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Do China-Financed Dams in Sub-Saharan Africa Improve the Region's Social Welfare? A Case Study of the Impacts of Ghana's Bui Dam

Keyi Tang and Yingjiao Shen

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CORRESPONDING AUTHOR:

Keyi Tang

Email: ktang13@jhu.edu

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ABSTRACT

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CHINA HAS BECOME AN INCREASINGLY important financier of energy infrastructure development in the Global South, especially hydropower projects. Despite an increase in investigations on Chinese models of infrastructure financing in these regions, there is a lack of empirical research on the impacts of China-financed infrastructure. Using data from Johns Hopkins SAIS CARI China-Africa Loan Database and the Demographic and Health Survey (DHS) Program Database, we estimate the impacts of the China-financed Bui Dam in Ghana. We use two difference-in-differences models to identify change of the likelihood to have access to electricity, and to own several electric appliances among over 29,000 local households receiving electricity transmitted from the Bui Dam. We find that after the Bui Dam's completion, the likelihood of households living in the treatment region having access to electricity increased by about 4 percent. However, given that urban households witnessed an average 14.5 percent increase in their likelihood of accessing electricity, our models also suggest that the Bui Dam's improvement of electrification may be predominant in urban and wealthy households.

INTRODUCTION

LACK OF ACCESS TO ELECTRICITY IN SUB-SAHARAN AFRICA is a major impediment to the region's economic growth. The scarcity of power generation capacity, transmission, and distribution networks as well as well-established utility frameworks poses significant challenges to sub-Saharan Africa's socio-economic development. According to the International Energy Agency (IEA), as of 2015, more than 635 million sub-Saharan Africans still live without electricity.[1]

In recent years, China has become an important source of financing and has contributed significantly to generation and transmission capacity in sub-Saharan Africa's power sector, especially hydropower. In spite of the large amount of financing that China has poured into Africa, little research has been done regarding what socio-economic impacts China-financed dams have brought to local households.

In this paper, we use an evidence-based approach to analyze the environmental and micro-level socio-economic impacts of China-financed hydropower projects in sub-Saharan Africa. Through the case study of Ghana's Bui Dam, we find that the Bui Dam has improved local urban households' access to electricity and increased their ownership of electric appliances.

BACKGROUND

SUB-SAHARAN AFRICA IS GROWING RAPIDLY, AND SO IS ITS DEMAND for electricity. Since the early 2000s, the region's gross domestic product (GDP) has doubled.[2] According to the IEA New Policies Scenario in the World Energy Outlook, by 2040, sub-Saharan Africa's electricity demand is expected to triple. To ameliorate the current situation and to meet this rapidly growing energy demand, greater access to capital and technology is urgent for the region.

China has become a major financier of sub-Saharan Africa's energy infrastructure. Chinese power-generation projects include nearly all primary sources, both fossil fuels and renewables, but excludes nuclear. Between 2010 and 2015, Chinese contractors were responsible for 30 percent of the new capacity additions in sub-Saharan Africa.[3]

China's engagement in the power sector is quite different from its Western counterparts, where donors and contractors from the Organization for Economic Co-operation and Development (OECD) countries tend to shy away from financing large dams or coal-fired power plants. While traditional Western investors are being scrutinized more strictly, Chinese companies' market share in energy and infrastructure markets in Southeast Asia, Latin America, and Africa has sharply increased.[4] Hydropower projects are important in this investment transition since Chinese companies are experienced in building dams, and other developing countries perceive hydroelectric dams as cost-effective and clean electrical generators that build up their energy capacity.[5] Between 2010 and 2020, 56 percent of the total capacity added by Chinese projects will be from renewable sources rather than fossil fuels, and hydropower accounts for 49 percent of these renewable additions. China's active engagement in the power sector has not only brought greater access to electricity but also promoted the diversification of sub-Saharan Africa's power capacity mix along with more renewable energy deployment in the region.[6]

Although the number of China-financed hydropower projects has surged in recent years, few have conducted research on the socio-economic impacts of these energy infrastructures. This is due to several reasons, (1) the Chinese government is not transparent about information regarding how many hydropower projects China has financed and what they are; (2) it is hard to make a macro-level assumption that China-financed large-scale hydropower projects have direct causation with the growth of an African country's per capita GDP because of potential selection bias; and (3) many of the China-financed dams have only recently been completed and put into use, and there are few dams that can actually be used to observe their socio-economic effects.

We selected Ghana's Bui Dam as our case study by reviewing data on Chinese infrastructures in Africa, provided by SAIS-CARI. Among the 34 large-scale China-financed hydropower projects implemented from 2000 to 2015 (Table 1), only 13 have been completed. Of the 13 completed, we find that only three have been completed in the past five years (Table 2). Bui Dam is among those recently completed which allowed us to observe how socio-economic household indicators differed before and after the dam was constructed.

The government of Ghana has also published information regarding the Bui Dam through the Bui Dam Authority, which makes it easier to identify the final destination of the electricity generated by the Bui Dam. Since the dam's completion, it has not only contributed to the power supply of four nearby regions, but has also contributed to local water supply, job creation, and the improvement of health facilities in local communities.[7] We compare region-level data of household characteristics with what the government claims to determine whether they were right about these projects bringing positive socio-economic effects to local households.

Focusing on the Bui Dam, we analyze Ghanaian households' living standard indicators using data from the Demographic and Health Surveys (DHS) program, which is funded by the U.S. Agency for International Development (USAID). We compare the living standards of households living within and outside the regions where the Bui Dam transmits electricity to, before, and after the Bui Dam was built, as well as between urban and rural households.

Lastly, we also address the major concern that has been raised regarding China-financed large-scale hydropower projects in Africa. These projects may have negative environmental impacts by changing the environment and affecting land use, relocating and failing to resettle communities, and harming natural habitats in the dam area.

Table 1a: Signed and Implemented China-funded Hydropower Projects* 2000-2015

Loan ID	Year	Country	Financier	US$ millions	Purpose
Signed:					
CM.049	2016	Cameroon	ICBC	289	Warak Hydropower Project
CD.011	2015	DRC	Eximbank	660	Busanga Hydropower Project - Sicomines
ML.006	2013	Mali	Eximbank	248	Gouina Hydropower Project (Mali and Mauritania portion)
ML.005	2014	Mali	Eximbank	100	Taoussa Hydropower Project
SN.011	2013	Senegal	Eximbank	147	Gouina Hydropower Project (Senegal portion)
SS.011	2013	South Sudan	Eximbank	24	Kinyeti Hydropower Project
TG.017	2016	Togo	Eximbank	58	Adjarala Dam add-on Loan
Implementation:					
BJ.004	2013	Benin	Eximbank	550	Adjarala Hydropower Project
CM.010	2009	Cameroon	Eximbank	53	Mekin Hydropower Project
CM.018	2012	Cameroon	Eximbank	541	Memve'ele Hydropower Project
CF.001	2011	CAR	Mofcom	27	Boali No. 3 Hydropower Project
CD.012	2011	DRC	Eximbank	367	Zongo II Hydropower Station
ET.007	2009	Ethiopia	Eximbank	270	Genale-Dawa III Hydropower Project
GH.022	2012	Ghana	Eximbank	152	Bui Hydropower Project additional finance
NG.010	2013	Nigeria	Eximbank	910	Zungeru Hydropower Project
CG.009.04	2012	ROC	Eximbank	105	Liouesso Hydropower Project
SD.052	2011	Sudan	CN Gov	104	Upper Atbara Hydropower Project
UG.009	2015	Uganda	Eximbank	483	Isimba Hydropower Project 183MW

*In Benin, Cameroon, Central African Republic, Cote d'Ivôire, Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Mali, Nigeria, Republic of Congo, Senegal, South Sudan, Sudan, Togo, Uganda, Zambia, and Zimbabwe.
**Source: Johns Hopkins University SAIS China-Africa Research Institute China-Africa Loan Database ©SAIS-CARI, updated January 15, 2018.

Table 1b: Completed China-funded Hydropower Projects* 2000-2015

Loan ID	Year	Country	Financier	US$ millions	Purpose
Completed:					
CI.009	2013	Cote d'Ivoire	Eximbank	500	Soubre Hydropower Project
GQ.004.02	2006	Equatorial Guinea	Eximbank	257	Djibloho Hydropower Project
ER.008	2014	Eritrea	Eximbank	100	Hirgigo Hydropower plant upgrade
ET.004	2007	Ethiopia	Eximbank	116	Finchaa-Amerti-Neshe Hydropower Project
ET.030	2010	Ethiopia	ICBC	235	Gibe III Hydropower Project - A
ET.031	2011	Ethiopia	Eximbank	100	Gibe III Hydropower Project - B
ET.032	2011	Ethiopia	Eximbank	89	Gibe III Hydropower Project - C
GA.004	2008	Gabon	Eximbank	300	Grand Poubara Hydropower Project
GH.005	2007	Ghana	Eximbank	306	Bui Hydropower Project (CL part)
GH.006	2007	Ghana	Eximbank	292	Bui Hydropower Project (CommL part)
GN.006	2011	Guinea	Eximbank	335	Kaleta Hydropower Project (new)
CG.004	2003	ROC	CMEC	238	Imboulou Hydropower Station, new, 120MW
SD.005	2003	Sudan	Eximbank	608	Merowe Hydropower Project

*In Benin, Cameroon, Central African Republic, Cote d'Ivôire, Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Mali, Nigeria, Republic of Congo, Senegal, South Sudan, Sudan, Togo, Uganda, Zambia, and Zimbabwe.
**Source: Johns Hopkins University SAIS China-Africa Research Institute China-Africa Loan Database ©SAIS-CARI, updated January 15, 2018.

