A Dam Problem:
Investigating the Influence of Dams on Economic Development

An Honors Thesis Submitted in Partial Fulfillment of the
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Abstract

Approximately 59,071 man-made large dams have been constructed worldwide to control flooding, provide electricity, supply water, improve navigation routes, farm animals, etc.; there is an extensive list of dams that are planning on being built for rapid development. While the intention of these dams is positive, their installation has displaced between 40 and 80 million people worldwide. The purpose of this study is to determine if the overall economic health of an area improves or diminishes after a dam is constructed. To address this question, a dataset from the Food and Agricultural Organization of the United Nations which contains characteristics of every man-made dam that has been constructed across all countries from 1960 to 2017 was combined with a dataset from NASA's Socioeconomic Data and Application Centers which contains the GDP of every one degree of surface area of every continent. Initial regression results show that in Africa and Asia, the presence of a dam has a nonlinear impact on the surrounding area's GDP; areas close to the dam are negatively impacted, however, past a certain distance that is specific to each continent, the dam's presence has a positive impact on the area's GDP.

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Introduction

Approximately 59,071 large man-made dams have been constructed worldwide to improve flood control, provide electricity, supply water, etc. (ICOLD, 2019). While the intention of these dams is positive, they have displaced between 40 and 80 million people (Altinbilek, 2002; Bosshard, 2009; Duflo and Pande, 2007). Dams are typically built in rural areas, and their construction alters the landscape of the surrounding area which is what leads to displacement. Even though dams may be beneficial for their intended purpose, it is important to look at their net effects. This research will determine whether the pros outweigh the cons in the areas that are surrounding the dam by calculating the net benefits in relation to changes in GDP.

There has been controversy from prior works as to whether or not displaced people's income increases or decreases due to the displacement. Income increases occur when governments subsidize the displaced; however, the subsidy does not last forever. Income decreases occur due to job losses and lifestyle changes since inhabitants of these rural areas are forced into moving to more urban areas. Instead of focusing on individuals' income like prior works in the literature review have done, this study is looking at how gross domestic product (GDP[1]) changes in surrounding areas in order to get a broader understanding of displacement effects. Since the displaced are faced with more obstacles than income changes, the hope is that GDP will account for this.

This research is important because the majority of the dam research has been anecdotal and focused on a specific country, region, or river. According to the literature, there has been no large scale research on how dams have affected surrounding areas, so this will add to the field by providing new information. It is important to understand the

[1] Gross Domestic Product (GDP) = measures the monetary value of final goods and services produced in a country in a particular period of time

overall impact dams have on the economy, and the best way to do this is by doing a large scale study. This study is strictly completed by using econometrics, not anecdotes, which establishes the credibility of the conclusion that the presence of a dam has a nonlinear impact on the surrounding area's GDP.

This study uses datasets from the Food and Agricultural Organization of the United Nations[2] (FAO) and NASA's Socioeconomic Data and Application Centers[3] (SEDAC) to look at the GDP of dams' surrounding area and see if/how GDP changes before and after the dam is constructed. GDP measures the economic activity of the area it is collecting data from, so this will show if the overall economic health of an area improves or diminishes after a dam is constructed. This study was completed across every continent, excluding Antarctica and North America. Antarctica had to be excluded since no dams are located there. North America was excluded due to the fact that it is a developed continent, and the majority of literature on dam displacement focuses on developing countries. Regressions are run on every continent separately due to the fact that the construction of a dam in one continent will not impact the GDP of another continent.

The dataset used in this study gathers information of dams built between 1960 to 2017 with a total of 6,156 dams being observed after cleaning the data to ensure every variable is available for every dam. While the regressions were run on every continent separately, the only significant results were obtained from Africa and Asia; however, the significant results from Africa and Asia are economically noteworthy because of the sheer number of dams and the total population in each continent. There are 1,419 dam observations in Africa and 2,793 dam observations in Asia, and the United Nations 2019

[2] http://www.fao.org/nr/water/aquastat/dams/index.stm
[3] http://sedac.ciesin.columbia.edu/data/set/spatialecon-gecon-v4/data-download

World Population Prospects states that Asia houses roughly 4.7 billion people which is 61% of the population and Africa houses roughly 1.3 billion which is 17% of the world population. Both continents also have a large number of developing countries, so studying how dams affect the local economic activity will make a valuable addition to the existing literature on the effect of large scale dam construction to the local economy.

Overall, I find that the presence of a dam has a nonlinear impact on the surrounding area's GDP; however, this impact varies across continents. This nonlinear impact means that areas close to the dam are negatively impacted by the presence of the dam, but, past a certain distance that is specific to each continent, the dam's presence has a positive impact on the area's GDP. Displacement from the area surrounding the dam is likely the reason why GDP decreased in this vicinity, and the increase in population past a certain distance of the dam is likely why GDP increases. I also find that dams built to provide *hydroelectricity* decrease GDP of the nearby cells; however, their impacts are partially offset as distance from the dam increases. This could be because the benefit of electricity generation is mainly felt by places away from the dam, and those not close to the dam. The results are robust to changes in the specifications of the model.

The following sections will discuss the influence dams have on their surrounding area. The literature review provides a brief history of dams, an explanation of dams' purposes, and an analysis of prior works that discuss displacement in relation to dams. The methods section discusses how the data for this study was collected and cleaned, and it discusses the two models used to complete the study. The initial findings section analyzes the data and discusses how dams influence GDP. Finally, the conclusion summarizes the thesis and discusses the implications of the research.

Literature Review

Dam Definition

The Food and Agricultural Organization of the United Nations (FAO) takes a very specific approach and defines a dam as "a barrier built across a stream, river, or estuary to conserve water for such uses as human consumption, irrigation, flood control, and electric-power generation" which is an accurate definition for the dams that are being observed in this thesis. This study will be focusing on how man-made dams affect their surrounding area. Specifically, this study will be observing large dams which the International Commission of Large Dams (ICOLD) defines as being 15 meters or more in height or having a reservoir capacity of 3 million meters^3 or more.

Dam History

Thorough investigation of remains in Africa concludes that around 2950-2750 B.C. the Egyptians constructed the Sadd-el-Kafara dam which is known as the world's first dam. The dam was placed on a valley in the Nile river, and scientists believe that it was built to prevent the nearby area from being flooded during wet winters (Jackson, 2017). Flood control is one of the dam purpose categories that the FAO uses along with irrigation, water supply, hydroelectricity, navigation, recreation, pollution control, and livestock rearing (Altinbilek, 2002; FAO, 2016; ICOLD, 2019; Thomas, 2002). While the purpose of dams is positive and meant to improve the economy, there are many times that their construction has the opposite effect as it has resulted in displacing millions of people across the globe.

Dam Purposes

Across the world, dams provide multiple purposes which the Food and Agricultural Organization of the United Nations puts into eight main categories:

irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution control, and livestock rearing (FAO, 2016). The FAO has complied a database of dams built across the globe from 1960 to 2017 where each dams' purpose is recorded. *Figure 1* provides a breakdown for why dams are constructed worldwide, and it concludes that dams are most popularly used to provide hydroelectricity. *Figure 2* and *Figure 3* provide a breakdown for why dams are constructed in Africa and Asia, respectively. Hydroelectricity is the most popular reason for dam construction in Africa (43 percent) and the second most popular reason for dam construction in Asia (21 percent).

