over 3,000 km of major roadways. Cambodia’s forests contain some of the most biologically diverse habitats in the world, and have experienced dramatic deforestation over the past two decades. We generate and subnationally geo-reference a dataset of Chinese government financed road projects between 2003 and 2021. We then merge these project data with two decades of satellite data on forest cover. Using the spatial and temporal roll-out of the highway improvements for causal identification, we find that these led to significant declines in forest cover, particularly in nearby plantations, where more than half of tree cover was lost. These effects first appear not long after construction begins, and grow even larger in the years after construction is completed. The effects are driven by changes in market access for rubber plantations, and are magnified or dampened as global rubber prices rise and fall. The largest forest losses occur around new roads in northern Cambodia, where other foreign funders have avoided new highway construction. Thus, the Chinese government’s funding of new road infrastructure in developing countries may pose distinct threats to local environments.

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1 Introduction

Over the last two decades, the People's Republic of China (hereinafter "China") has provided record amounts of international development finance and established itself as a financier of first resort for many low- and middle-income countries. China's international development finance commitments now average $85 billion annually, roughly double those of the U.S. (Malik et al., 2021). Much of this spending has focused on building the "hardware" of economic development, including highways, railroads, dams, bridges, ports, and electricity grids (Bluhm et al., 2020; Dreher, Fuchs, Parks, Strange and Tierney, 2021; Dreher, Fuchs, Hodler, Parks, Raschky and Tierney, 2021). As Western aid agencies and multilateral development banks have become significantly more risk-averse about bankrolling large infrastructure projects due to their environmental and social risks (Park and Vetterlein, 2010; Buntaine, 2011, 2016; Buchanan et al., 2018), 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 infrastructure supplier and financier.

Yet very little is known about the environmental risks posed by the projects that China has financed. Many large-scale development projects carry serious risks for nearby ecosystems—with a very active debate about the extent of these risks—but China's overseas development program adds several important wrinkles to this debate. Scholars, environmental activists, and journalists have raised concerns about the nature, pace, and scale of China's development finance activities and the potential for unintended environmental consequences (Bosshard, 2008; Kynge, 2016). Many have questioned whether China is sufficiently prudent in its design and implementation of large-scale infrastructure projects (Ascensão et al., 2018; Teo et al., 2019). There is particular concern about projects that are close to or even located within protected areas and other areas of key biodiversity importance (Taylor and Figgis, 2007), as well as 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). Others argue that increased competition in the international development finance market has encouraged 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). It is also possible that even if Chinese government-funded infrastructure projects themselves do not induce environmental damage, they might 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) (Li et al., 2013).

However, others have argued that there is limited evidence for these claims and some grounds for optimism. Several studies suggest that Chinese financiers and contractors behave in a more environmentally responsible manner than critics allege (Van Vliet et al., 2011; Van Vliet and Magrin, 2012; Sanborn and Dammert Bello, 2013; Irwin and Gallagher, 2013; Farrell, 2016). China Development Bank (CDB) and China Eximank—the two largest sources of Chinese development finance for infrastructure projects overseas—have also adopted many of the same environmental safeguards that are used by the major multilateral development banks, including ex ante environmental impact assessments (EIAs), project reviews, compliance with host country environmental laws and regulations, and ex-post EIAs (Friends of the Earth, 2016).[1][2] Additionally, many of the Chinese contractors that implement projects for China Eximbank and CDB also do so for multilateral and bilateral aid agencies (Farrell, 2016), and competitive pressures may push these firms to comply with stricter environmental standards (Dollar, 2016).[3]

The impacts of major development projects on the surrounding environment are themselves a focus of a longstanding controversy among scholars and policymakers, irrespective of the source of financing (Wade, 1997, 2016; Pandey and Wheeler, 2001; Kareiva, Chang and Marvier, 2008; Shandra, Shircliff and London, 2011; Buchanan et al., 2018). Among these projects, road-building is often seen as posing particular risks for nearby forests, as major roads reduce the costs of logging and converting forested land into cropland. Road investments can also facilitate household collection of fuelwood for cooking and heating, particularly when new roads are constructed in or near (previously remote) forested areas (Pfaff et al., 2007; Laurance et al., 2015; Damania et al., 2016; Asher, Garg and Novosad, 2020). To the extent they lead to income gains for nearby populations, road improvements can also increase demand for forest products and thus accelerate deforestation (Baland et al., 2010), particularly if non-forest alternatives remain costly to access. These risks appear to stem differentially from major roads (highways and secondary roads), while rural roads do not always have such impacts.[4]

These debates persist because it has proven difficult to subject the claim that Chinese government-funded developments projects cause large-scale environmental damage to rigorous empirical scrutiny (Peh and Eyal, 2010; Strange et al., 2017). To address this question, we precisely geo-reference Chinese government-funded road projects in Cambodia between 2003 and 2018. Cambodia is an ideal empirical setting because the country has experienced dramatic deforestation over the past two decades, which has coincided with the rapid expansion of its highway network and economic growth. We then spatially join the road project data with remotely sensed forest cover measure data and quasi-experimentally test the extent to which proximity to active Chinese government-funded roads has led to changes in forest

[1]Beyond limiting the potentially negative environmental impacts of infrastructure projects, the environmental safeguards of the China Eximbank and CDB 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.

[2]An open question whether and to what extent these provisions are enforced. In a comparative case study of a World Bank-financed infrastructure project and a China Eximbank-financed infrastructure project in Cameroon, Chen and Landry (2018) find that China Eximbank and the World Bank have adopted many of the same de jure environmental safeguards, but they diverge in their de facto application of these safeguards. They conclude that "[b]oth China Eximbank and the World Bank have upped their game in prioritizing environmental norms and standards. However, [...] the strictness with which they are applied differ. The World Bank [...] has prioritized its safeguard policies and demonstrated the political will to enforce them. [...] While [environmental] impact assessments and mitigation plans were a condition for loan disbursement [from China Eximbank], their monitoring and enforcement were largely the responsibility of the [Cameroonian government], for better or worse, thereby exposing a gap between theory and practice."

[3]Farrell (2016) 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."

[4]Baehr, BenYishay and Parks (2021) provide evidence that rural road investments (i.e., village-level roads measuring approximately 1 kilometer in length) did not lead to higher levels of forest loss in Cambodia during an overlapping period of study.

cover. Our panel framework covers 51,420 initially forested 1km^2 grid cells in Cambodia observed over 1999-2020, allowing us to control for cell-level fixed effects and a variety of time effects. We decompose the observed effects based on the forest protection and governance designation to understand how Chinese government-funded infrastructure projects interact with domestic institutions.

We find that the road improvements led to significant declines in forest cover, particularly in nearby plantations, where the impacts on tree cover are as much as 57% of the sample mean. These effects first appear not long after construction begins, and grow even larger in the years after construction is completed and traffic flows increase. We confirm that the post-completion effects are related to changes in market access for rubber plantations, with plantations that experienced greater improvements in travel times to major markets showing the greatest forest impacts. Moreover, the impacts of road completion on forest loss are magnified or dampened as global rubber prices vary, highlighting how global markets are linked to forest conversion through local infrastructure conditions. Finally, we confirm that these effects are largely due to new roads primarily in northern Cambodia, which holds some of the largest tracts of sensitive tropical rainforests and where other foreign funders have avoided new highway construction. Our findings therefore suggest that the Chinese government's funding of new road infrastructure may indeed pose distinct threats to local environments.

This paper is organized as follows: In Section 2, we describe the study context, including Cambodia's forest governance and the Chinese government-funded road improvement projects. Section 3 describes the data we use, while Section 4 lays out our empirical methodology. We present our results in Section 5, discuss mechanisms in Section 6, and provide robustness checks in Section 7. We conclude in Section 8.