RESEARCH QUESTION

THROUGH GHANA'S BUI DAM CASE STUDY, this paper analyzes the positive and negative socio-economic impacts of China-financed dams in Sub-Saharan Africa. It seeks to answer the question of whether China-financed hydropower projects have generated positive socio-economic effects. Effects are analyzed from three perspectives:

1. Compared to before the Bui Dam was built, was there an improvement of overall welfare of households living in the regions to which the Bui Dam transmits electricity compared with equivalent regions outside the Bui Dam area? The improvement of social welfare is indicated by:

- Increase in the rate of households' access to electricity;
- Increase in the rate of households' possession of electric appliances such as refrigerators, computers, televisions, radios, telephones, and mobile telephones;
- Increase in preventative measures against malaria, such as mosquito bed nets.

Table 2: Completed Hydropower Projects

<table>
<tr><th>Country</th><th>Year</th><th>Year of Completion</th><th>US$ millions</th><th>Power Capacity MW</th><th>Purpose</th><th>Notes</th></tr>
<tr><td>Cote d'Ivoire</td><td>2013</td><td>2017</td><td>500</td><td>275</td><td>Soubre Hydropower Project</td><td>Lacking up-to-date DHS data</td></tr>
<tr><td>Equatorial Guinea</td><td>2006</td><td>2012</td><td>257</td><td>120</td><td>Djibloho Hydropower Project</td><td>No DHS data</td></tr>
<tr><td>Eritrea</td><td>2014</td><td>2017</td><td>100</td><td>46</td><td>Hirgigo Hydropower plant upgrade</td><td>Lacking up-to-date DHS data</td></tr>
<tr><td>Ethiopia</td><td>2007</td><td>2011</td><td>116</td><td>97</td><td>Finchaa-Amerti-Neshe Hydropower Project</td><td>Lack of information on where electricity generated by FAN dam is transmitted to</td></tr>
<tr><td>Ethiopia</td><td>2010</td><td rowspan="3">2016</td><td>235</td><td rowspan="3">1,870</td><td>Gibe III Hyropower Project - A</td><td rowspan="3">Lacking up-to-date DHS data (only to 2016)</td></tr>
<tr><td>Ethiopia</td><td>2011</td><td>100</td><td>Gibe III Hyropower Project - B</td></tr>
<tr><td>Ethiopia</td><td>2011</td><td>89</td><td>Gibe III Hyropower Project - C</td></tr>
<tr><td>Gabon</td><td>2008</td><td>2013</td><td>300</td><td>160</td><td>Grand Poubara Hydropower Project</td><td>Lacking up-to-date DHS data (only to 2016)</td></tr>
<tr><td>Ghana</td><td>2007</td><td rowspan="2">2013</td><td>306</td><td rowspan="2">400</td><td>Bui Hydropower Project (CL part)</td><td rowspan="2">-</td></tr>
<tr><td>Ghana</td><td>2007</td><td>292</td><td>Bui Hydropower Project (CommL part)</td></tr>
<tr><td>Guinea</td><td>2011</td><td>2015</td><td>335</td><td>240</td><td>Kaleta Hydropower Project (new)</td><td>Lacking up-to-date DHS data (only to 2012)</td></tr>
<tr><td>Republic of Congo</td><td>2003</td><td>2010</td><td>238</td><td>120</td><td>Imboulou Hydropower Station, new, 120MW</td><td>Lacking up-to-date DHS data (only to 2011)</td></tr>
<tr><td>Sudan</td><td>2003</td><td>2009</td><td>608</td><td>1,250</td><td>Merowe Hydropower Project</td><td>Lacking up-to-date DHS data (only to 1989)</td></tr>
<tr><td>Zambia</td><td>2010</td><td>2014</td><td>315</td><td>360</td><td>Kariba North Bank Extension Hydropower Project</td><td>Lacking up-to-date DHS data (only to 2013)</td></tr>
</table>

Source: Authors' research

2. Within the regions where the Bui Dam was built and to which it transmits power, was the rate of change of the above-mentioned indicators different between urban and rural households? Have China-financed dams improved rural-urban inequality and social welfare?
3. Were there any adverse effects caused by the China-financed hydropower projects, such as resettlement or environmental pollution?

METHODOLOGY

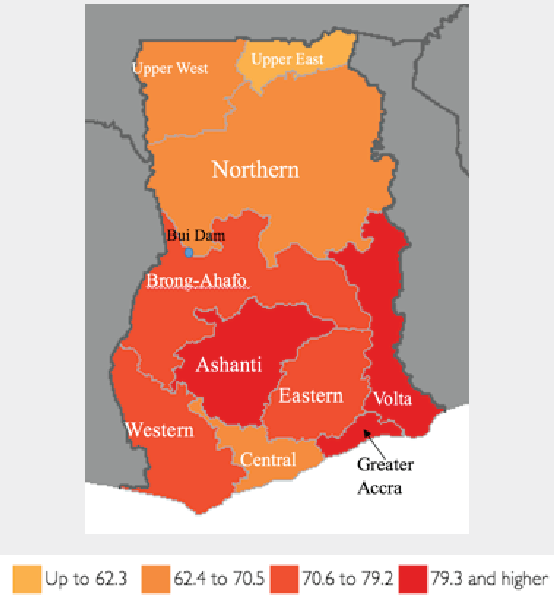
DATA

THIS PAPER EMPLOYS PRIMARY DATA FROM THE DATABASE provided by SAIS CARI and DHS. SAIS CARI has collected comprehensive data on China-financed hydropower projects in Africa. From CARI's data, we obtained information about the amount of investment, the amount of total electricity installed, and the financier and contractor of the hydropower project. We gathered demographic and health data from the DHS program which, since 1984, has been undertaking representative household-based surveys in about 70 countries, especially in developing countries.[8] DHS indicators focus on health, women, children, household characteristics, etc. By combining the results of DHS surveys and GPS household information, the DHS database makes household information available at the subnational level. Therefore, we can combine CARI's data on the information about China-financed dams with the geographically specific DHS data to see what socio-economic effects these projects have on local households.

RESEARCH DESIGN

TO MAKE A COMPARISON BETWEEN REGIONS with and without electricity transmitted from the Bui Dam, we set our treatment group to include households located in the four regions that receive electricity transmitted from the Bui Dam: Brong-Ahafo, Northern, Upper West, and Upper East. Completed in 2013, the Bui Dam is on the boundary between the Northern and Brong Ahafo regions. In addition, a total of 240 km of power transmission lines have been built to transmit power generated from the Bui Dam to four major towns nearby: Sawla, Techiman, Kintampo, and Sunyani.[9] It is estimated that the 400 MW plant will improve the quality of electricity service in the Brong-Ahafo, Northern, Upper East, and Upper West regions, especially Brong-Ahafo and Northern regions, which are adjacent to the dam. As shown in Figure 1, these four regions had relatively lower access to electricity than most of the other six regions before the completion of the Bui Dam's construction in 2013. In particular, less than 70.5% of households located in the Upper East, Upper West, and Northern regions have access to electricity. The Bui Dam will address the electricity needs in these regions. According to an International Water Power & Dam Construction report, in total the dam will increase Ghana's electricity generation capacity by about 20%.

Figure 1: Percentage of Households with Electricity in Ghana (2008)



Source: https://dhsprogram.com

Before the Bui Dam's completion, the Akosombo Dam and Kpong Dam were the only two large hydropower projects in Ghana. Generating power since 1965 and 1982 respectively, these two dams mainly provided electricity to the Southern and Eastern regions.[10] As no other large dam has been constructed recently, improvement of household access to electricity in the regions in the last five years can be mainly attributed to the Bui Dam's impacts. To make the control group as similar to the treatment group as possible, we chose regions within Ghana as the control group. Ghana only has ten administrative regions, and the Bui Dam can potentially improve electricity access in four of them. To ensure that we can compare more observations to achieve significant results, we include all of the remaining six regions as the control group. The control group includes households located in the other six regions: Western, Ashanti, Central, Eastern, Greater Accra, and Volta. Although it might be impossible to claim that the control regions receive zero electricity transmitted from the Bui Dam, the potentially omitted spillover of the Bui Dam electricity transmission will not affect the significant result of an increase of electricity access after the Bui Dam's completion in the treatment regions. In fact, the potentially omitted spillover effects could underestimate the effect of the dam on access to electricity on a national level.

To make a comparison of the time period before and after dam construction, we use DHS 2008 indicators before the Bui Dam's completion, and DHS 2014 and MIS 2016 for indicators afterwards.[11] We chose these years because our major data source for socio-economic evaluation indicators, the DHS program, does not have data for every year, and their most recent surveys on Ghana were conducted in 2008, 2014, and 2016.[12] Altogether, there are 29,454 observations in this repeated cross-sectional database.

Therefore, to evaluate the vertical and horizontal socio-economic impacts of the Bui Dam, we compare the differences between the household characteristics before 2013 and after 2013, as well as differences between households living within and outside the regions where the Bui Dam's electricity is transmitted.

CASE STUDY: GHANA'S BUI DAM

GHANA'S ACCESS TO ELECTRICITY BEFORE THE BUI DAM

GHANA'S ELECTRIC POWER GENERATION HAS GONE through several phases. Before the country's independence in 1957, Ghana relied heavily on diesel generators owned by mining factories. After gaining independence, Ghana began its industrialization and electricity demand rocketed. The Ghanaian government sourced loans from the World Bank and the United States to build the Akosombo Dam and a power station near Akosombo under the Volta River Authority (VRA) in 1961. The construction of this first dam began in 1962 and was completed in 1965. Ghana's demand for electricity kept increasing after the completion of the Akosombo Dam, however. With growing demand for electricity, the VRA conducted a study in 1971 on alternative generation capacity additions. This led to the construction of the Kpong Hydroelectric Project, the second hydropower project in Ghana, which became functional in 1982.[13] Combined, the Akosombo and Kpong dams have an installed capacity of 1,180 MW.