Figure 1: Worldwide Dam Purposes

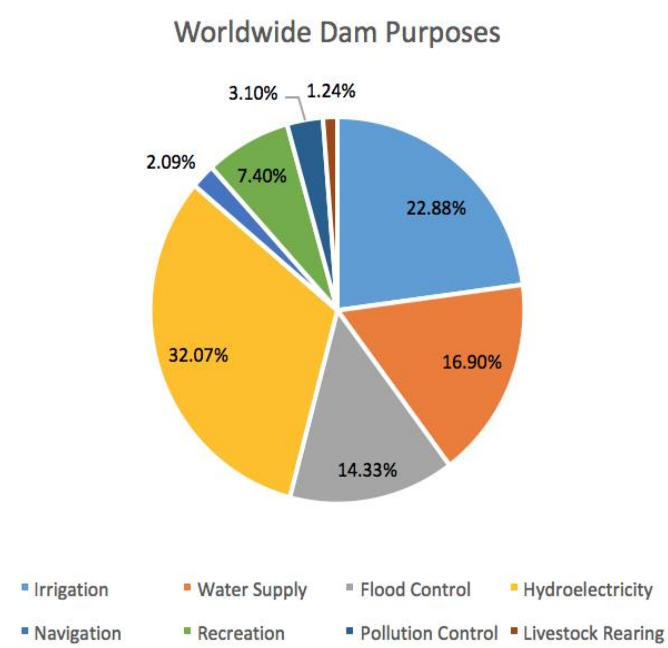


Figure 2: Africa Dam Purposes

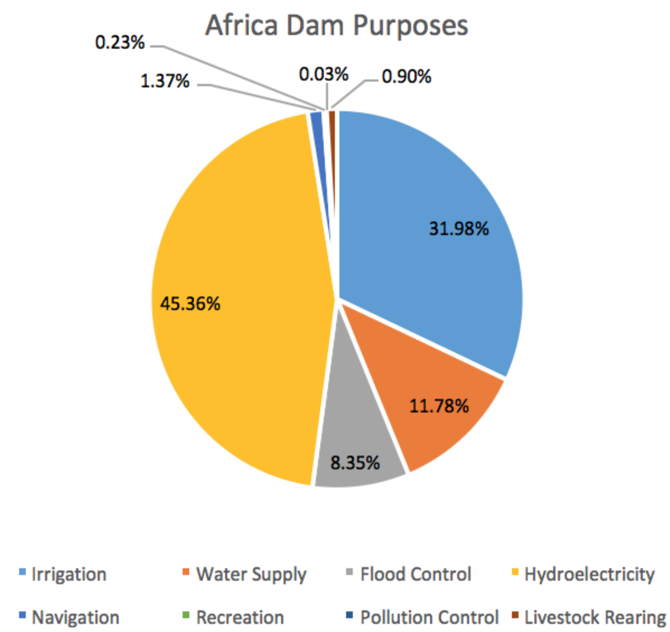
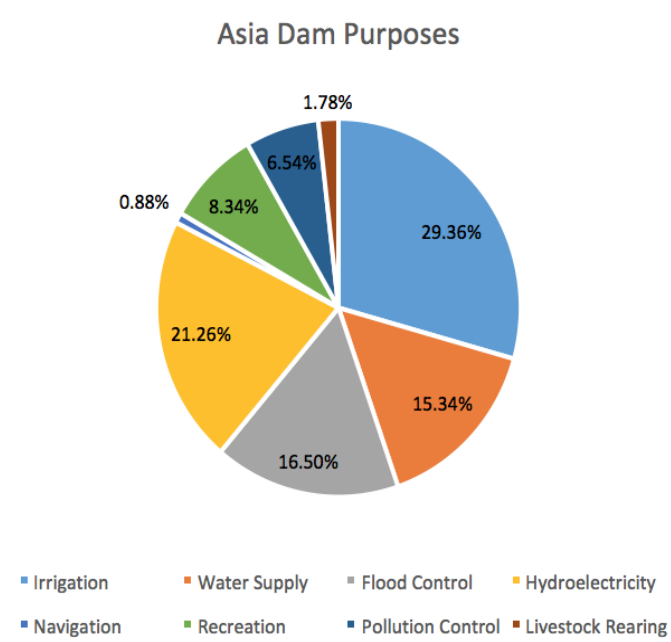


Figure 3: Asia Dam Purposes



For dams to be used for hydroelectricity, a reservoir must be created to store water. Downstream from the reservoir is where the hydroelectric dam is constructed. At the entrance of the dam is a gate, and opening and closing the gate regulates the flow of the water source. The force of the water source moving downstream pushes through a generator where the water flow's energy to converted to electricity, also referred to as hydroelectric power, and it is transferred straight to connected power lines (NREL, 2019).

When dams are built for irrigation purposes, water is saved in a reservoir to be used for watering crops. This purpose becomes especially beneficial during times of decreased rainfall (FEMA, 2019). The largest proportion of dams in Asia is for irrigation purposes, showing that Asia relies on dams for food security.

Maintaining water supply is a dam purpose that has become more prevalent over the past three centuries because the amount of freshwater consumed across the world has increased by 35%. This increase in demand has led to a decrease in its supply because it is supplied in a fixed amount. Water is a limited natural resource that is necessary for all living beings, so a solution was needed to help ensure access to freshwater. In order to combat this increasing demand, dams are continuously being installed (Altinbilek, 2002). Dams save water in a reservoir which allows water to be available at all times of the year, even when the natural flow of the river should be low (Altinbilek, 2002; Duflo and Pande, 2007).

There are two main reasons dams are built to control floods. First, since arable land is found around water sources, they are typically damned in order to prevent flooding which would result in the killing of crops. Second, water sources might also be damned if they are prone to flooding in order to prevent the destruction of nearby residencies (FEMA, 2019).

Recreational purposes include boating, kayaking, camping, docking areas, makeshift lake beaches, and additional water related activities. While this is not a very common worldwide dam purpose, this is why the majority of dams are built in the United

States (FEMA, 2019). This is not a typical construction purpose for developing countries who do not have the same resources as the U.S. to engage in these activities which further explains why the United States was removed from this thesis.

Pollution control dams are typically placed in water sources near construction sites. These dams are placed to control and divert runoff to a contained area where the runoff will cause the least harm, erosion, and flood damage to the surrounding area. Dams built for this purpose are sometimes temporary until the nearby construction is completed; however, they can be permanent as well (EPA, 2007).

Dams built for navigation purposes are known for altering the structure of the water source upon which the dam is placed. The typically altercations that occur are changes in the water source's width and volume, and these changes can consciously evolve over time. These structural changes have been known to lead to flooding of the surrounding area (Anderson and Grubaugh, 1989).

Worldwide, livestock rearing is the least common dam purpose. Dams used for livestock rearing are typically a way to control the supply of seafood.