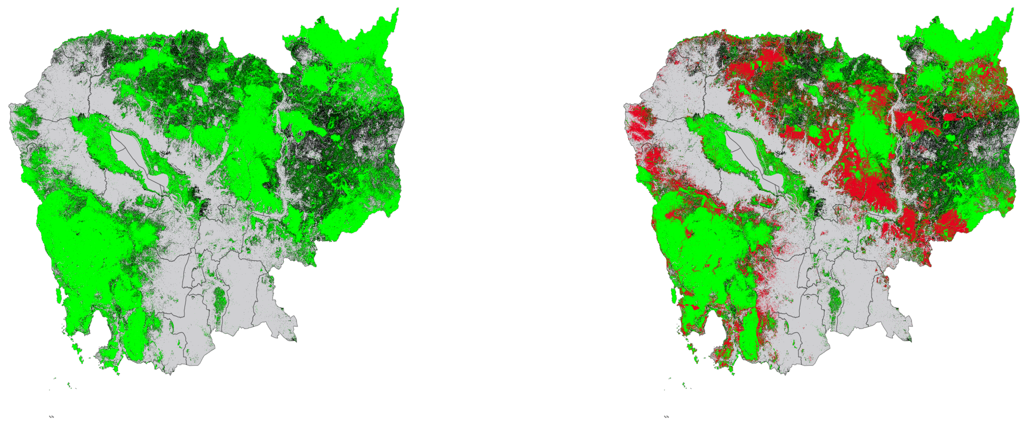
2 Context

We focus our study on Cambodia because of the country's recent record of rapid deforestation, concurrent with extensive expansion of its road network fueled in part by Chinese financial support. We discuss each in turn below.

2.1 Cambodia's forest governance

Cambodia's forests hold some of the globe's most biologically diverse habitats, but the country has also experienced one of the most rapid periods of deforestation over the past two decades. Between 2000 and 2014, for example, 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). Some estimates place these losses even higher (Grogan et al., 2019) estimates that 23.5% of national forest cover was lost in 2001-2015). Figure 1 shows forest cover in 2000 and 2019, highlighting major areas of loss, especially in the country's northeast. Despite some efforts to slow this deforestation rate, Cambodia is on pace to lose the entirety of its remaining intact forest landscape within 20 years (Potapov et al., 2017).

Figure 1: Forest Cover in Cambodia, 2000 and 2019



Green colors indicate areas of forest cover, with red areas indicating forest cover lost between 2000 and 2019

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; Trends, 2015). Much of this clearing was also associated with Economic Land Concessions (ELCs) (Davis et al., 2015; Beauchamp, Clements and Milner-Gulland, 2018). The Cambodian government leases state-owned land to private companies for agricultural and industrial purposes and as a result these lands are, on average, deforested at much higher rates (29-105% higher) than they otherwise would be (Davis et al., 2015). Some forest clearing is expected when re-purposing forests for agri-industrial use, but a weak governance regime around ELCs allows investors to ignore land use restrictions, contract expiration dates (63% of ELC deforestation occurs after contract end dates), and rules for treatment of local residents. ELCs covered 12.4% of Cambodia's forests in 2000, but accounted for 19.8% of total deforestation in Cambodia from 2000-12 (Davis et al., 2015). Due to ecological concerns and unrest from displaced people, the government issued a moratorium on new land concessions in 2012.

More broadly, Cambodia's governance of its forests was weak throughout the past two decades, and more focused on extraction than protection. A 1999 assessment identified Cambodia as having one of the least well-resourced protected areas networks in the entire world (James and Paine., 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 (International Centre for Environmental Management, 2003). A 2008 law subsequently increased the number and diversity of protected areas and granted the Ministry of Environment (MOE) more law enforcement authorities. 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 (Clements et al., 2014; Trends, 2015). 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 (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]" (Trends, 2015). 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).

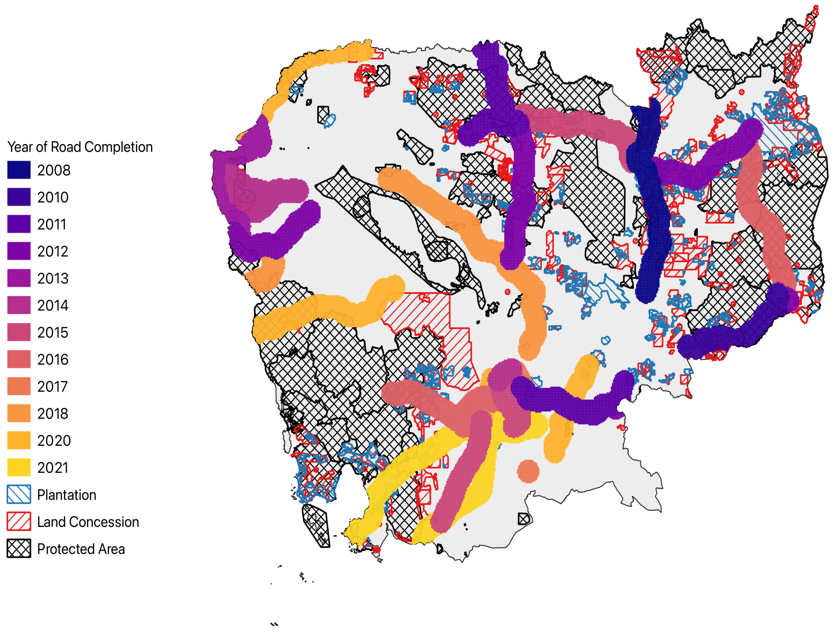
2.2 Chinese Government-Financed Road Projects in Cambodia

Over the last two decades, the Chinese government has financed the construction, rehabilitation, and upgrading of many major roads in Cambodia, primarily via concessional loans and preferential buyer's credits from the Export-Import Bank of China ("China Eximbank"). We identified and geo-referenced these road projects as described in Section 3 below. Between 2003 and 2018, China Eximbank and two additional Chinese government lenders and donors issued loans, export credits, and grants worth $4.16 billion (in constant 2017 USD) for 30 road projects in Cambodia.[5] These projects were completed between 2008 and 2021 and involved road segments totaling 3,127 kilometers in length. Nearly all of the projects supported major highways and trunk roads; the mean and median lengths of the Chinese government-financed road segments in our dataset are 104 km and 115 km, respectively. Two-thirds of the Chinese government's road sector funding ($2.78 billion in 2017 USD) was concentrated in northeastern and southwestern Cambodia, areas of the country that had especially high levels of forest cover density at baseline and deforestation during our study period (see Fig. 1). The vast majority of this funding was devoted to new road construction.

Figure 2 maps the locations of these Chinese-funded road improvements by year of completion. The figure highlights the extent of road investments in Cambodia's northeast (Mondulkiri, Kratie, Kampong Thom, Ratanakiri, Stung Treng, and Preah Vihear provinces) and southeast (Preah Sihanouk, Kampong Speu, Kampot, and Pursat provinces). The country's plantations and concession areas, which are heavily concentrated in these provinces and dominated by Chinese investors, experienced particularly high levels of forest cover loss during our period of study (Davis et al., 2015; Magliocca et al., 2020; Johansson, Olin and Seaquist, 2020). These roads serve as important transit routes for exports from these regions. Most of the agricultural and forest exports from northeastern Cambodia are transported to Vietnam via transboundary road networks. Most of the agricultural and forest exports from southeastern Cambodia are transported via ocean containers that depart from Sihanoukville seaport (Hang, 2009; Grogan et al., 2015).

[5] 27 of these road projects were financed with loans and export credits from China Eximbank. The other three projects were financed by China Development Bank and China's Ministry of Commerce (MOFCOM).

Figure 2: Chinese government-financed road projects and land designations



China Eximbank does not subject all projects to a common set of environmental standards and safeguards (Hensengerth, 2013; Weng and Buckley, 2016; Chen and Landry, 2018). Instead, it seeks only to ensure that its projects are compliant with host country laws and regulations (Export-Import Bank of China, N.d.). This means that environmentally risky projects—like roads that pass through or run alongside areas with high levels of forest density—can still be approved in countries with weak environmental laws and regulations (like Cambodia).