OVERVIEW OF THE BUI DAM

THE BUI DAM COMMENCED ITS OPERATIONS IN 2013 and is currently the second largest dam in Ghana, with a capacity of 400 MW. It is located on the Black Volta River within the Bui National Park, the third largest protected area in Ghana. Although the Bui Dam had been planned since the 1920s, the project was not implemented until the early 2000s. The government had made several attempts to plan construction that failed due to domestic conflicts, frequent changes in the incumbent government, and the lack of funding from traditional Western donors.[14] A large portion of the population was suffering from frequent power outages in the early 2000s, and this sparked an electricity crisis that triggered the immediate need for greater electric capacity. As a result, Ghana's former president, John Kufuor, decided to build a third hydroelectric dam across the Black Volta, which was an integral part of the government's overall strategy to triple the country's energy supply capacity from the 2,000 MW at the time to 6,000 MW by 2015. The dam aimed to provide energy security for Ghana, especially in northern Ghana where access to electricity was scarcer than in other parts of the country.

The Bui Dam is a collaborative project between the Ghanaian government and Sinohydro, a Chinese state-owned enterprise specializing in hydroelectric infrastructure projects. The overall cost of the project reached US$622 million, where the Export–Import Bank of China (EximBank) and the Ghanaian government were co-financiers, and Sinohydro was the contractor of the project. The EximBank disbursed two separate credit lines, one commercial and one concessional, of US$292 million and US$306 million, in 2008 and 2009 respectively. The Ghanaian government also contributed a loan of US$60 million.[15]

According to China's Ministry of Commerce, in August 2007, construction commenced on the Bui hydroelectric dam project at the Bui Gorge in the Brong-Ahafo region. Although the project had an expected completion date in 2012, the construction was not finished until December 2013. The construction and operation of the dam was expected to directly provide 3,000 local jobs. Apart from a 200 MW energy supply, the Bui Dam was also designed to provide a set of auxiliary services, including irrigation for 30,000-hectares of agricultural land.

Construction of the Bui Dam was expected to increase the country's electricity generation capacity; however, it was not only about electrification. The Ghanaian government aimed to boost cocoa exports to China through the Bui Dam's loan agreement. As mentioned earlier, the EximBank provided two credit lines. To ensure repayment, the government agreed to secure the loans with cocoa; under their agreement, a Chinese company would purchase 30,000 tons of cocoa each year from

Ghana at the world market price until 5 years after the dam was operational. The payments for this cocoa would go directly to the Eximbank. The remaining interest and principal of the loans would be repaid by 85% of the electricity sales.[16] A World Bank analysis concluded that the loan arrangement aligns with the Ghana Poverty Reduction Strategy II and debt distress is at a moderate risk.[17]

According to Han, the electricity output produced by the Bui Dam did not meet people's expectations.[18] The dam even temporarily stopped generating power shortly after it was put into use in June 2014. The Bui Power Authority claimed that the main causes behind the shutdown were a lack of water in the reservoir as well as the Ghana Grid Company's intervention. The situation did not improve, and when major power outages hit in 2016, the government decided to import power from Cote d'Ivoire. Besides generation issues, transmission capacity was worrisome as well. Ghana's electrical standards are not uniform. The power voltage of the dam was at 161KV, while the standard used in the Upper West Region is 34.5KV. This situation led to two economic losses. First, Sinohydro had to invest more money in power voltage conversion facilities and second, these lower voltages increased energy losses. Furthermore, the country was adopting an electricity voltage system at 330 KV, which meant that the Bui Dam also had to adapt to the new standards.

In addition, Han points out that the local community had a hard time benefiting from the electricity produced by the dam for multiple reasons.[19] First, they had no electricity access before resettlement, which meant they didn't own appliances or have prior experience using electricity. Second, the resettled communities were required to pay for connecting to the gird, creating an additional barrier. Lastly, with the price of electricity increasing locals had less of an incentive to buy electricity.

SOCIAL AND ENVIRONMENTAL IMPACTS OF THE BUI DAM

ACCORDING TO A REPORT CONDUCTED by the Environmental Justice Organisations, Liabilities and Trade in 2015, construction of the Bui Dam resulted in a 21% inundation of Bui National Park, along with a forced relocation of more than 1,200 Ghanaians.[20] The resettlement process has created a set of issues in local communities and the environment, including conflicts between host and settler communities as well as the loss of habitats in the Bui National Park. Despite concerns about the dam's damage to local habitation, a report published by Environmental Resource Management pointed out that inundation of the reservoir would not be devastating to the natural habitat.[21] While the inundation processes did result in terrestrial fauna drowning, the slow filling phase of the reservoir was able to avoid large-scale direct loss.

Many scholars have delved into the impacts of the Bui Dam Authority's resettlement of local communities. According to Abrampah, construction of the Bui Dam displaced at least three communities, which later struggled economically because they no longer had access to their traditional fishing grounds.[22] These communities also faced significant cultural and societal challenges, including the issue of redefining their own identities in the process of being evicted from their historical homelands.

Owusu analyzes the downstream social impacts of the Bui Dam and identified resource-use conflicts in seven non-resettled farming and fishing communities along the Black Volta River.[23] While he finds that construction of the dam has led to social infrastructure improvements, the influx of migrants and conflicts over resource usage have negatively impacted the non-resettled communities.

Compared to the Akosombo and Kpong dam constructions, the Bui Dam resettlement program was better prepared and designed. The previous two dams caused a total of 88,000 locals to resettle whereas the Bui Dam only affected 1,216 people.[24] The Bui Power Authority adopted the legal requirements of the "World Bank's Standard for Resettlement" and accordingly curated a resettlement and community support program which provided household buildings, two schools, one clinic, forestry compensation, relocation grants, agricultural land, as well as a one-year income subsidy. The outcomes of the resettlement program are promising. Public infrastructure, including roads and drainage systems, has improved. Economic activities and opportunities increased at both the Bui Dam construction and resettlement communities. Sanitation and health conditions have also greatly improved as the population continues to grow.[25]

Some other research has shown that dam project's adverse environmental impacts depend on more than the sole performance of the Chinese companies. Hensengerth argues that contracts with Chinese companies as well as the host countries' governance and environmental regulations are both crucial.[26] They co-determine the environmental protection measures that Chinese companies adopt. Many Chinese companies are still new players in the international market and are learning and adapting their practices to more closely follow those of other foreign actors.[27] In addition, Chinese companies have actively started to adopt corporate social responsibility policies because they have learned the lesson that improved practices could eventually lead them to a more competitive position in the international market.[28]

EximBank, the major financier in the project, also showed interest in improving its environmental standards and governance practices. As Brautigam points out, Chinese financial institutions, including EximBank, are becoming more aware of the evolving norms of export credits.[29] The bank emphasizes that its loans "generally" abide by the OECD Arrangement even though China is not an OECD member country. During an interview with Brautigam in 2008, the EximBank President stated that the bank only worked with Western agencies for the assessment of environmental impacts because senior management believed that Western players were more credible.[30] The bank published two environmental guidelines in 2004 and 2007 respectively.[31]

Other concerns include the nature of the non-bidding process of the project. Sinohydro was awarded the contract through sole source negotiation between the Chinese and Ghanaian governments. In 2005, the Ghanaian government signed a MOU with Sinohydro to finance and construct the Bui Dam. The deal to secure loans was finalized between the Ghanaian government and EximBank in 2008.[32] Hensengerth argues that although the Bui Dam project did not go through an international bidding process, international standards were implemented throughout the project.[33] The Ghanaian government not only commissioned European companies to conduct the feasibility study in 1995 and the environmental and social impact assessment (ESIA) study in 2007, but also implemented environmental laws aligning with international norms. Therefore, Sinohydro and Exim Bank were bound by international standards due to Ghana's legal enforcement.

A Global Witness report points out that the dedication of investing countries in ensuring transparency and good governance is a key factor because they are the governments of the world's major economies.[34] Even if they do not act to improve transparency and take responsibility, the international community has few ways to punish them. The Chinese government has also recognized the importance and need for Chinese companies to adopt environmental protection standards for overseas projects. In February 2013, China's Ministry of Commerce and Ministry of Environmental Protection co-issued a set of guidelines for Chinese companies' performance and behaviors regarding environmental protection.[35] As a large state-owned enterprise that routinely operates overseas, Sinohydro is expected to abide by these guidelines.

Some scholars are concerned about the workforce localization of Chinese companies in African countries. Kernen and Nam think that even though Chinese companies actively invest in Ghana, complete localization of Chinese SOEs in Ghana does not yet exist.[36] Even though the company hires local management staff, they are mostly employed for external operations, such as sales and human resources, because the company hopes to build a better image of engaging the local communities. This shows how the degree of Chinese management localization can be limited.