Displacement

Dams have been constructed on approximately 60% of the world's rivers (Altinbilek, 2002). While their construction has fulfilled their intended purposes, they have also imposed an extreme problem of displacing millions of people who live in the surrounding area of where the dam was installed (Altinbilek, 2002; Bosshard, 2009; Duflo and Pande, 2007; Galipeau, Ingman, and Tilt, 2013; Parasuraman, 1996; Randell, 2016; Thomas, 2002; Wilmsen, 2016). Displacement occurs because the installation of dams brings new roads, powerlines, buildings, etc. which changes the structure of the surrounding area. Those displaced often lived in rural areas around the river which has led to multiple variations of impoverishment including "landlessness, joblessness, homelessness, marginalization, food insecurity, morbidity and social disarticulation" because they have to change the way they were used to living after their resettlement (Bosshard, 2009; Parasuraman, 1996, p. 1529).

Various studies have been performed that have found displacement to have positive effects on the displaced people in the short run but only when the government intervenes. Increases in income occurs when the government of the area recognizes the displacement and provides subsidies/compensation to the displaced (Galipeau, Ingman, and Tilt, 2013; Randell, 2016; Wilmsen, 2016). For example, when the dams were built in the Yunnan Province of China, the displaced were provided government subsidies and their income increased (Galipeau, Ingman, and Tilt, 2013). When the Belo Monte Dam was installed in the Brazilian Amazon, the displaced who received government compensation saw an increase in their socioeconomic status (Randell, 2016). This increase in income/socioeconomic status has only been seen as short-run improvement because government subsidies do not last forever (Galipeau, Ingman, and Tilt, 2013; Randell, 2016). When the Three Gorges Dam displaced 1.13 million people in China, income levels of the displaced decreased for 8 years until the Chinese government stepped in by providing funds for the displaced (Wilmsen, 2016). Wilmsen's (2016) study emphasizes how governments intervention by providing subsidies is the main reason the displaced will benefit from their involuntary resettlement.

Gaps in current literature about dams include studying the displaced from a concentrated region, river, or country and only looking at how the displaced are affected in the short run. Research has not been completed on dams on a nationwide scale. This research project will help fill in the gaps by looking at continent and worldwide dam data to determine the overall effect of dams. Instead of focusing on individual and household income levels, this study will look at the total GDP of the surrounding area in order to determine the average effect dam displacement creates continent-wide and worldwide.

Methods

Data Sources

The first dataset is found on the Food and Agriculture Organization (FAO) of the United Nations' website, and the Excel dataset for each continent contains information from every dam that has been built and is planned on being built in the world from 1960 to 2017 including their exact latitude and longitude location to the nearest four decimal places. The FAO breaks up each dam dataset by region. The regions include Africa, Middle East, Central Asia, Southern and Eastern Asia, Europe, Oceania, Northern America, Central America and Caribbean, and Southern America. For conciseness, Middle East, Central Asia, and Southern and Eastern Asia were combined into "Asia". The following categories of data have been kept after cleaning this dataset: country, name of dam, nearest city, river, major basin, sub-basin, completed/operational since, the purpose of the dam, decimal degree latitude, and decimal degree longitude (FAO, 2016).

The second Excel dataset is from NASA's Socioeconomic Data and Applications Center (SEDAC) which has been compiled by William Nordhaus, a Nobel Prize winning Economist, and his team from Yale University. Information in this dataset was gathered by gridding every one degree of the surface area of every continent. The output of each cell was calculated using ArcGIS which is an information system that shows the height of economic activity in each cell in proportion to the output of each cell. Gross cell product was then calculated by multiplying the population of each gridded cell by the per capita gross cell product of each gridded cell. This value was adjusted for purchasing power parity by using 2005 United States exchange rates (*ppp)*, which is equivalent to the GDP for each grid, for the years 1990, 19995, 2000, and 2005 (Nordhaus et al., 2006). The following data for each grid has been kept after cleaning this dataset: area, country, latitude, longitude, the population of each grid, and *ppp* (SEDAC, 2019). Typically for developing countries, there is not an accurate measure of GDP at the subnational level since they have weak statistics offices and the majority of the economies are subsistence economies, so this dataset is unique in that it breaks down every country into one-degree gridded cells in order to get a more accurate estimation of GDP.

Do Files and Stata Datasets

Stata, a statistical software, was used to analyze the dataset created by combining the FOA and SEDAC Excel datasets to determine if the overall economic health of an area improves or diminishes after a dam is constructed. Three do files, which are Stata coding documents, were identically created for each continent to merge the FAO and SEDAC Excel datasets together so regressions could be run on a continental basis. Both these datasets contain longitude and latitude data which allowed these datasets to be merged together in Stata in order to relate each gridded cell to each dam within a specific country to determine the distance from each dam to each cell. The GDP of all cells within certain radiuses of the dam was looked at, so distance to the exact decimal place is not necessary. Each country and its amount of dam observations used in this study can be found in **Appendix Tables 1.1 – 1.6.**

The first do file starts by importing the SEDAC Excel dataset which contains each cell in the continent. This do file assigns a numerical id to each cell in the continent. *Table 1* shows how many cells are in each continent. Each cell has its specific associated longitude and latitude. Thus, the larger the surface area of the continent, the more cells the continent will contain. This do file contains the following variables: cell id, country name, latitude, and longitude.

Table 1: Cells in Each Continent

Africa	3,546 cells
Asia	4,023 cells
Central America	154 cells
Europe	4,899 cells
Oceania	877 cells
South America	923 cells

The second do file starts by importing the FAO Excel dataset which contains every dam in the continent. This do file assigns a numerical id for each dam in each country in each continent. Each dam has an associated longitude and latitude coordinates, and the Stata command "geodist" calculated the distance between the geographical location of a specific dam in a country and the geographical location of each cell in a specific country. Next, the smallest distance of these distances (labeled minimum distance) was found to determine the closest dam to each cell in each country. The purpose of finding the minimum distance is because the cell closest to the dam should have the initial impact of the dam construction. The final code in this do file merged in the population and ppp of each cell for the years 1990, 1995, 2000, and 2005. This do file contains the following variables: cell id, dam id, country name, latitude, longitude, distance to the closest cell, minimum distance between a dam and cell in the country, year, population, and ppp.

The third do file starts by importing the dam Excel dataset from the FAO into Stata. Each dam's purpose (i.e. irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution, and livestock rearing) were converted to dummy variables. If a dam was not built for the specified purpose, a 0 was assigned to the purpose; however, a 1 was assigned to the purpose if the specific purpose was why the dam was constructed. Longitude and latitude associated with each dam allowed this file to be merged with each gridded cell and its associated population and ppp. A new variable, *minimum distance squared*, was created by squaring minimum distance in order to account for any nonlinear implications dams may have on their surrounding area. This do file created a Stata panel dataset which contains the following variables: country name, the date the dam was completed, latitude, longitude, dummy variables for each dam purpose (i.e. irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution, and livestock rearing), dam id, year (i.e. 1990, 1995, 2000, 2005), population, ppp, distance to the closest cell, minimum distance between a dam and cell in the country, and minimum distance squared.