Over the past two decades, other donors and lenders—such as the World Bank, the Asian Development Bank, and the German Development Bank (KfW)—have provided funding for a variety of other road projects in Cambodia. However, these organizations demonstrated lower levels of appetite for environmental risk than China Eximbank. Rather than connecting forested areas to markets and population centers by expanding the geographical scope of the national (primary) road network, they largely funded (a) maintenance of existing highways and trunk roads, and (b) rural road improvements (Asian Development Bank, 2011). Neither of these activities pose major deforestation risks because they do not substantially reduce the costs of extracting forest products or undertaking large-scale, export-oriented agriculture in the northeastern and southwestern parts of the country (where many rubber, sugarcane, cassava, palm oil, and timber plantations and concessions are located).The fact that multilateral and OECD-DAC development finance institutions have avoided expanding highways and trunk roads near areas with high levels of forest density is most likely the result of their environmental screening procedures.[6]

[6]There is some anecdotal evidence that the weaker environmental standards and safeguards followed by

3 Data

3.1 Outcome Data

For our outcome data reflecting forest conditions, we rely on satellite-based measures derived from the Landsat satellite series. Our primary measures are based on the Hansen et al. (2013) Global Forest Change (GFC) dataset, which incorporates NASA Landsat OLI imagery to characterize forest cover and loss at a spatial resolution of 30 meters. The GFC dataset estimates tree canopy cover in the year 2000 on a scale of 0-100 percent, with a value of 100 representing an area with complete canopy cover. The data also include forest loss events, denoting the year in which each 30m cell shifted from a "forest" to a "non-forest" state. We incorporate both the 2000 tree canopy cover measure and the forest loss indicator to produce annual tree cover estimates. We restrict our sample to initially forested cells, defined as those with $\geq 10\%$ canopy cover in 2000.

As robustness checks, we also measure forest conditions via two alternative approaches. First, we use the Normalized Difference Vegetation Index (NDVI), a commonly used measure derived from remotely-sensed imagery taken by the Landsat satellites. The satellites capture reflectance of different types of light (i.e. red, near-infrared) and reflectance values from these images are used to construct the index, which estimates the density of vegetation cover, or "greenness", for a 30m grid cell. NDVI ranges from -1 to +1, with negative values representing bodies of water. Values from 0 to 0.2 typically indicate bare soil and values greater than 0.2 indicate vegetated areas.[7] We aggregate Landsat 16-day OLI imagery to annual scales, retaining only the maximum NDVI value for a cell in a given year to account for seasonality in NDVI. We mask out medium or high cloud cover areas from each image prior to the aggregation, reducing the likelihood of cloud cover biasing our greenness estimates.

As our second alternative measure, we also use the remotely-sensed Vegetation Continuous Fields (VCF) product from the NASA Moderate Resolution Imaging Spectrometer (MODIS) program (Hansen et al., 2003). The VCF product is similar to our other outcome measures in that it is processed from remotely-sensed imagery to create a measure of forest cover. However, the VCF is unique in that it defines three categories of forest cover: 1) tree cover, 2) non-tree vegetative cover, and 3) bare earth. Tree cover refers to the presence of vegetation with canopy height of at least 5 meters whereas the non-tree vegetative cover refers to green vegetation that is distinct from trees, such as shrubs or herbaceous plants. We

Chinese government financiers have led multilateral and OECD-DAC development finance institutions to reconsider their "limited development in areas of major conservation significance" approach. Laurance et al. (2015) 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."

[7] Only the most densely forested areas will have an NDVI value of 1. A concern associated with NDVI is saturation at the maximum value in densely forested areas (Schultz et al., 2016)). This concern is mitigated in our case because fewer than 0.002% of observations in our dataset have an NDVI value of 1 and no grid cells are saturated at a value of 1 across all periods.

use a pixel-level measure of the percentage of the pixel that falls into each of these categories: e.g., a "Bare Earth" value of 20 implies that twenty percent of a pixel is completely bare. This MODIS imagery is relative coarse, with a resolution of 250 sq. meters per pixel, but the VCF distinguishing of greenness into forest cover versus non-forest vegetation makes it a useful additional outcome measure for our analysis.

To focus on the areas most directly affected by the road improvements, we trim our sample to only cells within 10km of a Chinese government-funded road segment. We aggregate all of our outcome measures to a 1km grid cell scale to account for substantial noise at the 30m scale, as well as the potential for cross-unit spillovers at the 30m scale. We use these 1km cells as our primary units of analysis. This yields a panel of 51,420 grid cells observed over the 20 year sample period. At the 1km scale, our tree cover measure can be interpreted as the share of initially forested 30m cells that remain forested as of each year. Because the share of initially forested 30m cells within each 1km unit varies widely, we weight our estimates at the 1km scale by this share to represent the treatment effects on all forests. As we show in Section 7, our results are quite similar at both the 30m "native" scale and at the coarser commune-level scale, indicating that the choice of geographic unit of analysis is not driving the results.

3.2 Road Network Data

Through the AidData research lab, we collected information on Chinese government-funded road improvements in Cambodia over the past twenty years using the "Tracking Underreported Financial Flows" (TUFF) methodology introduced by Strange et al. (2017) and used extensively for a wide array of analyses (e.g., Dreher et al. (2018); Isaksson and Kotsadam (2018); Dreher et al. (2019); Anaxagorou, Efthyvoulou and Sarantides (2020); Dreher, Fuchs, Parks, Strange and Tierney (2021); Malik et al. (2021); Iacoella et al. (2021). We relied primarily on the aid and debt information management system of the Cambodian government, press releases from the Chinese Embassy in Cambodia and Chinese contractors working in Cambodia, and online news media, which yielded information on the timing and location of 30 road construction and improvement projects.

We then geo-referenced the road projects using a modified version of AidData's Geocoding Methodology Version 2.0.2. For each project, we identified the end points of road construction, and then combined satellite imagery and a national road map from the Cambodian Ministry of Public Works and Transport to identify the path of each road between its end points. We created line features using GIS software to trace the exact path of the improved segment. The geo-referenced roads were then joined with project attribute data collected in the prior stage.

We follow Donaldson and Hornbeck (2016) and Donaldson (2018) by developing market access measures that incorporate changes in travel time to key market destinations. To do so, we also need measures of road travel conditions along the full network, not only the specific segments improved with Chinese government funding. We thus developed annually updating network maps for 2008-2020 covering the entire country. We source GIS data of the Cambodia road network in 2020[8]. The road network data digitizes the existing highway

[8]https://mapcruzin.com/free-cambodia-country-city-place-gis-shapefiles.htm

infrastructure in Cambodia in 2020, and classifies each highway as primary, secondary, or tertiary, with additional classifications for smaller roads.

We create annually-updating networks for 2008-20 from this "master" road network. First, we establish a baseline 2008 road network by cross-referencing our 2020 network with a static map of 2008 national road infrastructure produced by the Cambodian Ministry of Public Works and Transport. The static map allows us to view which roads were not in operation yet in 2008 and "trim" them from our network for that year. This yields a road network that is representative of the actual conditions for 2008. Using this 2008 network as our baseline, we build a network that updates annually to incorporate new Chinese government-financed roads that were built in a given year. In other words, we do not incorporate *all* new roads that appear in a given year into our network, only those that are from our treatment set of Chinese government-financed roads. We omit new non-treatment roads because we have clear information on the timing of activation for roads in our sample, but not for roads outside the sample. This means that the final road network we obtain for 2020 will contain all roads that existed in 2008 as well as all Chinese government-financed road segments constructed between 2008 and 2020.

There is substantial variation in how quickly one can travel along a well-paved major highway versus more sinuous and poorly-maintained local roads. An appropriate travel time analysis must account not only for distance, but for variation in the speed of travel through the road network. Because Cambodia doesn't provide consistent data on average travel speed limits for roads in the country, we manually choose average travel speeds for our network roads based on general averages from other countries. We define five categories of roads: primary (or trunk) highways, secondary highways, tertiary highways, track (connecting roads), and local roads. We assign average speeds of 100 km/hr to primary roads, 80 km/hr to secondary and tertiary roads, 60 km/hr to track roads, and 50 km/hr to local roads (reference EU data on speeds).

Newly constructed Chinese government-financed roads are omitted from the network prior to the year they are completed. Repaired or upgraded roads are included in the network prior to servicing of the road. The travel speed on these roads is correspondingly lowered, considering that a repair or upgrade was necessary. In the years prior to repair/upgrade, these roads are assigned an average speed of 50 km/hr. All Chinese government-financed roads are assigned average speeds of 100 km/hr post-construction, the standard speed assigned to all primary highway segments.

This process yields 13 instances of the annual road network in Cambodia for 2008-20, each containing all major roads in the country prior to 2008 as well as any Chinese government-financed roads that were completed before the given year. Additionally, each road is assigned a speed limit that may vary year-to-year depending on whether the road is pending repairs or upgrades.