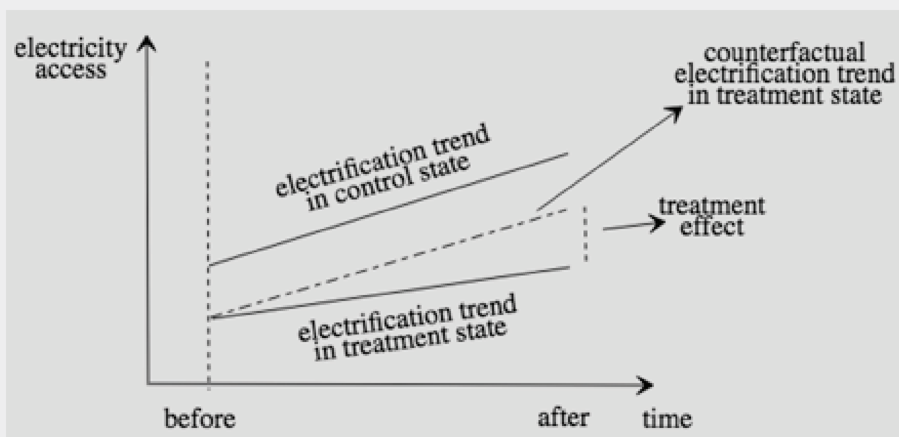
However, Han points out that the Bui Dam construction period, 2009-2013, required up to 2,600 persons for 65 types of jobs, and the number Chinese workers never exceeded 400 workers.[37] Around 100 of them were Pakistanis who were employed for specific positions such as machinery operators. Most workers on the Bui Dam site were Ghanaians, and they were unskilled before the construction. The Ghanaians received a three-stage training once employed. Kernen and Lam state that during onsite work, more skilled Chinese employees often supervised, mentored, and worked with local employees in groups for a period until the Ghanaians workers fully grasped the techniques and skills for independent work.[38] The construction project not only provided a large number of employment opportunities in the local community but also transferred some technical skills to local workers. Furthermore, according to Han, the Bui Dam project management office set up a medical center onsite due to the high incidence of malaria and other waterborne diseases as well as the lack of medical facilities in the region. In order to improve relations between expatriates and locals, Chinese Communist Party committees also organized onsite recreational activities and made donations to local communities and schools. However, due to overtime work, low wages, lack of secured leave, as well as health and safety risks, two strikes happened in 2008 and 2013. As a result, a local labor union was established in 2009. Sinohydro also signed an agreement with Ghana's Trades Union Congress that demanded both workers and supervisors better understand their rights and obligations.

Currently, most literature regarding the Bui Dam only focuses on the adverse social and environment impacts. Very little literature has touched upon its potential benefits in bringing more electricity access, employment, and improving health and education. In terms of methodology, almost all the literature regarding the impacts of China-financed infrastructures are conducted through qualitative case studies. Quantitative studies showing convincing causal relations are rare.

EMPIRICAL FRAMEWORK

SELECTION BIAS IS ONE OF THE REASONS WHY it is so hard to quantify the socio-economic impacts of electrification. Angrist and Steffen mention that in evaluating development projects, one of the major obstacles is to rule out pre-existing differences between the treatment and control groups and ensure you are comparing apples to apples.[39] As Figure 2 shows, only after taking into consideration the selection bias between the treatment and control group can a more precise treatment effect be predicted. In our case, we cannot directly compare household access to electricity in regions where the Bui Dam transmits power with the rest of the regions without disregarding pre-existing differences between the two groups.

Figure 2: Selection Bias



Source: Authors' Research, Adapted from Angrist and Steffen (2008) Figure 5.2.1

However, some literature has addressed the problem of selection bias and tried to solve it through statistical or econometric methods. For instance, Angrist and Steffen argue that a randomized controlled trial (RCT) is the best way to eliminate selection bias.[40] Lenz *et al*. propose that in evaluating the socio-economic impacts of hydropower projects, a randomized phasing-in of electrification is difficult to implement, but they suggest that a non-randomized difference-in-differences (DiD) approach can control for unobserved differences between the households of electrified and non-electrified communities under the Rwanda Electricity Access Role-Out Program.[41]

We propose two difference-in-differences (DiD) models to evaluate the socio-economic impacts of the Bui Dam. The first DiD estimator shows the aggregate changes of influences in different regions over time, while the triple DiD model adds an urban dummy variable to show the urban-rural disparity in the influences of the Bui Dam.

DIFFERENCE-IN-DIFFERENCES (DID) MODEL

$$y_{ijt} = \partial + \beta_1 Dam_{ij} + \beta_2 Post_t + \beta_3 Dam_{ij} * Post_t + \beta_4 Region_j + \varepsilon_{ijt} \quad (1)$$

In equation (1), notations respectively represent:

∂: a constant;

i: one household;

j: 10 administrative regions in Ghana;

t: year (2008, 2014, and 2016) of the socio-economic outcome survey;

y_{ijt}: outcome variable (such as electricity access, wealth quantile, and ownership of electric appliances) for household i in j region in the year t;

Dam_{ij}: a binary variable taking a value of one when household i is located in one of the four regions to which the Bui Dam transmitted electricity: Brong-Ahafo, Northern, Upper East, and Upper West. It takes a value of zero when the household i in region j belongs to the other six areas to which the Bui Dam's electricity is not transmitted;

$Post_t$: a binary variable that denotes whether the year is before or after the Bui Dam's completion;

$Dam_{ij} * Post_t$: the interaction term that shows the average treatment effects;

$Region_j$: the 10 administrative regions in Ghana;

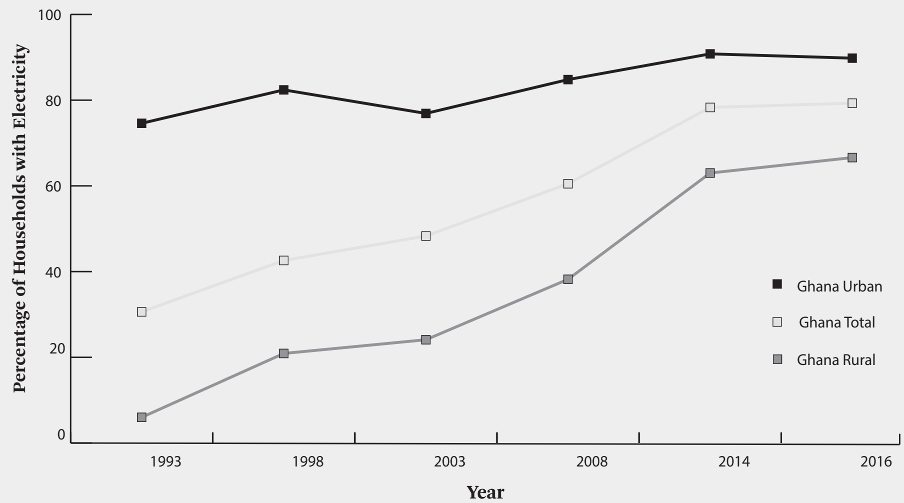
ε_{ijt}: an error term.

In the first model, β_3 is the DiD estimator that captures the change of likelihood to access electricity for households living in the treatment regions before and after the Bui Dam was built.

DIFFERENCE-IN-DIFFERENCE-IN-DIFFERENCES (TRIPLE DID) MODEL

MODEL 1 CAN ESTIMATE THE AGGREGATE RURAL-URBAN treatment effect of the Bui Dam's impacts on households in the treatment group but cannot show the heterogeneous treatment effects between urban and rural households.[42] We want to further investigate whether there is a difference between the Bui Dam's impacts on urban and rural households because Ghana's rural electrification rate has always been lower than that of urban areas. Despite the narrowing gap, the rate of access to

Figure 3: Percentage of Households with Electricity in Ghana (1993-2016)



Source: https://dhsprogram.com[43]

electricity for urban households was 23.2 percentage points higher than their rural counterparts in 2016, as Figure 3 shows.

To show whether the Bui Dam improved urban household access to electricity more than rural households, we designed a triple DiD model by adding an urban dummy variable to Model 1:

$$y_{ijt} = \partial + \beta_1 Dam_{ij} + \beta_2 Post_t + \beta_3 Urban_i + \beta_4 Dam_{ij} * Post_t + \beta_5 Dam_{ij} * Post_t * Urban_i + \beta_6 Dam_{ij} * Urban_i + \beta_7 Post_t * Urban_i + \beta_8 Region_j + \varepsilon_{ijt} \quad (2)$$

In function (2), other notations are the same as in function (1) except for the following:

$Urban_i$: equals one if household *i* is urban and zero if it is rural;

$Dam_{ij} * Post_t * Urban_i$: an interaction term that shows the average treatment effects on urban households;

$Dam_{ij} * Urban_i$: covariate of treatment and urban variable;

$Post_t * Urban_i$: covariate of time and urban variable.

In the second model, β_5 is the triple DiD estimator representing the change of likelihood to access electricity for urban households in the treatment regions before and after the Bui Dam.

Because the size of our cluster sample—10 regions—is very small, and to ensure the robustness of standard error, we need a larger cluster sample size, and therefore we used an econometric procedure called bootstrapping. We repeated the regression model 400 times and only observed some small standard errors.