The final Stata datasets for each continent were then merged together into a large Stata dataset so fixed effects regressions could be run in a loop for each continent in order to determine if the construction of a dam has an impact on the overall economic health of its surrounding area. *Ppp* is the dependent variable, which is the GDP of the cell, and the main regressor is the distance of the nearest dam to a cell (*min distance*). The dummy variables for dam purposes (i.e. irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution, and livestock rearing) were included in many regressions to determine if the dam's purpose plays any role in the dam's effect on the surrounding area. Regressions were run on each continent individually and not on a worldwide basis because the placement of a dam in one continent will not affect the overall economic health of another continent or of another country within that continent.

For example, if a dam was constructed in Australia, this dam will not affect the economic health of any country in South America since they are not connected.

The summary statistics for each continent can be found in **Appendix Tables 2.1 – 2.6**. These statistics show how often each dam purpose is used in each continent. They also show the mean population and *ppp* in each continent. In Africa, the mean *ppp* for a one-degree gridded cell is 0.4795986 and the mean population is 621432.1 people (see **Table 1**). In Asia, the mean *ppp* for a one-degree gridded cell is 3.417778 and the mean population is 851743.8 people (see **Table 2**).

Models

Two main models were used for this study in order to determine the impact the placement of a dam has on the overall economic health of its surrounding area. The dependent variable for this study is gross domestic product of the cell, referred to as *ppp* throughout this paper, which is benchmarked to 2005 United States dollars at purchasing power parity exchange rates. The theory behind this model is that dams are constructed in rural, subsistence economy areas around rivers. Constructions of dams changes the landscape of the surrounding area and displaces inhabitants due to the fact that buildings, power lines, roads, and various other developmental infrastructures have to be placed upon the locals' homes and land. This displacement is what leads to a decrease in *ppp* in the area nearby surrounding the dam because there is now less economic output being produced there since the inhabitants are forced to move out. The results of the nonlinear dam implications are shown in areas where the displaced move to because there are now more people in the area which increases the amount of economic output being produced.

Ceteris paribus, if *ppp* increases after a dam is constructed, this implies that the overall economic health of the area improved. Vice versa, if *ppp* decreases after a dam is constructed, this implies that the overall economic health of the area decreased. Each independent variable will be studied to see how it impacts *ppp*.

$$1. PPP_{it} = b_0 + \theta_1 mindist_i + \delta x_{it} + \varepsilon_{it}$$

The main variable of interest for this study, also known as the main regressor, is the distance of the nearest dam to a cell (*mindist*). The goal is to determine if/how the *ppp* of the nearest cell to a dam changes once a dam is constructed. In this equation, X represents all of the dam purpose variables included in the model: irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution control, and livestock rearing. Each purpose is constructed as a dummy variable; it is assigned the value 1 if it is the dam's purpose and a 0 if it is not. In this model, ε_{it} is the error term.

The one problem with this model (1) is that it does not take the dam's nonlinear effects into consideration. For example, if the coefficient of θ is negative, this model shows that the construction of a dam will have a negative impact on its surroundings, and the negative impact will increase as we move away from the dam. However, a dam may have a negative local effect, but its overall effect on the country may be positive. To improve on this, an additional model was created by adding a squared minimum distance term:

$$2. PPP_{it} = b_0 + \theta_1 mindist_i + \theta_2 mindist^2 + \delta x_{it} + \varepsilon_{it}$$

Adding minimum distance squared to the model (2) accounts for any nonlinear dam placement implications. Dams pose different effects on their surrounding area if the coefficients $\theta_1$and θ_2 are positive or negative. These different effects are shown in *Table*

2. This model (2) is an improvement from the first model (1) because it shows the different effects distance has on *ppp*.

Table 2: How the Sign of θ Effects PPP

Sign of Coefficients	Effect
$\theta_1 > 0, \theta_2 > 0$	Always Positive
$\theta_1 < 0, \theta_2 > 0$	Positive impact until mindist=$\theta_1/2\theta_2$, then negative
$\theta_1 > 0, \theta_2 < 0$	Negative impact until mindist=$\theta_1/2\theta_2$, then positive
$\theta_1 < 0, \theta_2 < 0$	Always Negative

Table 2 says the following: (1) if both θ_1 and θ_2 are greater than 0, this implies that dams in this area increase *ppp* locally and throughout the country (2) if θ_1 is less than 0 and θ_2 is greater than 0, this implies that dams in this area increase *ppp* locally but have a negative impact past a certain mileage that is specific to each continent (3) if θ_1 is greater than 0 and θ_2 is less than 0, this implies that dams in this area decrease *ppp* locally but have a positive impact past a certain mileage that is specific to each continent (4) if both θ_1 and θ_2 are less than 0, this implies that dams in this area decrease *ppp* both locally and throughout the country.

Regressions were run on the following continental areas to determine if the placement of a dam affected its nearby area: Africa, Asia, Central America, Europe, Oceania, and South America. The main regressor, *min distance,* is never significant for Europe, Oceania, and South America (see **Appendix Tables 3.1**, **3.2**, and **3.4**), and it is inconsistently significant for Central America (see **Appendix Table 3.3**). *Min distance* is always significant for Africa and Asia which is why the majority of the analysis for this study will be focused on these two continents.

Findings

The main regressor of this study is the distance of the nearest dam to a cell (*min distance),* and this study is looking at how *min distance* affects the dependent variable, gross domestic product of the cell *(ppp)*. Additional variables that were included in the regressions were dummy variables indicating the purpose for constructing the dam: irrigation, water supply, flood control, hydroelectricity, navigation, recreation, pollution control, and livestock rearing. Originally, regressions were run without squaring *min distance* (see **Table 3** and **Table 4**); however, this did not control for any nonlinear implications dams have on their surrounding area. This resulted in dams only having a negative impact on *ppp* which translates to dams consistently decreasing *ppp*. Squaring *min distance* (see **Table 5** and **Table 6**), takes into consideration the nonlinear implications dams have on their surrounding area.

Regressions were run on Africa and Asia to determine if the placement of a dam affected its nearby area[4]. Below is an analysis of how dams affect the surrounding areas of Africa and Asia which are shown in **Table 5** and **Table 6**, respectively.

Africa

The concatenated result for Africa's main regression is shown in **Table 5 Regression (1)** which is written as the following:

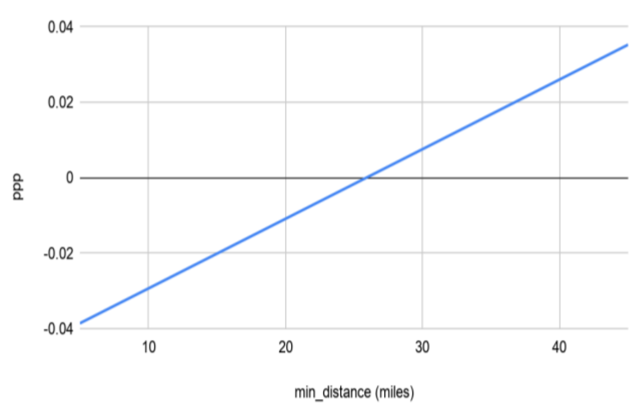
$$Equation\ 1: Y = a - 0.0478x + 0.000923x^2$$

$$Equation\ 2: \delta Y/\delta x = -0.0478 + 0.001846x$$

[4] Africa and Asia are important continents to study since they contain the largest percentage of the world's population and dams.