We define travel time as the average number of minutes required to move from a grid cell to the most accessible populated area with 10,000 or more inhabitants. There are 421 such areas in Cambodia, and they are heavily concentrated in the southeastern part of the country. The most accessible populated area is defined as that which minimizes total travel time. Using the QNEAT3 package in QGIS we compute the average travel time from a grid cell to the nearest populated area, considering both the travel costs along the road network and the costs of getting to the road network. To quantify the costs of getting to the network, we use the Euclidean distance from a grid cell to the nearest point on the network and assume an average speed of 20 kilometers per hour for off-network travel. Travel costs along the road network are computed as the distance traveled along the road network, weighted by the average travel speed along each road. The sum of off-network and on-network costs yields a measure of total travel time to the nearest populated area.

3.3 Land Governance Data

We reflect the land governance conditions for forests using a variety of GIS files. We use plantation boundaries provided by Global Forest Watch[9], concession boundaries from Open Development Cambodia[10], and protected area boundaries from the World Database of Protected Areas[11]. We build binary variables that indicate if a grid cell falls within each of these three governance regimes.

The protected area and concession data each record the year that a given designation became active, but the plantation data do not. We utilize this timing information for concession zones and protected areas, allowing a grid cell to shift its land status in the year its new status becomes active. For example, a cell that falls within a land concession zone that became active in 2008 has a land concession value of 0 prior to 2008 and a value of 1 thereafter. The plantation variable remains constant within each grid cell, essentially an indicator variable of whether a grid cell ever had status as a tree plantation during the period studied.

In our sample, 14 percent of grid cells fall within a land concession zone, 24 percent are within a protected area, and 8 percent are on tree plantations. In 2008, the Cambodian government permitted the establishment of concessions within protected areas. Of the grid cells that are within a protected area, 17 percent are also concessions. There are also notable overlaps in designation between protected areas and plantations, as well as between all three designations. Figure 2 shows these overlaps are present. Intuitively, protected areas that are littered with land concessions will not be as effective deterrents against deforestation as intact protected areas. We incorporate this expectation into our analysis and test how the presence of land concessions within protected areas moderates the effectiveness of these areas.

3.4 Climate Data

We source historical precipitation data provided by the Climatic Research Unit at the University of East Anglia [12]. They provide raster data measuring annual rainfall at a 0.5x0.5 degree resolution. Rainfall is measured in millimeters. The relative coarseness of this measure gives us a broad sense of precipitation patterns around each grid cell, but we can't precisely capture the amount of precipitation individual cells received. We use annual temperature raster data from the MODIS program [13]. The measure we use captures annual averages

[9] http://data.globalforestwatch.org/ datasets/tree-plantations
[10] https://opendevelopment cambodia.net/dataset/?id=economiclandconcessions
[11] https://protectedplanet.net/ country/KH
[12] https://crudata.uea.ac.uk/cru/data/hrg/
[13] https://e4ftl01.cr.usgs.gov/MOLT/MOD11C3.006/

of daytime land surface temperature in 5x5 kilometer pixels. The MODIS raster measures temperature in Kelvin units - we convert it to Fahrenheit.

Summary statistics for our full analysis data are presented below.

Table 1: Summary Statistics

	Variable	Mean	SD	Min	Max
Road completion year	1022890	2014.3	3.61	2008	2020
Mean NDVI	1115170	0.67	0.14	0.016	1
Plantation	1131240	0.077	0.27	0	1
Concession	1131240	0.15	0.35	0	1
Protected Area	1131240	0.24	0.42	0	1
Temperature (annual mean)	1079651	88.2	3.99	72.9	99.8
Precipitation (annual mean)	1028400	1908.2	510.3	1061.3	4316.2

4 Empirical Methodology

Our overall goal is assessing the impacts of road projects on nearby forests using variation in the timing of project construction and completion. We use cell-level fixed effects to adjust for cross-sectional unobservables, as well as year fixed effects to account for common temporal shocks. Our base specification is

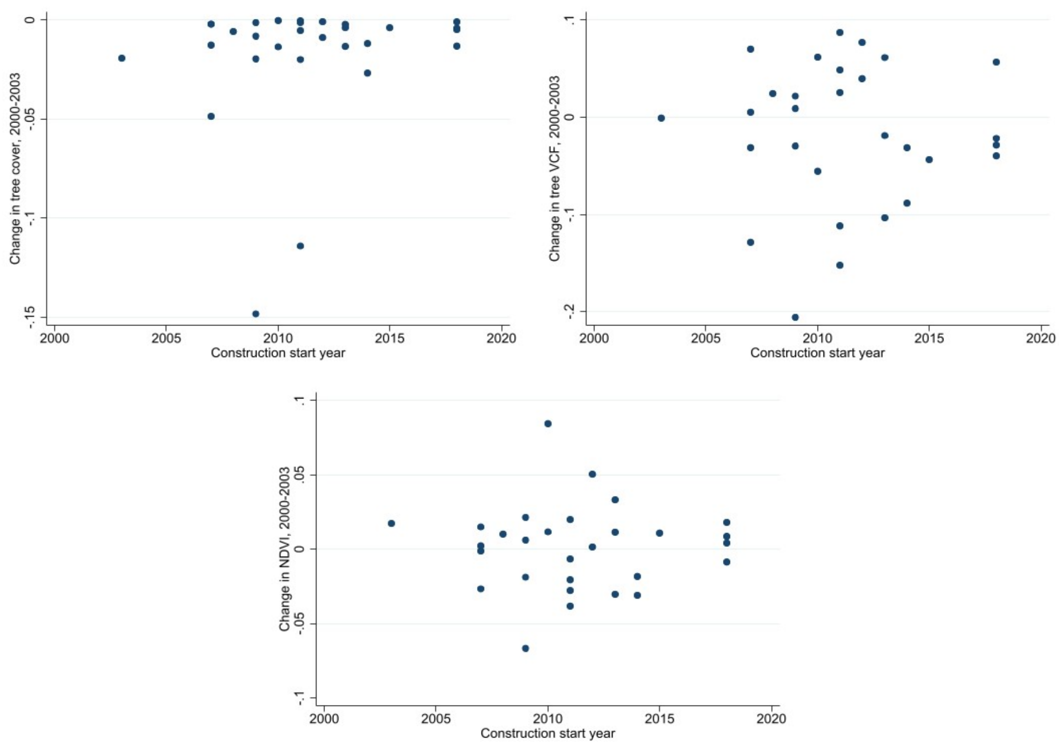
$$Y_{irpt} = \alpha + \beta_1 * ConstructionPeriod_{rt} + \beta_2 * ConstructionCompleted_{rt} + D_i + D_{pt} + \Lambda X_{irpt} + \epsilon_{irpt} \quad (1)$$

where Y_{irpt} is the tree cover share for cell i near road r in province p in year t, $Construction\ Period_{rt}$ indicates whether the improvements to road r have be begun by year t, and $ConstructionCompleted_{rt}$ indicates whether it has been completed. We differentiate between the construction period and the post-completion period because they relate to distinct mechanisms for potential effects on nearby forests. Forest loss may be due to the direct removal of trees and vegetation as part of the construction itself; after the road has been completed, subsequent forest loss may be due to clearing or other activities enabled by the greater market access or higher incomes afforded by the infrastructure.

In Eq. 1, D_i represents a vector of grid-cell fixed effects, while D_{pt} is a vector of province-by-year fixed effects, and X_{irpt} are annual temperature and precipitation controls. We primarily estimate treatment effects via ordinary least squares, weighted by the share of initially forested underlying 30m cells within the 1km cell. We use two-way clustering of standard errors by road project and year, clustering over the same dimensions (time and space) as our fixed effects following Abadie et al. (2017).

Using this design, our identification relies on variation in the sequence of nearby road project construction and completion. The critical assumption embedded in this design is that this sequence is otherwise uncorrelated with potential unobservables related to changes in forest conditions. We therefore begin by assessing whether the timing of road construction appears correlated with preceding changes in forest conditions. Our data contain three years (2000-2003) in which no Chinese government-funded projects were yet under construction, allowing us to test whether the changes in this window were correlated with the eventual year of construction (or completion). In Figure 3 below, we show that there is little correlation at the road project level between the start of construction and the earlier changes in tree cover, NDVI or VCF for trees. None of these correlations are statistically significant, and none of their magnitudes approaches the annual rates needed to generate the treatment effects we estimate below. Appendix Figures 1 further show pretrends against construction start year among each of the land designation types (plantation, concession, or PAs), again indicating very little correlation among any of these land types.