Table 3: Access to Electricity and Cooking Fuel Using Electricity

	Access to Electricity		Cooking Fuel_Electricity	
	Model 1	Model 2	Model 1	Model 2
1. dam#1.post	0.0416*** (0.0121)	-0.0672*** (0.0156)	-0.00384* (0.00168)	-0.00289 (0.00168)
1. post#1.urban# 1. dam	-	0.145*** (0.0227)	-	0.00282 (0.00320)
1. dam	-0.261*** (0.0150)	-0.205*** (0.0152)	0.00160 (0.00172)	0.00377* (0.00177)
1. post	0.164*** (0.00678)	0.256*** (0.0110)	0.00550*** (0.00116)	0.00139 (0.000782)
2. region	0.0212 (0.0117)	0.0155 (0.0110)	0.000136 (0.00168)	-0.0000753 (0.00168)
3. region	0.199*** (0.00991)	0.0595*** (0.00960)	0.0143*** (0.00246)	0.0112*** (0.00252)
4. region	-0.0778*** (0.0120)	-0.0561*** (0.0112)	-0.00327** (0.00126)	-0.00280* (0.00125)
5. region	-0.0715*** (0.0116)	-0.0732*** (0.0106)	0.00308 (0.00188)	0.00294 (0.00187)
6. region	0.0995*** (0.0109)	0.0499*** (0.0103)	0.00217 (0.00168)	0.000822 (0.00167)
7. region	0.117*** (0.0135)	0.0161 (0.0121)	0.000447 (0.00163)	0.000122 (0.00158)
8. region	-0.0365** (0.0139)	-0.0832*** (0.0121)	0.00451 (0.00207)	0.00430* (0.00205)
9. region	-0.137*** (0.0147)	-0.149*** (0.0128)	-0.00192 (0.00142)	-0.00222 (0.00141)
1. urban	-	0.411*** (0.0115)	-	0.00300* (0.00138)
1. dam#1.urban	-	0.133*** (0.0192)	-	-0.00774*** (0.00191)
1. post#1.urban	-	-0.214*** (0.0131)	-	0.00672** (0.00215)
_cons	0.613*** (0.00935)	0.442*** (0.0108)	0.000563 (0.00128)	-0.0000134 (0.00119)
N r2 F	29,454 0.138 507.7	29,454 0.268 847.4	29,454 0.00487 9.824	29,454 0.00661 11.72

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

EMPIRICAL RESULTS

ACCESS TO ELECTRICITY & COOKING FUEL WITH ELECTRICITY

FROM BOTH MODELS, WE CAN SEE THAT THE LIKELIHOOD for all households to have access to electricity has been largely enhanced, as Table 3 shows. Model 1 shows that access to electricity for Ghanaian households living in the four regions is 4.16 percent higher after construction of the Bui Dam. Increased access to electricity is larger if we only consider urban households, which saw their access to electricity increase by 14.7 percent after the treatment. This implies that Bui Dam-generated electricity may have been largely transmitted to urban households.

The rural-urban disparity in the improvement of access to electricity may be related to the lack of rural electrification infrastructure and the so-called last-mile problem. According to Sackey, Ghana's electricity transmission system consists of an interconnected system of lines, distribution centers, control plants, and substations connecting the power plants, district capitals, and nearby towns, which are all classified as urban areas in the DHS database.[44] The existence of a gap between urban and rural electricity transmission infrastructure may have several causes including high costs to build long-distance transmission lines to serve small communities, which becomes even harder for rural communities without the ability to pay rates high enough to cover the cost of transmission infrastructure.[45] Additionally, under the framework of Ghana's Universal National Tariff (UNT), rural households have to pay a large portion of their income for high-priced electricity to subsidize the cost of extending rural extension transmission lines if they want access to electricity. Due to the so-called last-mile problem—the high cost of connecting individual households to the grid—small-scale or rural communities may choose to substitute expensive grid-based electricity with more affordable electricity directly generated through solar panels, batteries, and the like.[46] Field research in the Bui resettlement community also shows that households' desire for electricity is decreased by higher electricity prices.[47]

However, it is hard to claim that the Bui Dam has not improved rural electrification at all. Even if all of the dam's electricity were transmitted to urban areas that still might have allowed electricity from other sources that would have gone to urban areas to then become available for rural areas. Thus, the dam could still have indirectly increased the amount of electricity sent to rural areas even if none of its own electricity was sent there. Moreover, the existence of informal connectivity of electricity through neighborhood sharing has made it hard to measure the spillover effect of grid electricity. For example, previous research on the power transmission system in Ghana has found that the main characteristic of a residential community is the "compound house", which is a living commune entailing several households that allows them to share amenities such as a single electric metering system.[48] Likewise, even if a rural household is not on the grid, it may gain access to electricity through illegal connectivity to an urban area.

In addition to access to electricity, we also tested the impacts on the rate of using electricity to cook. We did not get significant coefficients from Model 2. Model 1 shows that after construction of the Bui Dam, the percentage of households using electricity to cook decreased by 0.3 percent. However, we are not confident enough to claim that this result has a strong correlation with the Bui Dam because the correlation coefficient is very small, as 0.3 percent does not represent a large impact and cooking using electricity requires some electric implements, such as electric cooktops, which are relatively more expensive and may be unaffordable for Ghanaians, especially those from the less developed Northern Ghana. The fall in the share of using electricity for cooking may not necessarily be caused by a decrease in accessibility or willingness to use electricity to cook, but may instead be related to the unaffordability of electric cooking implements for households living in the dam areas in comparison to those in the control regions. Previous research has also found that electrification did not bring significant increases in the use of electricity for cooking or heating in rural Thailand, China, or India.[49]

OWNERSHIP OF ELECTRIC APPLIANCES

THE TWO DID MODELS ALLOW US TO INVESTIGATE whether the likelihood for a household living in the four treatment regions (the Brong-Ahafo, Northern, Upper East, and Upper West regions) to own various electric appliances increased faster in comparison with their counterparts living in the control regions. Our DiD estimators measure households' rate of ownership of these electric appliances in an aggregate level, instead of their purchasing behaviors, because people may only purchase electric devices, such as computers, refrigerators, TVs, washing machines, telephones, mobile phones, and radios, once every few years. We find a very significant increase of household's possibility to own electric appliances, except for washing machines, as Table 4 and 5 show. The regression results in Table 5 show that the overall rate of household ownership of computers, refrigerators, and TVs decreased by 2.37, 3.31, and 2.85 percent respectively.

How should we explain the Model 1 result that people buy less computers, refrigerators, and TVs after the dam's completion? One possible explanation could be that these items are likely luxury items in Ghana. Therefore, the population with relatively high incomes will be the ones who have the most access to these items. If wealthier households' ownership of these items increases more slowly in the dam regions than in the control regions, this would make it look like the dam reduced the usage of these items.

To further test how wealth distribution may have affected the negative coefficients in Model 1 results, we run a regression of Model 1 on the richest, richer, middle, poorer, and the poorest households respectively based on the DHS wealth index, which is calculated through households' ownership of selected assets, types of water access and sanitation facilities, and materials used for housing construction.[50] The regression results in Tables 6, 7, and 8 show that: (1) middle-income, poorer, and the poorest households' ownership of computers increased respectively by 6.92, 3.27, and 0.51 percent after the completion of the Bui Dam, while results for the richest and richer households are not statistically significant; (2) compared to their counterparts in the

Table 4: Electric Appliances Ownership

	Computer		Refrigerator		TV		Washing Machine		Telephone	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
1. dam#1. post	-0.0237*** (0.00648)	-0.0312*** (0.00670)	-0.0331** (0.0102)	-0.0834*** (0.0102)	-0.0285* (0.0123)	-0.136*** (0.0145)	0.00310 (0.00342)	0.00976 (0.00508)	0.0271*** (0.00473)	0.0105 (0.00587)
1. post#1. urban #1. dam	-	0.0483*** (0.0144)	-	0.123*** (0.0233)	-	0.208*** (0.0259)	-	-0.00506 (0.00720)	-	0.0262* (0.0104)
1. dam	-0.0288*** (0.00773)	-0.00814 (0.00759)	-0.133*** (0.0128)	-0.0591*** (0.0113)	-0.247*** (0.0148)	-0.164*** (0.0143)	-0.0121*** (0.00309)	-0.0127** (0.00462)	-0.0257*** (0.00435)	-0.0109* (0.00550)
1. post	0.0777*** (0.00594)	0.0512*** (0.00664)	0.0823*** (0.00853)	0.0930*** (0.00968)	0.186*** (0.00890)	0.245*** (0.0116)	0.00414 (0.00353)	-0.00877 (0.00525)	-0.0396*** (0.00435)	-0.0187** (0.00572)
2014.year	-0.00469 (0.00517)	-0.00772 (0.00510)	-0.00110 (0.00693)	-0.00802 (0.00667)	-0.0129 (0.00755)	-0.0237*** (0.00711)	-0.000203 (0.00203)	-0.000581 (0.00203)	0.00478** (0.00152)	0.00459** (0.00151)
2. region	-0.0153* (0.00771)	-0.0179* (0.00760)	-0.000539 (0.0122)	-0.00679 (0.0118)	-0.0547*** (0.0131)	-0.0617*** (0.0125)	-0.00558* (0.00279)	-0.00604* (0.00279)	-0.00363 (0.00307)	-0.00388 (0.00304)
3. region	0.118*** (0.00872)	0.0748*** (0.00919)	0.327*** (0.0120)	0.202*** (0.0123)	0.281*** (0.0114)	0.130*** (0.0112)	0.0357*** (0.00419)	0.0303*** (0.00457)	0.0670*** (0.00708)	0.0562*** (0.00741)
4. region	-0.0520*** (0.00766)	-0.0454*** (0.00752)	-0.0875*** (0.0112)	-0.0683*** (0.0109)	-0.150*** (0.0127)	-0.127*** (0.0121)	-0.00921* (0.00404)	-0.00840* (0.00398)	-0.00775 (0.00424)	-0.00607 (0.00417)
5. region	-0.0279*** (0.00722)	-0.0294*** (0.00706)	-0.0384*** (0.0108)	-0.0412*** (0.0103)	-0.0875*** (0.0127)	-0.0902*** (0.0118)	-0.00159 (0.00397)	-0.00193 (0.00396)	-0.00593 (0.00398)	-0.00583 (0.00396)
6. region	0.0232** (0.00839)	0.00538 (0.00843)	0.148*** (0.0115)	0.0999*** (0.0111)	0.0967*** (0.0122)	0.0407*** (0.0116)	0.00881 (0.00524)	0.00619 (0.00561)	0.0107 (0.00545)	0.00741 (0.00580)
7. region	0.0109 (0.00690)	-0.00935 (0.00688)	0.0949*** (0.0105)	0.0413*** (0.0103)	0.140*** (0.0130)	0.0500*** (0.0118)	0.00572* (0.00225)	0.00363 (0.00221)	-0.0000734 (0.00236)	-0.00233 (0.00237)
8. region	-0.00824 (0.00662)	-0.0182** (0.00648)	0.0160 (0.00994)	-0.00960 (0.00945)	0.0387** (0.0139)	-0.00374 (0.0122)	-0.00243 (0.00155)	-0.00351* (0.00162)	-0.000861 (0.00239)	-0.00183 (0.00238)
9. region	-0.0101 (0.00688)	-0.0153* (0.00668)	0.299** (0.0105)	0.0205* (0.00964)	-0.00953 (0.0138)	-0.0237* (0.0120)	-0.000829 (0.00183)	-0.00160 (0.00185)	0.00522 (0.00293)	0.00534 (0.00291)
1. urban	-	0.0710*** (0.00748)	-	0.293*** (0.0112)	-	0.400*** (0.0119)	-	-0.000734 (0.00661)	-	0.0454*** (0.00869)
1. dam#1. urban	-	-0.0292** (0.0106)	-	-0.0760*** (0.0196)		0.00325 (0.0220)	-	-0.000768 (0.00664)	-	-0.0235* (0.0102)
1. post#1. urban	-	0.0398*** (0.00942)	-	-0.0500*** (0.0136)	-	-0.145*** (0.0142)	-	0.0229*** (0.00657)	-	-0.0422*** (0.00870)
_cons	0.0585*** (0.00587)	0.0353*** (0.00604)	0.211*** (0.00899)	0.0974*** (0.00891)	0.438*** (0.00994)	0.277*** (0.0105)	0.0188*** (0.00284)	0.0140*** (0.00445)	0.0387*** (0.00364)	0.0183*** (0.00504)
N	29,454	29,454	29,454	29,454	29,452	29,452	29,454	29,454	29,451	29,451
r2	0.0384	0.0608	0.104	0.173	0.123	0.230	0.00734	0.00927	0.0175	0.0204
F	87.44	107.5	255.9	437.0	414.6	691.3	26.77	24.28	16.36	18.99