For the derivative of this regression, the coefficient on *min distance* is negative and it is positive on *min distance squared*. Setting *equation 2* equal to zero finds the mileage distance where the placement of a dam switches from having a negative impact on the area's GDP to a positive impact. This means that the dam has a negative impact on the surrounding area's GDP until the area is 25.89 miles away from the dam; past this mileage, the dam's presence has a positive impact on the area's GDP (*ppp*). This is further illustrated in *Figure 2* below. If the area is within 25.89 miles from the dam, the impact of the dam on the area is negative, but if the dam is located further than 25.89 miles, economic impact on the area becomes positive (see *Figure 2*).

Figure 4: The Derivative of Cell GDP with Respect to Distance from the Dam in Africa



Even when dam construction purposes were added and country fixed effects were taken into consideration to run additional regressions, *min distance* continued to be a significant variable. In comparison to **Table 5 Regression (1)**, every regression has a negative coefficient on *min distance* and a positive coefficient on *min distance squared*, so this follows the same explanation as above. When regressions are run using dam construction purposes without country fixed effects being considered, *recreation* and *livestock rearing* are the only two dam construction purposes that are not significant. Once adding country fixed effects to the regression (see **Table 5 Regression (4)**) *hydroelectricity* becomes the only significant dam construction purpose. Alone, *hydroelectricity* only decreases *ppp*; however, its negative impact is partially offset by *min distance* and *min distance squared*. This regression (**Table 5 Regression (4)**) shows that when a dam is built to provide *hydroelectricity*, GDP of the nearest cell *(ppp)* decreases by 20.5%. Even when adding these variables, *min distance* remains significant.

Asia

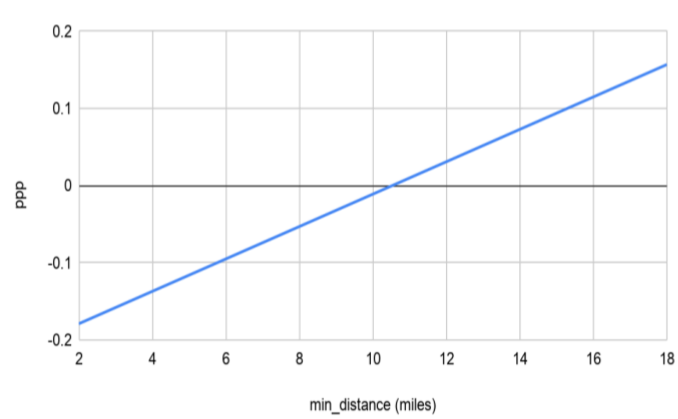
The concatenated result for Asia's main regression is shown in **Table 6 Regression (1)** which is written as the following:

$$Equation\ 3: Y = a - 0.221x + 0.0105\,x^2$$

$$Equation\ 4: \delta Y/\delta x = -0.221 + 0.021x$$

Similar to Africa, for the derivative of this regression, the coefficient on *min distance* is negative and it is positive on *min distance squared*. Setting *equation 4* equal to zero finds the mileage distance where the placement of a dam switches from having a negative impact on the area's GDP to a positive impact. This means that the dam has a negative impact on the surrounding area's GDP until the area is 10.52 miles away from the dam; past this mileage, the dam's presence has a positive impact on the area's GDP (see *Figure 3*).

Figure 5: The Derivative of Cell GDP with Respect to Distance from the Dam in Asia



Even when dam construction purposes were added and country fixed effects were taken into consideration to run additional regressions, *min distance* continued to be a significant variable. When regressions are run using dam construction purposes without country fixed effects being considered, *recreation*, *navigation*, and *livestock rearing* were the dam construction purposes that are not significant. Once adding country fixed effects to the regression (see **Table 6 Regression (4)**) *hydroelectricity* and *irrigation* become the only significant dam construction purposes. Alone, *hydroelectricity* only decreases *ppp* and *irrigation* only increases *ppp*; however, their impacts are partially offset by *min distance* and *min distance squared*. This regression (see **Table 6 Regression (4)**) shows that when a dam is built to provide *hydroelectricity* and *irrigation*, *ppp* decreases by 29.17%, and when a dam is built for *irrigation* purposes, *ppp* increases by 25.86%.

Other Continents

For Central America, *minimum distance* and *minimum distance squared* are only significant in model 2 when all dam purposes are included and country fixed effects are not accounted for (see **Appendix Table 3.3**). *Minimum distance* and *minimum distance squared* are never significant for Europe, Oceania, and South America (see **Appendix Tables 3.1**, **3.2**, and **3.4**). Since these continents are less populated than Africa and Asia, this could explain why the placement of a dam does not significantly impact the surrounding area. The less people there are surrounding the dam, the less people will be displaced which will not lead to as many drastic changes in GDP.

Hydroelectricity

Hydroelectricity is the most popular reason for dam construction in Africa (43 percent) and the second most popular reason for dam construction in Asia (21 percent). When a dam is constructed for hydroelectricity purposes, the flow of a river is completely blocked so water can be stored in a reservoir. The construction of a dam for this purpose typically occurs in rural areas, and it results in changes to the natural landscape of and around the river because land developments are being introduced. This dam changes the ecosystem for wildlife and the natural ecosystem around the river which forces whomever lived in this area prior to the dam construction to move. This displacement is what leads to a decrease in *ppp* of the cells surrounding the river in both Africa and Asia. The urban areas that typically surround rivers are not receiving the benefits of the hydroelectricity because it is being transported to cities further from the rivers, which is why there is a decrease in *ppp* .

Findings Summary

Overall, I find that the presence of a dam has a nonlinear impact on the surrounding area's GDP; however, this impact varies across continents. This nonlinear impact means that areas close to the dam are negatively impacted by the presence of the dam, but, past a certain distance that is specific to each continent, the dam's presence has a positive impact on the area's GDP. Displacement from the area surrounding the dam is likely the reason why GDP decreased in this vicinity, and the increase in population past a certain distance of the dam is likely why GDP increases. I also find that dams built to provide *hydroelectricity* decreases GDP; however, their impacts are partially offset as distance from the dam increases.

Robustness

The goal for this study is to determine whether the pros (purposes) of dams outweigh their cons (displacement) in the areas that are surrounding the dam by calculating the net benefits in relation to changes in GDP. The theory behind the model

($PPP_{it} = b_0 + \theta_1 mindist_i + \theta_2 mindist^2 + \delta x_{it} + \varepsilon_{it}$) for this study is that dam construction leads to displacement which decreases the GDP of the dam's surrounding area. Inhabitants are displaced due large infrastructures being built around the river which decreases the population in the dam's surrounding area and these people are forced to relocate. With less people in the dam's surrounding area, there is less output/economic activity, and thus less GDP. A successful robustness test that confirms population decreases in the area surrounding the constructed dam emphasizes that the placement of dams has a nonlinear impact on the surrounding area's GDP in Africa and Asia.