Figure 3: Pretrends for tree cover, tree VCF, and NDVI



Units of analysis are individual road segments improved under each project. For each segment, the mean change in outcomes for baseline period is plotted along vertical axis, and construction start year along horizontal axis.

In addition to examining pretrends in this early period preceding *all* treatment, we also assess whether differential trends existed in the window immediately preceding each road's construction. To do so, we use an event study design with fully saturated years-to-construction bins incorporated into Eq. 1. We discuss the resulting figures in more detail below in Section 5 below, but they also reveal very little change in forest cover associated with the upcoming construction.

As our methodology leverages the treatment timing variation in a difference-in-difference (DD) approach implemented via two-way fixed effects (TWFE), our treatment estimates can be thought of as weighted sums of underlying DDs for each time period based on the road segments that had been improved by that period. We follow Goodman-Bacon (2021) by decomposing the sources of this variation. We implement the Goodman-Bacon decomposition for our Eq. 1 and find that the DD comparisons based only on the timing groups are weighted by 0.67 in our overall estimate, confirming that our approach is not likely to be biased by other features of our sample. In Section 7, we further confirm that our TWFE design is robust to issues arising from dynamic and heterogeneous treatment effects.

5 Results

We begin by examining the overall treatment effects from road construction and completion on tree cover. Table 2 shows the primary results for tree cover outcomes. In Column 1, we include only the treatment variables as regressors, with no fixed effects or controls. This estimate reflects the sample correlation between tree cover and the road variables, with both road construction and completion negatively correlated with tree cover. In Column 2, we add year FEs, in Column 3 we add grid cell FEs, Column 4 adds temperature and precipitation covariates, and finally Column 5 adds province-by-year FEs. The resulting estimates generally show negative coefficients, although point estimates vary based on the set of FEs and controls. With our full set of FEs and controls as in Eq. 1, we find a significant average treatment effects due to road completion of -0.0385, significant at the 99% level (Col. 5). These impacts are reasonably large, equivalent to 12% of the full sample mean (0.321). We find much smaller and non-significant coefficients associated with the road construction.

These effects mask substantial heterogeneity across specific types of land. We return to our baseline specification and decompose the heterogeneous responses based on land designation. In Column 6, we use the static designations (i.e. whether each grid cell was ever classified as a plantation, concession, or PA). Our estimates indicate no impacts of road completion on tree cover in non-designated lands, but important, significant effects on all designated lands. The impact of road completion on tree cover in concessioned lands is -0.04 and in PAs it is -0.06. Plantations see a dramatically larger effect, with the post-completion average effect of -0.18 equal to 57% of the sample mean.

Notably, we do not find similar impacts during the road construction period. The effect on non-designated lands is effectively zero during the construction window, as is the effect on plantations and protected areas. Lands that ever become designated as concessions do experience a 0.02 drop in tree cover share during the construction window.

However, because the land designations themselves overlap frequently, we further decompose the overlapping land designations into mutually exclusive categories (i.e. a cell is only plantation, plantation and concession, a plantation and PA, etc.). For succinctness, we focus on the effects of road completion, interacted with the seven land categories. In Column 7, we find no effects on non-designated lands, nor lands that are only concessions or PAs. However, the effects on lands that are plantations exhibit large negative effects from road completion, irrespective of whether they are also concessions or PAs. In fact, the largest negative effects we find are on lands that are designated as plantations, concessions, *and* PAs. These effects are very large, equivalent to more than 50% of the mean tree cover for this category of land. Notably, we also find negative effects (albeit somewhat smaller ones) on lands that

Table 2: Impacts on tree cover

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Construction years	-0.064***	-0.039	-0.00084	-0.0055	-0.0044	0.0022	
	(0.016)	(0.034)	(0.0082)	(0.0056)	(0.0060)	(0.0063)	
Road completed	-0.17***	-0.11	-0.029	-0.017	-0.038***	0.012	-0.00085
	(0.039)	(0.086)	(0.016)	(0.0097)	(0.0080)	(0.013)	(0.0081)
Temperature (annual mean)				-0.049***	-0.056***	-0.052***	-0.051***
				(0.0054)	(0.0070)	(0.0056)	(0.0055)
Precipitation (annual mean)				-0.000038	0.0000030	0.000021	0.000019
				(0.000019)	(0.000043)	(0.000034)	(0.000032)
Construction years X Plantation						0.011	
						(0.021)	
Construction years X Concession						-0.020*	
						(0.0078)	
Construction years X Protected Area						-0.0030	
						(0.0091)	
Road completed X Plantation						-0.18***	
						(0.036)	
Road completed X Concession						-0.034*	
						(0.013)	
Road completed X Protected Area						-0.057*	
						(0.021)	
Road completed X Only concession							0.00093
							(0.016)
Road completed X Only PA							-0.029
							(0.019)
Road completed X Only plantation							-0.16*
							(0.072)
Road completed X Concession and PA							-0.11**
							(0.033)
Road completed X Plantation and concession							-0.17***
							(0.030)
Road completed X Plantation and PA							-0.18***
							(0.033)
Road completed X Plantation, concession and PA							-0.34***
							(0.066)
Observations	540680	540680	540680	540680	540660	540660	540660
Climate controls	N	N	N	Y	Y	Y	Y
Time FEs	N	Year	Year	Year	Province-Year	Province-Year	Province-Year
Grid cell FEs	N	N	Y	Y	Y	Y	Y

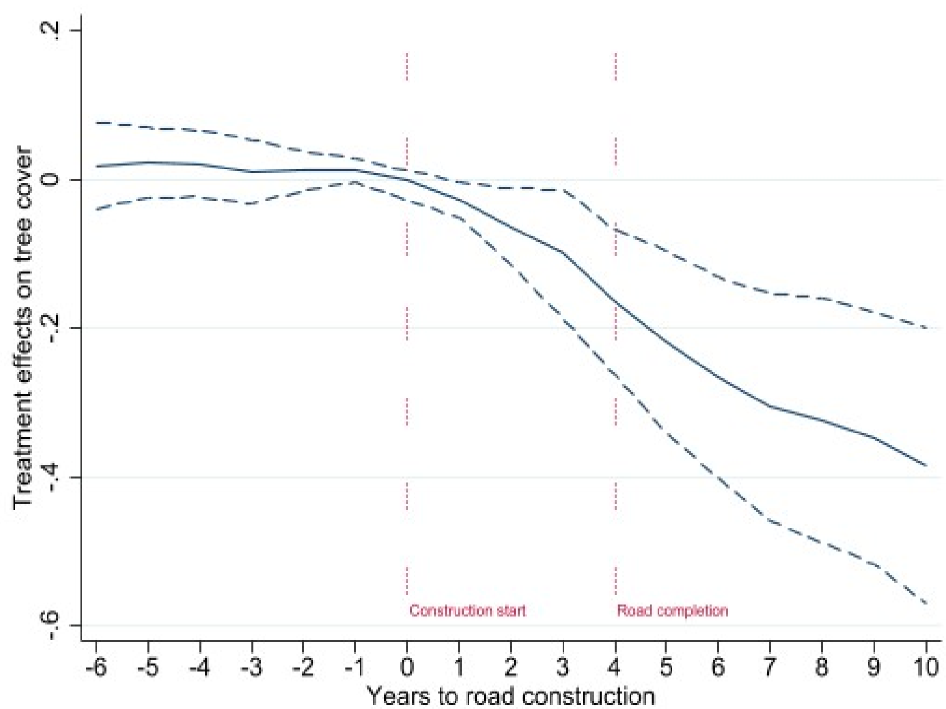
Sample consists of 1 sq. km grid cells w/in 10km of a Chinese government-funded road. Drop cells with lower than 10% treecover. Standard errors clustered by road segment and year. * denotes p=95%, ** p=99%, *** p=99.9%.

are in both PAs and concessions, indicating that the extractive effects of concessions may be concentrated in areas that are more heavily forested initially.

Taken together, these dramatic effects based on land status suggest that the impacts of road improvements are not uniformly dispersed but instead are highly shaped by the governance of nearby forests.