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

Table 5: Electric Appliances Ownership (Radio and Mobile Phone)

	Radio		Mobile telephone	
	Model 1	Model 2	Model 1	Model 2
1. dam#1.post	0.0111 (0.0122)	0.0220 (0.0161)	0.127*** (0.0115)	0.0485*** (0.0147)
1. post#1.urban# 1. dam	-	-0.0502* (0.0253)	-	0.0501* (0.0237)
1. dam	-0.140*** (0.0151)	-0.136*** (0.0168)	-0.254*** (0.0146)	-0.191*** (0.0152)
1. post	-0.0880*** (0.00729)	-0.0797*** (0.0106)	0.272*** (0.00639)	0.402*** (0.00966)
2. region	-0.0684*** (0.0126)	-0.0698*** (0.0125)	-0.0391*** (0.0109)	-0.0427*** (0.0105)
3. region	0.0598*** (0.0116)	0.0291* (0.0120)	0.203*** (0.00916)	0.0958*** (0.00907)
4. region	-0.0455*** (0.0122)	-0.0408*** (0.0122)	-0.0236* (0.0109)	-0.00695 (0.0105)
5. region	-0.0145 (0.0119)	-0.0151 (0.0119)	-0.0331** (0.0110)	-0.0334** (0.0105)
6. region	0.0532*** (0.0118)	0.0418*** (0.0118)	0.0699*** (0.0100)	0.0345*** (0.00956)
7. region	0.116*** (0.0134)	0.104*** (0.0135)	0.142*** (0.0126)	0.0889*** (0.0120)
8. region	-0.0267 (0.0143)	-0.0320* (0.0142)	0.0622*** (0.0134)	0.0387** (0.0127)
9. region	0.0315* (0.0146)	0.0318* (0.0145)	0.0696*** (0.0134)	0.0683*** (0.0127)
1. urban	-	0.0787*** (0.0121)	-	0.0374*** (0.0110)
1. dam#1.urban	-	0.0321 (0.0201)	-	0.0370 (0.0212)
1. post#1.urban	-	-0.0249 (0.0148)	-	-0.275*** (0.0214)
_cons	0.766*** (0.00931)	0.735*** (0.0108)	0.567*** (0.00896)	0.405*** (0.0101)
N r2 F	29,454 0.0282 68.55	29,454 0.0322 57.43	29,454 0.160 513.0	29,454 0.232 633.2

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

control group, richer households' likelihood of refrigerator ownership decreased by 8.84 percent. However, the poorer and poorest households witnessed an increase of refrigerator ownership by 5.63 and 1.25 percent; (3) as for TVs, richer households' ownership decreased by 12.4 percent while that of the poorest households increased by 5.54 percent after the Bui Dam's completion.

This break-down of Model 1's results for households in each of the five wealth quintiles may imply that the overall negative DiD coefficient of all households' ownership of computers, TVs, and refrigerators might be caused by the fact that rich people are far more likely to have the means to buy these appliances. The relatively smaller increase of ownership among the richer households in the dam areas offsets the relatively faster increase of their ownership among poor households. Part of the relatively low impact on high-income households may be explained by the fact that they already had many of these appliances, so the dam had a relatively small effect on them.

Table 6: Computer Ownership by Wealth Quantile

	Richest	Richer	Middle	Poorer	Poorest
1. dam	0.0799 (0.0589)	0.150*** (0.0303)	0.0119 (0.0155)	-0.00889 (0.00720)	-0.00247* (0.00111)
1. post	0.184*** (0.0137)	0.0934*** (0.00710)	0.0361*** (0.00583)	-0.00534 (0.00908)	0.000711 (0.000719)
1. dam#1.post	0.0582 (0.0424)	0.0209 (0.0200)	0.0692*** (0.0117)	0.0327** (0.0104)	0.00512*** (0.00155)
2. region	0.0193 (0.0308)	0.00296 (0.0156)	-0.00837 (0.00883)	0.00749 (0.00413)	-0.000226 (0.000231)
3. region	0.00397 (0.0227)	-0.0334** (0.0129)	-0.0188* (0.00948)	0.0132 (0.0108)	0.0255 (0.0252)
4. region	-0.0487 (0.0363)	0.00263 (0.0170)	-0.0172* (0.00851)	0.0129 (0.0122)	-0.0000712 (0.0000773)
5. region	-0.00126 (0.0308)	0.00186 (0.0155)	-0.00995 (0.00876)	0.00243 (0.00306)	-0.0000793 (0.0000852)
6. region	-0.0774** (0.0245)	0.00194 (0.0137)	0.0102 (0.0139)	0.0310 (0.0187)	-0.0000141 (0.0000358)
7. region	-0.0793 (0.0572)	-0.152*** (0.0307)	-0.0414* (0.0183)	-0.00363 (0.00673)	0.00104 (0.00183)
8. region	-0.0263 (0.0637)	-0.118** (0.0362)	-0.0246 (0.0206)	0.0184 (0.0102)	0.00329 (0.00183)
9. region	0.0640 (0.0678)	-0.0978* (0.0398)	-0.0140 (0.0260)	0.0122 (0.0112)	0.00546* (0.00216)
_cons	0.270*** (0.0216)	0.0311** (0.0110)	0.0139* (0.00695)	0.00556 (0.00518)	-0.000357 (0.000362)
N r2 F	5,317 0.0484 24.97	5,822 0.0458 26.96	5,991 0.0252 20.59	5,857 0.00324 4.008	6,467 0.00525 1.740

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

Model 1 allows us to see how wealth distribution may have affected the average ownership of electric appliances in the dam regions, while Model 2 further shows us an urban-rural division. Table 4 shows that urban households alone enjoy an increase of 4.83, 12.3, and 20.8 percent respectively in the ownership of computers, refrigerators, and TVs. This may indicate that urban households had a higher consumption and ownership of these appliances after construction of the Bui Dam.

In contrast, Table 5 shows that the urban household increase of ownership of telephones and mobile phones was smaller than that of rural households, with the coefficients of ownership of telephones and mobile phones in Model 2 increasing respectively by 2.62 and 5.01 percent, and those in Model 1 increasing by 2.71 and 12.7 percent. This indicates that rural household ownership of telephones and mobile phones grew more quickly than that of urban households. In addition, although the

Table 7: Refrigerator Ownership by Wealth

	Richest	Richer	Middle	Poorer	Poorest
1. dam	0.0364 (0.0526)	0.169* (0.0666)	0.0144 (0.0243)	-0.0101 (0.0104)	-0.00964* (0.00397)
1. post	0.0218 (0.0119)	0.157*** (0.0161)	0.143*** (0.00876)	0.0217* (0.00980)	0.00153 (0.00253)
1. dam#1.post	0.0211 (0.0329)	-0.0884* (0.0390)	-0.0120 (0.0195)	0.0563*** (0.0132)	0.0125*** (0.00336)
2. region	0.0487 (0.0273)	0.0673* (0.0325)	0.00354 (0.0167)	0.0122 (0.00715)	-0.00460 (0.00460)
3. region	0.133*** (0.0206)	-0.0169 (0.0246)	-0.0796*** (0.0168)	0.0149 (0.0153)	0.0212 (0.0256)
4. region	0.137*** (0.0286)	-0.0118 (0.0286)	-0.0241 (0.0167)	0.0161 (0.0134)	0.0000332 (0.00525)
5. region	0.0797** (0.0266)	0.00500 (0.0263)	0.00783 (0.0170)	0.0147* (0.00686)	-0.00429 (0.00427)
6. region	0.142*** (0.0210)	0.0746** (0.0236)	0.0146 (0.0171)	0.0495* (0.0199)	-0.00415 (0.00414)
7. region	0.0654 (0.0464)	-0.0343 (0.0556)	0.00263 (0.0239)	-0.00912 (0.0111)	0.00135 (0.00271)
8. region	0.0780 (0.0507)	-0.00880 (0.0614)	0.0308 (0.0282)	0.0423** (0.0160)	0.00252 (0.00227)
9. region	0.113* (0.0513)	0.0827 (0.0629)	0.139*** (0.0391)	0.0773*** (0.0213)	0.0196*** (0.00397)
_cons	0.726*** (0.0200)	0.267*** (0.0213)	0.0449*** (0.0125)	0.0000105 (0.00616)	0.00335 (0.00358)
N r2 F	5,317 0.0144 6.903	5,822 0.0266 15.89	5,991 0.0508 36.36	5,857 0.0148 12.04	6,467 0.0137 4.730