Africa

The concatenated result for Africa's population robustness check is shown in **Table 7** which is written as the following:

$$Equation\ 5: Population = a - 122{,}608x + 2{,}145\, x^2$$

$$Equation\ 6: \delta Population/\delta x = -122{,}608 + 4{,}290x$$

For the derivative of this regression, the coefficient on *min distance* is negative and it is positive on *min distance squared*. Setting *equation 6* equal to zero finds the mileage distance where the placement of a dam switches from displacing inhabitants to where the displaced move. This means that the dam displaces people up to 28.58 miles away from the dam; past this mileage is where the displaced move.

Asia

The concatenated result for Asia's population robustness check is shown in **Table 8** which is written as the following:

$$Equation\ 7: Population = a - 411{,}258x + 19{,}558\, x^2$$

$$Equation\ 8: \delta Population/\delta x = -411{,}258 + 39{,}116x$$

Similar to Africa, for the derivative of this regression, the coefficient on *min distance* is negative and it is positive on *min distance squared*. Setting *equation 8* equal to zero finds the mileage distance where the placement of a dam switches from displacing inhabitants to where the displaced move. This means that the dam displaces people up to 10.51 miles away from the dam; past this mileage is where the displaced move.

Conclusion

Overall, this study is helping to close gaps in dam literature by providing a large scale analysis of how dams impact the overall health of the economy. The 59,071 large dams that have been constructed worldwide have displaced millions of people, and this study helps understand how this displacement influences economic output. While their intended purposes, to improve flood control, provide electricity, supply water, etc., may seem beneficial, it is important to consider dams' impacts beyond fulfilling their purposes.

The large infrastructures (i.e. power liens, roads, the dam itself, etc.) that are required to construct dams change the landscape of the area surrounding the river, and their placement is what forces the area's inhabitants to move. Since there are now less people in the area surrounding the river, there is now less economic output, which is calculated as *ppp* in this study. *PPP* of the areas the displaced move to increases because there are now more people in the area to produce economic output. This translates to why the results of this study find that construction of large dams in Africa and Asia have a nonlinear impact on the surrounding area's GDP; areas close to the dam are negatively impacted, however, past a certain distance that is specific to each continent, the dam's presence has a positive impact on the area's GDP.

This study also finds that when dams are built to provide *hydroelectricity* in Africa and Asia, GDP decreases; however, their impacts are partially offset as distance from the dam increases. The other continents in this study (Central America, Oceania, Central America, and South America) did not have significant results when regressions were run.

A major implication for this study is that it will be a resource for all those who advocate against the construction of dams. Many debates occur when new dams are proposed to being built, and this study emphasizes that not only does the construction of dams displace people, but it also decreases the GDP of the dam's surrounding area. If area's want to maintain their current GDP, then they should not build a dam.

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Table 1: Summary Statistics of Africa Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	13,120	3.32959	3.279396	0	16.78153
Min Distance Squared	13,120	21.83979	40.72305	0	281.6197
PPP	13,390	0.4795986	2.365279	0	85.04198
Irrigation	13,120	0.3780488	0.4849184	0	1
Water Supply	13,120	0.1393293	0.346303	0	1
Flood Control	13,120	0.0987805	0.2983784	0	1
Hydroelectricity	13,120	0.5362805	0.498701	0	1
Navigation	13,120	0.0161585	0.1260898	0	1
Recreation	13,120	0.0027439	0.0523124	0	1
Pollution Control	13,120	0.0003049	0.0174588	0	1
Livestock Rearing	13,120	0.0106707	0.1027505	0	1
Population	14,180	217396.9	621432.1	0	2.20e+07

Table 2: Summary Statistics of Asia Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	16,092	3.305664	3.560151	0	22.29993
Min Distance Squared	16,092	23.6013	49.90635	0	497.2867
PPP	15,235	3.417778	20.42264	0	1058.671
Irrigation	16,092	0.5488441	0.497624	0	1
Water Supply	16,092	0.2868506	0.4523053	0	1
Flood Control	16,092	0.3084763	0.4618787	0	1
Hydroelectricity	16,092	0.3974646	0.4893888	0	1
Navigation	16,092	0.0164057	0.1270336	0	1
Recreation	16,092	0.1558538	0.362728	0	1
Pollution Control	16,092	0.1222968	0.3276385	0	1
Livestock Rearing	16,092	0.0333085	0.1794464	0	1
Population	16,076	851743.8	1893453	0	2.87e+07

Table 3: Africa Regressions Model 1

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.0311***	-0.0349***	-0.0473***	-0.0467***
	(-6.748)	(-7.542)	(-8.748)	(-8.631)
Irrigation		0.274***		0.0878
		(7.083)		(1.597)
Water Supply		-0.176***		-0.0354
		(-4.156)		(-0.728)
Flood Control		0.161***		0.0227
		(3.183)		(0.377)
Hydroelectricity		-0.168***		-0.231***
		(-4.685)		(-5.113)
Navigation		-0.204**		0.0388
		(-2.154)		(0.342)
Recreation		-0.0653		0.126
		(-0.873)		(1.065)
Pollution Control		-0.264**		-0.0696
		(-2.472)		(-0.223)
Livestock Rearing		0.135		0.0267
		(0.886)		(0.113)
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Table 4: Asia Regressions Model 1

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.0834***	-0.0794***	-0.0953***	-0.0926***
	(-7.062)	(-6.512)	(-7.283)	(-6.976)
Irrigation		0.218**		0.195
		(2.117)		(1.609)
Water Supply		-0.271**		-0.143
		(-2.153)		(-1.051)
Flood Control		0.270**		0.0568
		(2.258)		(0.440)
Hydroelectricity		-0.216**		-0.421***
		(-2.383)		(-4.175)
Navigation		0.0429		-0.0959
		(0.125)		(-0.277)
Recreation		-0.106		0.190
		(-0.422)		(0.383)
Pollution Control		-0.470*		-0.309
		(-1.809)		(-0.501)
Livestock Rearing		0.527		0.568
		(1.471)		(0.630)
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Table 5: Africa Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.0478***	-0.0537***	-0.0763***	-0.0757***
	(-7.186)	(-8.040)	(-9.916)	(-9.802)
Minimum Distance to Dam^2	0.000923***	0.00103***	0.00140***	0.00139***
	(3.484)	(3.903)	(5.294)	(5.250)
Irrigation		0.278***		0.0867
		(7.172)		(1.578)
Water Supply		-0.175***		-0.0340
		(-4.120)		(-0.699)
Flood Control		0.169***		0.0371
		(3.344)		(0.618)
Hydroelectricity		-0.168***		-0.229***
		(-4.700)		(-5.077)
Navigation		-0.214**		0.0357
		(-2.258)		(0.314)
Recreation		-0.0689		0.106
		(-0.921)		(0.896)
Pollution Control		-0.258**		-0.0627
		(-2.421)		(-0.201)
Livestock Rearing		0.117		0.0165
		(0.767)		(0.0700)
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Table 6: Asia Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.221***	-0.211***	-0.275***	-0.266***
	(-7.370)	(-6.813)	(-8.562)	(-8.116)
Minimum Distance to Dam^2	0.0105***	0.00997***	0.0132***	0.0127***
	(4.981)	(4.616)	(6.114)	(5.774)
Irrigation		0.201*		0.230*
		(1.956)		(1.901)
Water Supply		-0.251**		-0.101
		(-2.000)		(-0.746)
Flood Control		0.316***		0.0932
		(2.637)		(0.725)
Hydroelectricity		-0.164*		-0.345***
		(-1.801)		(-3.407)
Navigation		-0.0677		-0.210
		(-0.198)		(-0.610)
Recreation		-0.0811		0.154
		(-0.323)		(0.313)
Pollution Control		-0.457*		-0.301
		(-1.767)		(-0.491)
Livestock Rearing		0.410		0.560
		(1.144)		(0.624)
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Table 7: Africa Robustness Check