These estimates provide average effects over the construction and post-completion periods, which we decompose further using an event study design. We return to Eq. 1 and replace the treatment measures with years-to-start-of-construction bins. Because the overall effects differ substantially based on land designations, we estimate the event study separately for each designation. Figure 4 plots the coefficients on years-to-construction effects for plantations. First, we note that there are no significant trends in the six years leading up to the start of construction, reinforcing our pre-trends analysis described in Section 4. Second, we now observe a decline in tree cover emerging after construction begins. We see significant negative effects two years after construction begins, worsening over time. Four years after the start of construction–the point at which construction is typically complete–we see declines of nearly 20 percentage points of tree cover. These results show patterns of emerging forest loss on plantations due directly to construction, patterns that can be masked by looking at the average effects over the construction period.

Figure 4: Event Study for Plantations



Strikingly, these effects continue to worsen after completion, roughly doubling in magnitude over this period. The newly improved roads pose serious risks to nearby forests designated as plantations, and these risks grow over time. For those locations that we observe 10 years after road construction begins (six years post-completion, on average), we find tree cover reduced by nearly 40 percentage points. These areas had a sample mean of 71 percent cover in 2000, meaning the road construction and completion led to conversion of well over half of the forests in these areas.

In Figures 5 and 6, we show the corollary estimates for concessions and PAs. Again, we find very little evidence of any trends in the pre-treatment years for either of these land designations, again bolstering the validity of our panel design. In both cases, we do see some reductions in tree cover occurring toward the end of the typical construction period, but these coefficients are not as large or significant as in the case of plantations. For PAs, the negative coefficients continue to grow in magnitude after road completion, but their overall size remains roughly half of those for plantations. The coefficients for concessions stabilize post-completion and never reach 10 pp tree cover loss. For neither PAs nor concessions are the coefficients in the out years statistically distinguishable from zero.

Figure 5: Event Study for Concessions

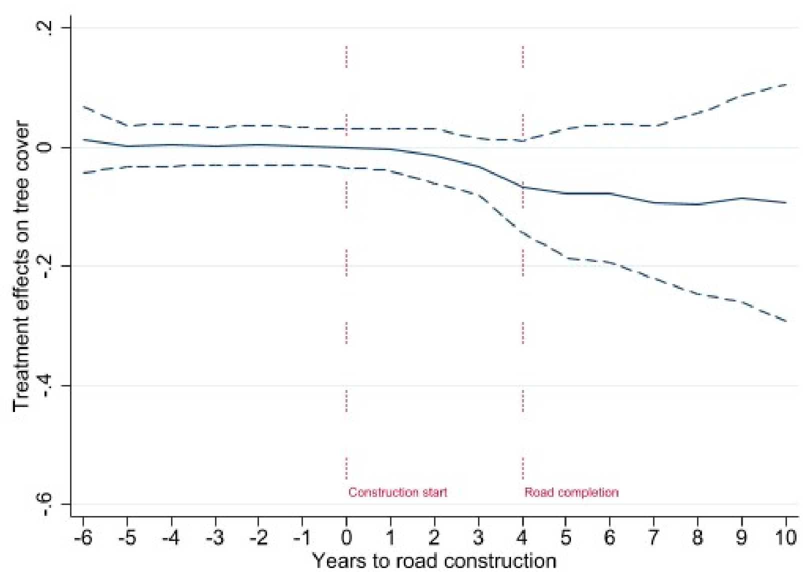
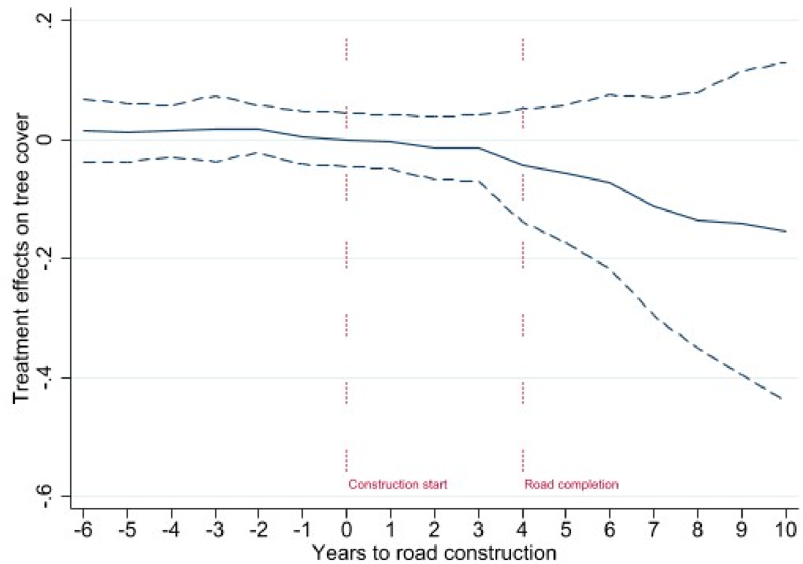


Figure 6: Event Study for Protected Areas



6 Mechanisms

We further explore the mechanisms underlying these accelerating responses to Chinese government-funded road improvements. We begin by asking whether the road improvements lead to changing access to markets, and then interpret how market access shapes forest conversion. As described in Section 3, we calculate the travel time to market destinations with populations over 10,000, based on the 2008 baseline network map, updated annually to incorporate only changes in road segments improved with Chinese government financing. In Table 3 Column 1, we first show that road completion reduced the average travel time to a market by an average of 18 minutes across our full sample.

We then consider whether expanding access to markets due to road improvements also expanded the conversion of forests, especially for plantations. To do so, we use two-stage least squares (2SLS) estimation, with market access as the endogenous regressor and nearby road completion as the instrumental variable (with the results in Column 1 reflecting the first stage). We show these estimates for the full sample in Column 2, with the significant coefficient on average time to reach markets indicating that there does appear to be a strong relationship between market access and tree cover loss. In other words, forest impacts from road improvements do seem to operate at least in part by reducing travel times to key markets.

In Column 3, we decompose these effects by land designation. We again use a 2SLS regression, now with market access measures for each of our land designations as endogenous regressors and interactions between road completion and these designations as instruments. We find that while market access plays a significant role in shaping forest outcomes on all land types, this role is substantially larger for plantations. Travel time improvements from plantations to markets are particularly closely linked with forest conversion on these plantations. These results are consistent with forest loss on plantations being driven by the falling costs to reach export markets when nearby roads are improved.

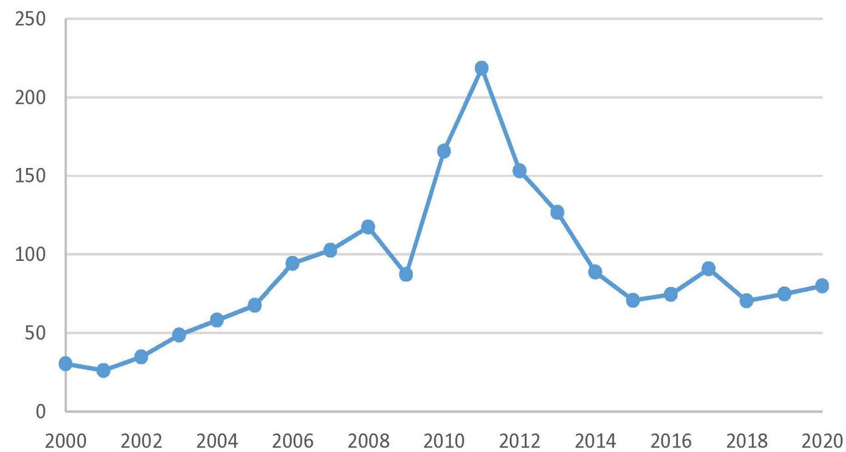
Table 3: Mechanisms

	(1)	(2)	(3)	(4)
Specification:	OLS	2SLS	2SLS	OLS
Dependent variable:	Travel time to market	Percent tree cover	Percent tree cover	Percent tree cover
Road completed	-18.6*			0.0072
	(6.35)			(0.018)
Travel time to market		0.0023*		
		(0.00099)		
Travel time X non-designated			0.0012	
			(0.00060)	
Travel time X concession			0.0011*	
			(0.00040)	
Travel time X plantation			0.0024*	
			(0.00087)	
Travel time X protected_area			0.0011	
			(0.00062)	
Road completed × L.Rubber price				-0.000064
				(0.000078)
Concession=1 × Road completed				-0.051*
				(0.021)
Protected Area=1 × Road completed				-0.076*
				(0.030)
Plantation=1 × Road completed				-0.25***
				(0.037)
Concession=1 × L.Rubber price				-0.00010
				(0.000078)
Protected Area=1 × L.Rubber price				-0.00023*
				(0.000094)
Plantation=1 × L.Rubber price				-0.00040*
				(0.00017)
Concession=1 × Road completed × L.Rubber price				0.00024*
				(0.000099)
Protected Area=1 × Road completed × L.Rubber price				0.00026
				(0.00016)
Plantation=1 × Road completed × L.Rubber price				0.00078***
				(0.000085)
Observations	324840	324396	324396	540660

All columns include weather controls, grid cell fixed effects, and province-year fixed effects. In column (2), travel time to market is instrumented with nearby road improvement. In column (3), the travel time interactions with land designations are instrumented with nearby road improvement interactions with the land designations. Standard errors are clustered by road and year.