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

Table 8: Television Ownership by Wealth

	Richest	Richer	Middle	Poorer	Poorest
1. dam	0.0141 (0.0121)	0.110*** (0.0294)	0.0770* (0.0378)	0.0650* (0.0270)	0.00577 (0.0116)
1. post	-0.00487 (0.00524)	0.180*** (0.0127)	0.371*** (0.0154)	0.208*** (0.0124)	0.0471*** (0.00799)
1. dam#1.post	-0.0108 (0.00926)	-0.124*** (0.0231)	-0.0152 (0.0285)	0.0420 (0.0299)	0.0554*** (0.00986)
2. region	-0.00410 (0.00911)	-0.0507* (0.0203)	-0.0945*** (0.0246)	-0.00565 (0.0181)	0.0221 (0.0206)
3. region	0.00606 (0.00718)	-0.0531** (0.0181)	-0.187*** (0.0339)	-0.00155 (0.0349)	0.301*** (0.0746)
4. region	-0.00909 (0.0121)	-0.0378 (0.0223)	-0.0796*** (0.0234)	0.0109 (0.0181)	0.00696 (0.0121)
5. region	-0.00432 (0.00920)	0.00120 (0.0239)	-0.0530* (0.0233)	-0.000630 (0.0173)	-0.0000724 (0.0119)
6. region	0.00242 (0.00675)	0.00437 (0.0174)	-0.0225 (0.0235)	0.0232 (0.0281)	0.00919 (0.0145)
7. region	-0.0109 (0.0137)	-0.00214 (0.0261)	-0.106** (0.0338)	-0.0774** (0.0247)	-0.0221* (0.0105)
8. region	0.0101 (0.0104)	0.0394 (0.0295)	0.0939* (0.0385)	0.131** (0.0436)	0.0130 (0.00973)
9. region	-0.00980 (0.0160)	0.0816** (0.0270)	0.168*** (0.0416)	0.154** (0.0487)	-0.000379 (0.00943)
_cons	0.985*** (0.00686)	0.729*** (0.0167)	0.273*** (0.0193)	0.0364** (0.0122)	-0.00309 (0.00976)
N r2 F	5,317 0.00144 6.050	5,822 0.0526 28.07	5,991 0.145 99.28	5,856 0.0714 70.35	6,466 0.0496 33.66

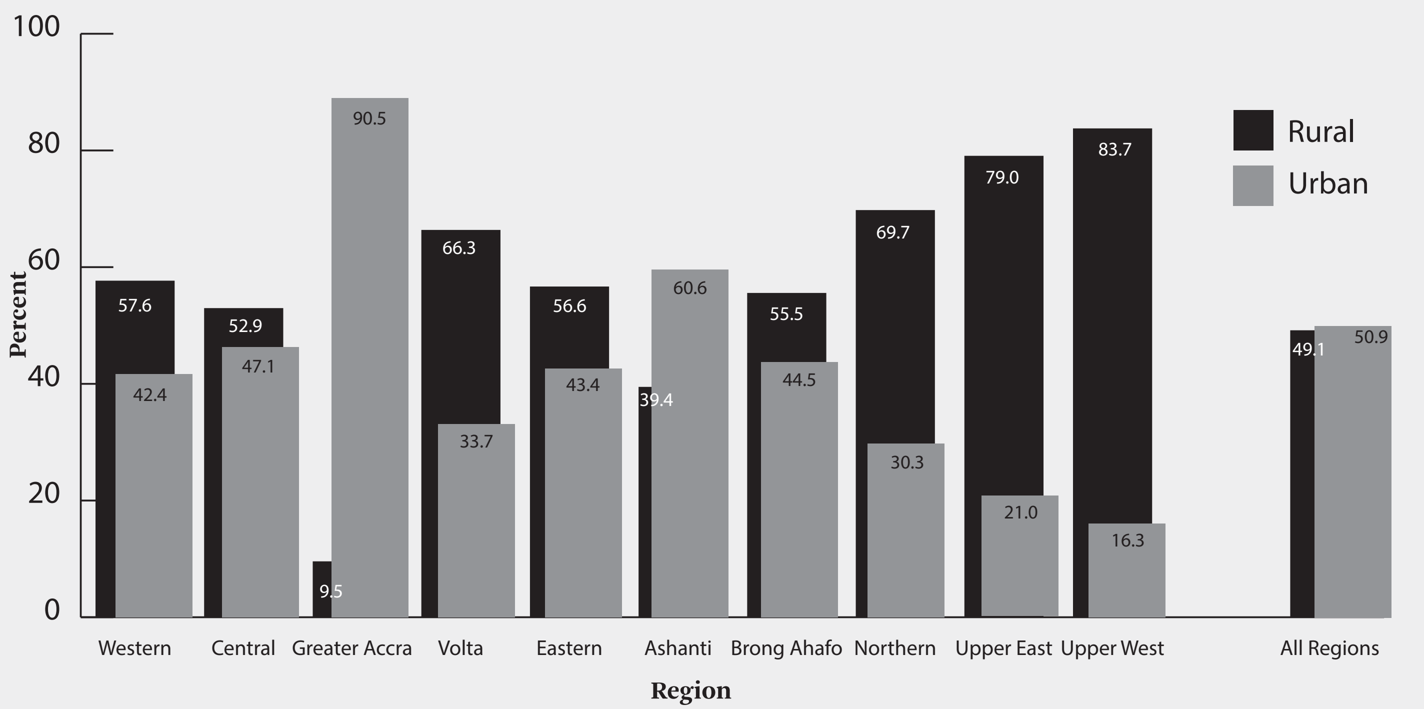
Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

ownership of radios is insignificant in Model 1, it is significant in Model 2 and shows that an urban household's likelihood of owning a radio decreased by 5.02 percent.

Urban households witnessed a faster increase in ownership of computers, refrigerators, and televisions, while rural households saw a higher increase of ownership of telephones and mobile phones. This might be because urban households have a relatively higher income to afford comparatively more expensive and high-energy-consuming appliances. Previous literature also shows that with the increase of access to electricity, middle and high-income urban households typically improve their ownership of high-wattage appliances such as air conditioners, refrigerators, water heaters, and electric cookers.[51] In contrast, low-wattage appliances, such as radios, telephones, and mobile phones may be more affordable and accessible for rural households due to their lower cost of use. In addition, these low-wattage appliances may have been more widely owned by urban households before construction of the Bui Dam and therefore did not witness a sharp increase of ownership.

It is difficult to explain why there is a decreasing trend of all households but an increasing trend of urban household ownership of computers, refrigerators, and TVs after construction of the Bui Dam. There might be two potential explanations for this discrepancy. First, people might be choosing to move from rural areas to urban regions for better lives. Second, the population from northern Ghana, which is only sparsely populated, may have moved to southern Ghana where more urban cities are situated. According to a report published by the Ghana Statistical Service in 2012, the proportion of the population living in urban areas was 50.9% whereas in 2000, the proportion was 43.8%.[52] When a smaller proportion of the population lives in rural areas, the ownership of electric devices naturally shrinks or grows at a much slower rate compared to urban regions. As shown in Figure 4, the four regions connected to the Bui Dam, the Brong-Ahafo, Northern, Upper East, and Upper West region, have the highest proportion of their population in rural areas.

Figure 4: Population by type of locality (urban and rural) in Ghana - 2010



Source: Ghana Stasticial Service, 2012.[53]

MALARIA PREVENTION

ACCORDING TO KIBRET *ET AL.*, IN SUB-SAHARAN AFRICA, dams contribute significantly to malaria risk particularly in areas of unstable malaria transmission.[54] Kibret stated that in areas of unstable transmission, approximately 919,000 malaria cases per year were associated with the presence of 416 dams. In areas of stable malaria transmission, 204,000 malaria cases per year were associated with the presence of 307 dams. Therefore, additional malaria control measures should be taken into consideration along with the construction of dams to reduce the impact of dams on malaria.