	(1)
VARIABLES	population
Minimum Distance to Dam	-122,608***
	(-23.02)
Minimum Distance to Dam^2	2,145***
	(11.60)
Irrigation	135,702***
	(3.641)
Water Supply	-84,876**
	(-2.521)
Flood Control	-15,255
	(-0.369)
Hydroelectricity	-240,544***
	(-7.716)
Navigation	-39,391
	(-0.496)
Recreation	146,224*
	(1.801)
Pollution Control	-333,997
	(-1.526)
Livestock Rearing	-49,344
	(-0.318)
Country Fixed Effects	yes

Note: The dependent variable is cell population. The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Table 8: Asia Robustness Check

	(1)
VARIABLES	population
Minimum Distance to Dam	-411,258***
	(-20.01)
Minimum Distance to Dam^2	19,558***
	(14.10)
Irrigation	340,193***
	(4.546)
Water Supply	-227,337***
	(-2.693)
Flood Control	14,561
	(0.183)
Hydroelectricity	-351,676***
	(-5.556)
Navigation	-6,301
	(-0.0290)
Recreation	549,960**
	(2.041)
Pollution Control	-662,087*
	(-1.715)
Livestock Rearing	190,326
	(0.458)
Country Fixed Effects	yes

Note: The dependent variable is cell population. The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Appendix 1: Countries' Dam Observations

Appendix Table 1.1: Africa Country List & Dam Observations

Algeria	42	Madagascar	11
Angola	22	Malawi	12
Benin	7	Mali	11
Botswana	8	Mauritania	1
Burkina Faso	81	Mauritius	9
Burundi	6	Morocco	51
Cameroon	20	Mozambique	18
Cape Verde	0	Namibia	22
Central African Republic	3	Niger	3
Chad	0	Nigeria	77
Comoros	0	Rwanda	6
Congo	11	Saint Helena	0
Cote d'Ivoire	33	Sao Tome and Principe	0
Democratic Republic of the Congo	29	Senegal	5
Djibouti	0	Seychelles	0
Egypt	12	Sierra Leone	8
Equatorial Guinea	0	Somalia	0
Eritrea	2	South Africa	529
Ethiopia	24	South Sudan	4
Gabon	2	Sudan	13
Gambia	1	Swaziland	9
Ghana	20	Tanzania	18
Guinea	22	Togo	5
Guinea Bissau	0	Tunisia	42
Kenya	22	Uganda	14
Lesotho	7	Zambia	12
Liberia	8	Zimbabwe	148
Libya	9		

Appendix Table 1.2: Asia Country List & Dam Observations

Armenia	18	North Korea	36
Azerbaijan	19	Oman	7
Bangladesh	1	Pakistan	30
Bhutan	5	Papua New Guinea	2
Brunei	2	Philippines	14
Cambodia	2	Saudi Arabia	2
China	722	Singapore	3
Georgia	11	South Korea	54
India	287	Sri Lanka	59
Indonesia	60	Syria	5
Iran	84	Tajikistan	14
Iraq	16	Thailand	39
Japan	543	Turkey	582
Jordan	10	Turkmenistan	15
Kazakhstan	11	United Arab Emirates	67
Laos	7	Uzbekistan	1
Lebanon	2	Vietnam	10
Malaysia	20	Yemen	30
Nepal	3		

Appendix Table 1.3: Central America Country List & Dam Observations

Antigua and Barbuda	7
Costa Rica	12
Cuba	1
Dominican Republic	17
El Salvador	4
Grenada	4
Guatemala	3
Honduras	14
Jamaica	2
Nicaragua	1
Panama	6
Saint Lucia	1

Appendix Table 1.4: Europe Country List & Dam Observations

Albania	5	Luxembourg	1
Austria	22	Macedonia	9
Belgium	5	Netherlands	0
Bosnia and Herzegovina	9	Norway	125
Bulgaria	46	Poland	29
Croatia	8	Portugal	53
Cyprus	4	Republic of Moldova	1
Czech Republic	35	Romania	80
Finland	19	Russia	49
France	114	Serbia and Montenegro	30
Germany	60	Slovakia	16
Greece	19	Slovenia	2
Hungary	4	Spain	252
Iceland	6	Sweden	49
Ireland	4	Switzerland	38
Italy	87	Ukraine	9
Latvia	3	United Kingdom	89
Lithuania	2		

Appendix Table 1.5: Oceania Country List & Dam Observations

Australia	188
New Zealand	65

Appendix Table 1.6: South America Country List & Dam Observations

Argentina	17
Bolivia	276
Chile	1
Colombia	27
Ecuador	3
French Guiana	1
Guyana	4
Paraguay	4
Uruguay	2

Appendix 2: Continent Summary Statistics

Appendix Table 2.1: Summary Statistics of Africa Data

Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Min Distance	13,120	3.32959	3.279396	0	16.78153
Min Distance Squared	13,120	21.83979	40.72305	0	281.6197
PPP	13,390	0.4795986	2.365279	0	85.04198
Irrigation	13,120	0.3780488	0.4849184	0	1
Water Supply	13,120	0.1393293	0.346303	0	1
Flood Control	13,120	0.0987805	0.2983784	0	1
Hydroelectricity	13,120	0.5362805	0.498701	0	1
Navigation	13,120	0.0161585	0.1260898	0	1
Recreation	13,120	0.0027439	0.0523124	0	1
Pollution Control	13,120	0.0003049	0.0174588	0	1
Livestock Rearing	13,120	0.0106707	0.1027505	0	1
Population	14,180	217396.9	621432.1	0	2.20e+07

Appendix Table 2.2: Summary Statistics of Asia Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	16,092	3.305664	3.560151	0	22.29993
Min Distance Squared	16,092	23.6013	49.90635	0	497.2867
PPP	15,235	3.417778	20.42264	0	1058.671
Irrigation	16,092	0.5488441	0.497624	0	1
Water Supply	16,092	0.2868506	0.4523053	0	1
Flood Control	16,092	0.3084763	0.4618787	0	1
Hydroelectricity	16,092	0.3974646	0.4893888	0	1
Navigation	16,092	0.0164057	0.1270336	0	1
Recreation	16,092	0.1558538	0.362728	0	1
Pollution Control	16,092	0.1222968	0.3276385	0	1
Livestock Rearing	16,092	0.0333085	0.1794464	0	1
Population	16,076	851743.8	1893453	0	2.87e+07