We next consider whether global demand for rubber also shaped forest conversion on plantations. Global rubber prices fluctuated considerably over our study period (Fig. 7), from a low of \$0.26/lb in 2001 to a high of \$2.18/lb in 2011, then falling again below \$1/lb in 2014 onwards (International Monetary Fund, 2021). These prices have been shown to drive forest loss in Cambodia and elsewhere, generally with a lag of 8-12 months (Grogan et al., 2019). In other words, global rubber prices spikes lead to shortly ensuing jumps in forest conversion to rubber plantations, both in Cambodia and in other rubber producing countries.

Figure 7: Global rubber prices (USD)



This phenomenon is consistent with standard theory models of competitive, profit-maximizing operations which yield equilibria in which the first derivative of forest cover with respect to the price of output (like rubber) is negative. In such models, the derivative with respect to marginal costs (like road transport costs) is positive, again consistent with our findings that road improvements (reducing marginal costs) lead to falling tree cover. At the same time, however, the second derivative of forest cover with respect to both price and costs is positive. In other words, both greater revenues (due to higher prices) and lower costs (due to better market access) drive deforestation, but changes in one of these can compensate for the other. That is, because road improvements serve to reduce the costs of rubber extraction, they allow for conversion of forests even when prices are actually low or falling.

To test this, we return to our base specification and interact road completion and land designations with the preceding year's global rubber prices.[14] We show these results in Column 4. We find that rubber prices do interact directly with plantation designations (as well as protected areas, to a lesser degree). To test our theory that higher prices offset cost reductions, we look at the triple interaction of land designations, road completion, and prices. We find that the coefficients on these interactions are indeed positive, with the coefficient for plantations being much larger and significant at higher confidence levels than those for other types. These results confirm that Chinese government-funded road improvements served to connect sensitive forests to global markets and thereby heighten extraction and conversion dynamics.

7 Robustness

We conduct a variety of robustness checks to confirm that our findings are not due to biases related to our choice of outcome measures, definition of treatment periods, or designations of plantations. While the Hansen tree cover measure is widely used in both

[14]The direct effect of annual rubber prices is subsumed in our province-year fixed effects.

natural and social science settings, it does suffer from some limitations, including its focus on the discrete time at which forest loss occurs rather than more continuous annual fluctuations in conditions. We therefore consider several alternative measures, as described in Sec. 3. In Table 4, we return to our base specification and use NDVI as our outcome measure in Column 1 and VCF tree cover in Column 2. In both cases, we continue to find large significant impacts on these outcomes for plantations, although effects on concessions and protected areas are not distinguishable from zero.

Table 4: Robustness Checks

	(1)	(2)	(3)	(4)
Dependent variable:	NDVI	VCF tree	VCF non-tree veg	Tree cover
Construction years	-0.0045	0.0014	-0.0014	-0.023
	(0.0045)	(0.0060)	(0.0052)	(0.019)
Road completed	-0.0080	-0.0057	0.0034	-0.088*
	(0.0061)	(0.012)	(0.011)	(0.034)
Construction years X	0.0011	-0.0018	-0.0014	-0.066*
Plantation	(0.0039)	(0.0078)	(0.0062)	(0.022)
Construction years X	-0.0014	-0.0087	0.0074	-0.026
Concession	(0.0027)	(0.0052)	(0.0044)	(0.015)
Construction years X	0.00067	-0.0022	0.0038	-0.015
Protected Area	(0.0039)	(0.0033)	(0.0042)	(0.014)
Road completed X	-0.019*	-0.073*	0.059*	-0.16**
Plantation	(0.0067)	(0.026)	(0.022)	(0.052)
Road completed X	-0.0020	0.0020	-0.0062	-0.063***
Concession	(0.0026)	(0.0070)	(0.0085)	(0.011)
Road completed X	0.0077	-0.022	0.026	-0.023
Protected Area	(0.0046)	(0.013)	(0.013)	(0.029)
Observations	540833	516888	516888	251180
Climate controls	Y	Y	Y	Y
Time FEs	Province-Year	Province-Year	Province-Year	Province-Year
Grid cell FEs	Y	Y	Y	Y
Sample	Full	Full	Full	Roads improved post-2013

Standard errors clustered by road segment and year. * denotes p=95%, ** p=99%, *** p=99.9%.

In Column 3, we use VCF non-tree vegetation as our outcome; we expect sections of converted rubber plantations to be more likely to be classified as non-tree vegetation and thus to see an increase in this outcome measure post-road completion. Indeed, we find positive, significant coefficients on road completion for plantations, as well as smaller effects significant at the 5% level for PAs.

We also consider whether the timing of our measure of plantations affects the interpretation of our results. The plantation extents provided as part of the Global Forest Watch data reflect conditions as of 2013. Thus, it is possible that roads completed early in our study period (between 2008 and 2013) led to plantation conversions or expansions nearby, and the GFC measure only reflects these conversions. This would change the interpretation of the land designation measures to endogenous land categories that may serve as mechanisms for the observed effects. This would not invalidate our base findings but instead alter the interpretation of the plantation designations.

We therefore return to our base specification and limit our analysis to only those roads completed after 2013. Our measures of plantation extents near these roads are thus "fixed" at baseline and do not change in response to the completion of these roads' improvement. In Column 4 of Table 4, we show these estimates. Indeed, we find effects that are even larger in general in this later time window, with nearby road completion now leading to a reduction in forest cover on all lands (irrespective of designation). Plantations continue to have the largest reductions, however, with forest cover reduced by more than 25 percentage points on these lands after nearby roads are improved (17 percentage points more than non-designated lands, and 10 percentage points more than concessions). These findings confirm that deforestation intensified as a result of Chinese government-funded road improvements even on lands that were already used as plantations.

Finally, we also consider whether our TWFE design is robust to recently identified issues arising from heterogeneous treatment effects (De Chaisemartin and d'Haultfoeuille, 2020) or dynamic treatment effects (Borusyak, Jaravel and Spiess, 2021). To do so, we employ the estimators proposed by these author to conduct alternative event study analyses for plantations with the Hansen et al. (2013) tree cover as our outcome. Figure 8 plots the resulting event study using the estimator proposed by De Chaisemartin and d'Haultfoeuille (2020), with results that are quite similar to those in our base event study (shown in Fig. 4). These estimates again show no evidence of differential pretrends that might otherwise bias our counterfactual design. Similarly, Figure 9 shows the results using the estimator proposed by Borusyak, Jaravel and Spiess (2021), which accounts for potential dynamic treatment effects and separates the estimation of pretrends from treatment effects. We again find little evidence of differential pretrends (if anything, these appear to be sloping upward, albeit very gradually), with drops in tree cover arising a few years after construction begins and rapidly worsening in the decade after the road improvements are completed. Taken together, these checks confirm that our findings are not due to mis-specification issues.