Table 9: Malaria Prevention

	Has Mosquito Bed Net for Sleeping		# of Children Sleeping under Bed Nets		#of Mosquito Bed Nets	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
1. dam#1.post	-0.0751*** (0.0119)	-0.119*** (0.0148)	-0.0235 (0.0157)	-0.0492* (0.0221)	-0.000863 (0.0302)	-0.120** (0.0405)
1. post#1. urban#1.dam	-	0.103*** (0.0249)	-	0.0500 (0.0301)	-	0.224*** (0.0603)
1. dam	0.254*** (0.0154)	0.261*** (0.0169)	0.210*** (0.0203)	0.229*** (0.0227)	0.631*** (0.0389)	0.689*** (0.0417)
1. post	0.273*** (0.00698)	0.315*** (0.00978)	0.0600*** (0.00732)	0.116*** (0.0124)	0.758*** (0.0158)	0.939*** (0.0242)
2. region	0.0372** (0.0123)	0.0408*** (0.0121)	0.0135 (0.0137)	0.0172 (0.0135)	0.0889** (0.0299)	0.0985*** (0.0294)
3. region	-0.115*** (0.0118)	-0.0552*** (0.0123)	-0.0907*** (0.0115)	-0.0336** (0.0117)	-0.188*** (0.0274)	-0.0459 (0.0286)
4. region	0.129*** (0.0121)	0.120*** (0.0121)	0.0949*** (0.0152)	0.0861*** (0.0151)	0.457*** (0.0334)	0.435*** (0.0332)
5. region	0.0149 (0.0119)	0.0169 (0.0118)	0.00227 (0.0133)	0.00450 (0.0131)	0.0631* (0.0289)	0.0694* (0.0286)
6. region	-0.0140 (0.0116)	0.0104 (0.0116)	0.0131 (0.0128)	0.0372** (0.0127)	-0.0171 (0.0272)	0.0447 (0.0270)
7. region	-0.0794*** (0.0122)	-0.0500*** (0.0121)	-0.0760*** (0.0186)	-0.0280 (0.0185)	-0.345*** (0.0348)	-0.242*** (0.0347)
8. region	-0.116*** (0.0130)	-0.102*** (0.0128)	0.0380 (0.0214)	0.0606** (0.0212)	-0.103* (0.0405)	-0.0543 (0.0399)
9. region	-0.0959*** (0.0130)	-0.0930*** (0.0130)	-0.104*** (0.0190)	-0.0965*** (0.0189)	-0.106** (0.0403)	-0.0902* (0.0399)
1. urban	-	-0.0930*** (0.0114)	-	-0.0752*** (0.0109)	-	-0.146*** (0.0211)
1. dam#1.urban	-	-0.0797*** (0.0211)	-	-0.137*** (0.0232)	-	-0.317*** (0.0418)
1. post#1.urban	-	-0.0590*** (0.0137)	-	-0.0872*** (0.0149)	-	-0.294*** (0.0315)
_cons	0.425*** (0.00986)	0.456*** (0.0111)	0.169*** (0.0104)	0.190*** (0.0119)	0.597*** (0.0217)	0.628*** (0.0234)
N	29,454	29,454	29,454	29,454	29,454	29,454
r2	0.103	0.121	0.0277	0.0475	0.128	0.150
F	321.1	300.5	81.38	88.01	469.4	396.3

Notes: Adjusted standard errors in parantheses: * p<0.05, ** p<0.01, *** p<0.001

People who live within five kilometers of the reservoir, which is estimated based on mosquitoes' limited flight range, are considered at risk of being infected by malaria. Increased malaria cases following dam construction are reported in many sub-Saharan African countries including the Bamendjin Dam in Cameroon, the Kamburu Dam in Kenya, the Koka reservoir in central Ethiopia, the Gilgel Gibe Dam in southwest Ethiopia, the Manyuchi Dam in Zimbabwe, and the Akosombo Dam in Ghana.

According to Ghana Health Service, as of 2016 malaria was still the top disease in the country. Long-lasting insecticide treated bed nets (LLINs), one of the most cost-effective malaria prevention devices, were allocated, distributed, and covered 89.7 percent of Ghana. The Upper West region, where the reservoir is located, had 98-percent coverage of the region as of September 2016. The number of health facilities increased from 6,869 in 2015 to 7,060 in 2016, which is a 2.8 percent increase. Malaria cases recorded increased from 4,319,919 in 2015 to 4,533,431 in 2016, which is a 4.9 percent increase. Based on national statistics of malaria incidence, it is hard to tell whether the construction of the Bui Dam has negatively affected the local population.

According to its website, the Bui Dam Authority provides support through its Community Health Program which provides access to primary health care, and holds regular awareness campaigns on communicable diseases to improve healthcare for local households, especially for relocated people.[55] Thus, we chose three malaria prevention indicators to evaluate the Bui Dam's potential impacts on health: whether the household has mosquito bed nets for sleeping, number of mosquito bed nets households own, and number of children under five sleeping under the mosquito bed net.

We do not see significant coefficients through Model 1, but do observe a significant and positive DiD coefficient from Model 2 for households with mosquito bed nets as well as the number of mosquito bed nets these households possess. On average, in the dam regions, the likelihood for an urban household to have a mosquito bed net has increased by 10.3 percent after the Bui Dam's construction, and the number of mosquito bed nets an urban household possessed increased by 0.23. The improvement in ownership of mosquito bed nets shows that household prevention of malaria may be related to the Bui Dam Authority's efforts to improve the healthcare of local communities.

CONCLUSION

CHINA HAS BECOME A MAJOR FINANCIER OF ENERGY infrastructure projects in Africa. However, most research on the impacts of China-financed energy infrastructure only focuses on the environmental damage and resettlement of local communities; few people have investigated the potential social-economic benefits China-financed infrastructure might have brought to the region. Focusing on the case study of the China-financed Bui Dam in Ghana, this paper uses qualitative literature review and quantitative analysis to study the Bui Dam's environmental and socio-economic impacts.

The literature review shows that there are many worries about the adverse social and environmental impacts of the Bui Dam. These concerns have been raised along with the project due to the nature of the hydroelectric dam as well as the involvement of Chinese actors. However, as the Bui Dam was planned long before China's participation, Western companies and organizations executed the feasibility studies and environmental impact assessments, ensuring that the project was in line with international norms and standards. In addition, the major financier of the project, EximBank, also intends to improve its environmental standards and governance, as it has required borrowers to submit to internal review and comply with local laws of the host country since 2004. Eximbank even emphasizes the OECD Arrangement in its lending practices. Even though the Bui Dam project did not go through an international bidding process, it appears to have been bounded by international norms and standards.

We also find that the adverse environmental impacts of dams do not only depend on the performance of Chinese companies. Local governance and Chinese companies' contractual setting co-determine the environmental protection measures that Chinese companies adopt in their project implementation. The cooperation between Ghana's Bui Dam Authority and Sinohydro have helped minimize the environmental damage during the construction of the dam as well as smooth the turn-key process afterwards.

Compared to other previously built dams, Sinohydro, the Chinese Communist Party, and the Bui Dam Authority designed and prepared for the Bui Dam project in better ways, including a more comprehensive resettlement program, activities that helped expatriates and local workers have more harmonious relationships, and established medical facilities for combating malaria and other waterborne diseases. It is fair to say that the Bui Dam project adopted more improved standards and management practices than prior dam projects in the country.

In the quantitative analysis of the Bui Dam's social-economic impacts, two DiD models were used. We first compared the socio-economic indicators of all households in the four northern regions to which the Bui Dam's power largely transmits power with their counterparts living in the other six Ghanaian regions before and after the completion of the Bui Dam. Then we used a triple DiD model to evaluate whether urban and rural households in the treatment regions had different levels of improvement in standards of living.

Empirical analysis shows that the Bui Dam has a statistically significant correlation with the improvement of all households' access to electricity. The likelihood of households in the treatment regions to have access to electricity increased 4.16 percent after the Bui Dam's construction. All household ownership of mobile phones and telephones increased significantly. Although the average ownership of computers, refrigerators, and TVs saw a decrease among the dam regions after the treatment, a breakdown of this negative coefficient into households with different incomes shows that poorer households' ownership of these appliances was increasing faster than their counterparts in the control regions, while that of the richer households was not as fast as the control regions after the completion of the dam. As these high-wattage appliances are relatively expensive in Ghana and might be owned mostly by wealthier households, the slower increase of rich households' ownership of these items may have influenced the general increase rate in the dam regions and caused these households' ownership of these expensive appliances to be smaller than that of the control regions.

We found stronger treatment effects on urban households when using the triple DiD model. On average, urban households saw an increase of 14.5 percent in their likelihood of accessing electricity. They were 12.3 percent more likely to have refrigerators, and 20.8 percent more likely to own TVs after the Bui Dam was built. As the likelihood of owning mosquito bed nets increased by 10.3 percent, their malaria prevention also improved. The urban-rural disparity in the improvement of standards of living may be caused by the lack of rural electrification infrastructure due to the last-mile problem. Migration from rural to urban areas and from the under-developed northern regions (treatment regions) to the more developed South (control regions) may also have contributed to the relatively slower increase of rural ownership of high-wattage electric appliances.

This paper intends to contribute to the ongoing observation of the socioeconomic impacts of China-financed hydropower projects in developing regions, especially Sub-Saharan Africa, through a combination of quantitative and qualitative case analysis of Ghana's Bui Dam. Although some other literature suggests that construction of the Bui Dam might negatively impact health conditions near the dam while also not significantly increasing people's access to electricity and appliances, our analysis and models show that it indeed has had positive influences on malaria prevention and increased local communities' usage of electricity and appliances. ★

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AUTHOR BIOS

KEYI TANG:

Keyi Tang is a M.A. student of International Economics at the Hopkins-Nanjing Center. As a Nanjing Scholar at SAIS D.C., she conducted empirical and field research on China's hydropower projects in Ghana and China's special economic zones in Ethiopia and Vietnam. Previously, she researched the role of Western FDI on China's structural change through internships at Apple, the European Union Chamber of Commerce in China, and CNBC. She holds a B.A. from Nanjing University in English Language and Literature.

YINGJIAO SHEN:

Yingjiao Shen is currently an Arabic and Chinese research analyst at Duff and Phelps. From 2016 to 2018 she worked at CARI as a research assistant where she mainly focused on the North Africa region and conducted research in English, Chinese, Arabic, and French. Shen earned her M.A. from Johns Hopkins SAIS in the Spring of 2018.

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SAIS China-Africa Research Initiative
1717 Massachusetts Avenue NW, Suite 733
Washington, DC 20036
www.sais-cari.org
Email: sais-cari@jhu.edu

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