Appendix Table 2.3: Summary Statistics of Central America Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	616	1.841737	1.240078	0.0308702	5.908583
Min Distance Squared	616	4.927292	6.558529	0.000953	34.91136
PPP	517	1.794533	3.246708	0.0000214	21.02909
Irrigation	616	0.3051948	0.4608641	0	1
Water Supply	616	0.1363636	0.3434532	0	1
Flood Control	616	0.012987	0.1133102	0	1
Hydroelectricity	616	0.5	0.5004063	0	1
Navigation	616	0.025974	0.159187	0	1
Recreation	616	0.038961	0.1936594	0	1
Pollution Control	616	0	0	0	0
Livestock Rearing	616	0	0	0	0
Population	616	364053.1	621969.8	0	4546100

Appendix Table 2.4: Summary Statistics of Europe Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	5,568	1.319912	3.27521	0.0120388	74.5764
Min Distance Squared	5,568	12.46724	203.5131	0.0001449	5561.64
PPP	19,552	2.756061	14.33044	0	514.0542
Irrigation	5,568	0	0	0	0
Water Supply	5,568	0.2808908	0.4494746	0	1
Flood Control	5,568	0.174569	0.3796321	0	1
Hydroelectricity	5,568	0.6867816	0.463844	0	1
Navigation	5,568	0.141523	0.3485915	0	1
Recreation	5,568	0.0847701	0.2785643	0	1
Pollution Control	5,568	0.0014368	0.0378811	0	1
Livestock Rearing	5,568	0	0	0	0
Population	19,592	143482.3	484901.6	0	1.49e+07

Appendix Table 2.5: Summary Statistics of Oceania Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	3,508	3.537835	2.715541	0.0060913	15.84137
Min Distance Squared	3,508	19.88834	26.57461	0.0000371	250.949
PPP	3,508	0.6933942	4.06381	0.0000156	90.58359
Irrigation	3,508	0	0	0	0
Water Supply	3,508	0.5769669	0.494111	0	1
Flood Control	3,508	0.0171038	0.1296766	0	1
Hydroelectricity	3,508	0.1527936	0.1296766	0	1
Navigation	3,508	0.0125428	0.1113058	0	1
Recreation	3,508	0.0307868	0.1727642	0	1
Pollution Control	3,508	0	0	0	0
Livestock Rearing	3,508	0	0	0	0
Population	3,508	25600.77	142152.3	.7673238	2665862

Appendix Table 2.6: Summary Statistics of South America Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Min Distance	3,692	4.873275	4.912518	0.0857431	23.90672
Min Distance Squared	3,692	47.87511	99.36735	0.0073519	571.5314
PPP	3,692	0.9757733	7.914778	0	256.016
Irrigation	3,692	0.1711809	0.376718	0	1
Water Supply	3,692	0.1830986	0.3867997	0	1
Flood Control	3,692	0.5016251	0.5000651	0	1
Hydroelectricity	3,692	0.6468039	0.4780277	0	1
Navigation	3,692	0.0021668	0.0465052	0	1
Recreation	3,692	0.4279523	0.4948489	0	1
Pollution Control	3,692	0	0	0	0
Livestock Rearing	3,692	0.0314193	0.1744717	0	1
Population	3,692	129342.6	559386.4	0	1.28e+07

Appendix 3: Other Continents' Regressions

Appendix Table 3.1: Europe Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	0.0104	0.0157	0.0143	0.0127
	(0.417)	(0.626)	(0.560)	(0.495)
Minimum Distance to Dam^2	-0.000116	-0.000218	-0.000154	-0.000132
	(-0.290)	(-0.540)	(-0.381)	(-0.327)
Irrigation		n/a		n/a
		n/a		n/a
Water Supply		-0.00978		0.104
		(-0.106)		(1.011)
Flood Control		-0.168		0.0864
		(-1.623)		(0.646)
Hydroelectricity		-0.0283		0.00875
		(-0.322)		(0.0943)
Navigation		-0.297**		0.119
		(-2.508)		(0.815)
Recreation		0.129		0.101
		(0.930)		(0.618)
Pollution Control		0.219		0.301
		(0.225)		(0.319)
Livestock Rearing		n/a		n/a
		n/a		n/a
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Appendix Table 3.2: Oceania Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.000306	-0.00200	-0.000513	-0.00156
	(-0.0765)	(-0.484)	(-0.124)	(-0.370)
Minimum Distance to Dam^2	3.49e-05	0.000152	4.96e-05	0.000119
	(0.0863)	(0.369)	(0.121)	(0.287)
Irrigation		n/a		n/a
		n/a		n/a
Water Supply		0.00254		0.00310
		(0.344)		(0.416)
Flood Control		0.00494		0.00744
		(0.181)		(0.270)
Hydroelectricity		-0.0155		-0.0182
		(-1.382)		(-1.498)
Navigation		-0.00646		-0.00533
		(-0.203)		(-0.168)
Recreation		0.0336		0.0358
		(1.555)		(1.631)
Pollution Control		n/a		n/a
		n/a		n/a
Livestock Rearing		n/a		n/a
		n/a		n/a
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Appendix Table 3.3: Central America Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.122	-0.161**	-0.0856	-0.0947
	(-1.492)	(-2.073)	(-1.211)	(-1.518)
Minimum Distance to Dam^2	0.0221	0.0404*	0.0184	0.0206
	(0.983)	(1.868)	(0.932)	(1.182)
Irrigation		0.205***		0.116
		(2.976)		(1.624)
Water Supply		0.0372		0.280**
		(0.578)		(2.498)
Flood Control		0.175		-0.0763
		(1.028)		(-0.430)
Hydroelectricity		0.105**		0.282**
		(2.153)		(2.520)
Navigation		0.168		-0.0893
		(1.308)		(-0.598)
Recreation		0.0124		0.0720
		(0.130)		(0.806)
Pollution Control		n/a		n/a
		n/a		n/a
Livestock Rearing		n/a		n/a
		n/a		n/a
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent

Appendix Table 3.4: South America Regressions Model 2

	(1)	(2)	(3)	(4)
VARIABLES	ppp	ppp	ppp	ppp
Minimum Distance to Dam	-0.00452	-0.00482	-0.0119	-0.0114
	(-0.409)	(-0.435)	(-1.058)	(-1.000)
Minimum Distance to Dam^2	0.000160	-8.51e-06	-3.51e-05	-5.36e-05
	(0.294)	(-0.0153)	(-0.0643)	(-0.0974)
Irrigation		-0.0566		0.0145
		(-1.008)		(0.156)
Water Supply		-0.0338		-0.0143
		(-0.664)		(-0.250)
Flood Control		0.00911		0.0147
		(0.184)		(0.228)
Hydroelectricity		-0.0769		0.0463
		(-1.430)		(0.428)
Navigation		0.486		0.464
		(1.261)		(1.170)
Recreation		-0.00512		-0.00657
		(-0.100)		(-0.0728)
Pollution Control		n/a		n/a
		n/a		n/a
Livestock Rearing		-0.0192		-0.0134
		(-0.182)		(-0.105)
Country Fixed Effects	no	no	yes	yes

Note: The dependent variable is cell GDP (ppp). The t-values of the coefficients are in parenthesis. * indicate significance at 10 percent, ** at 5 percent, and *** at 1 percent