Figure 8: Event Study for Plantations using de Chaisemartin D'Haultfoeuille (2020)

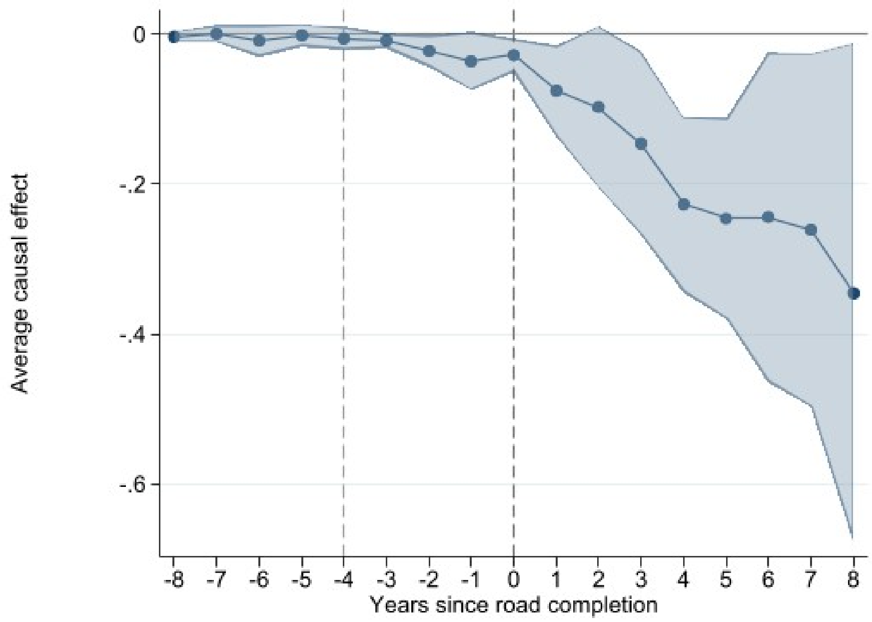
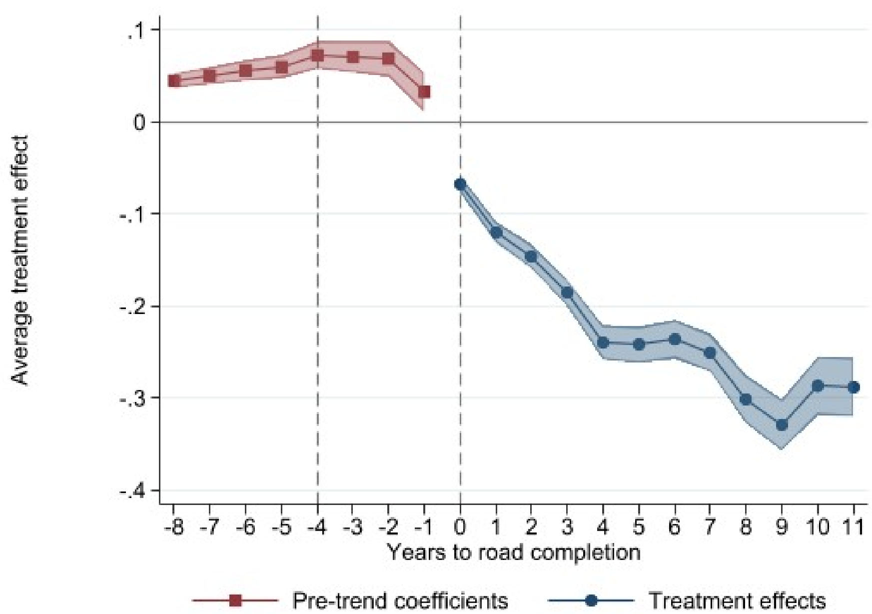


Figure 9: Event Study for Plantations using Borusyak et al (2021)



8 Conclusions

Our study is the first to identify the specific effects of Chinese government-funded infrastructure investments on nearby forests and ecosystems in a developing country setting. By financing new road construction in Cambodia's northeast—through critical tracts of sensitive tropical rainforests—China's development finance has diverged from the geographical and environmental targeting of other donors and lenders. Importantly, we find that these effects begin during road construction but grow substantially over time and are not limited to the immediate road corridors. We find forest impacts even in the latter part of our study period, when EIAs and other protective measures were already in place. Taken together, these results suggest the impacts of Chinese government-financed infrastructure are due in large part to the geographical targeting of infrastructure near or within sensitive forest ecosystems.

Recent shifts by the United States and European Union toward more financing of international "green" infrastructure, such as those announced by the Biden Administration in 2021 (White House, 2021), could trigger more—or less—coordination with Chinese funders. Improved coordination could result in Chinese state-owned banks moving away from financing major transport infrastructure in sensitive ecosystems. There is indeed recent precedent for China Eximbank co-financing large-scale highway and trunk road projects—like the Nairobi-Thika Highway in Kenya—with multilateral development banks (Dreher et al., 2022). At the same time, if strategies continue to be competitive rather than coordinated, more infrastructure funding by the US and EU could shift Chinese investments into even more vulnerable ecosystems.

Our findings also highlight the links between these investments, global markets for forest products, and domestic land governance. With weak environmental protections and policies largely aimed at forest extraction rather than protection, Cambodia was primed for dramatic deforestation responses to many new highway investments. When coupled with growing demand for rubber and other forest products, this domestic land governance context leads to use of new transport infrastructure for rapid forest extraction. But this need not be the only outcome; with adequate forest protection policies (properly enforced), it may be possible for Chinese government-funded infrastructure to actually slow loss in nearby forests. Policymakers should therefore carefully consider the governance and dynamics of complementary land and export markets in understanding the likely impacts of future infrastructure investments.

Our study also points to important directions for future research. First, while we find important impacts on key outcome measures reflecting forest conditions, future studies should aim to assess impacts on a broader range of measures of forest health, biodiversity, and other ecological conditions. Second, it is quite likely that the impacts from tropical forest loss in response to highway investments are unequally distributed. In Cambodia's northeastern region, many plantations and concessions straddle the lands traditionally held by marginalized communities. It is thus crucial to understand to what degree the benefits and losses from forest impacts due to the highway improvements flow to these communities. Finally, as China's overseas development finance continue to expand into new regions, it will be important to assess how the results we obtain extend to these new settings. For example, do the new infrastructure projects financed by China's state-owned banks in the Tropical Andes region of South America lead to similar ecological impacts?

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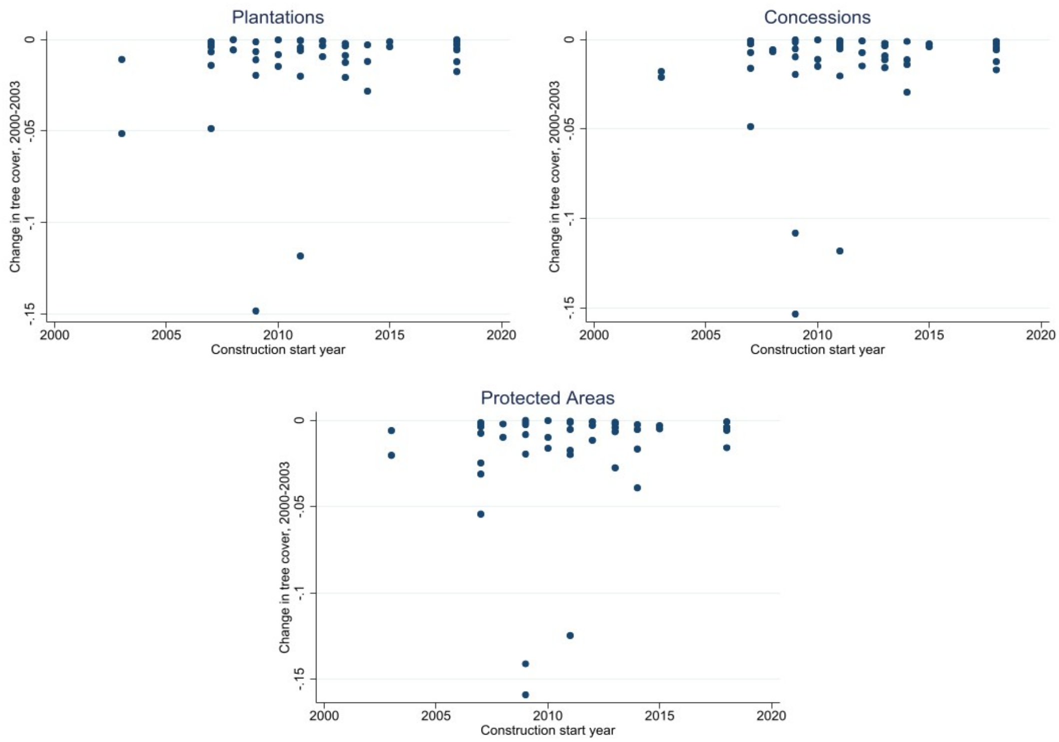
9 Appendix: Additional Results

Figure 10: Pretrends for Land Designations



Units of analysis are individual road segments improved under each project. For each segment, the mean change in outcomes for baseline period is plotted along vertical axis, and construction start year along horizontal axis.