

**THE EFFECTS OF WATER ACCESS ON GOVERNMENT HEALTH CARE
SPENDING WORLDWIDE**

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Abstract:

Water access worldwide affects numerous areas of personal health. This paper attempts to analyze the effects that water access has on total government health care expenditure in different countries. By utilizing a cross-sectional analysis on data from over 80 countries, we provide a unique view of how lack of water access may burden health care. This paper grounds its hypothesis in Pareto economic welfare policy, which helps explain the relationship between these variables. In addition to water access, we utilized additional independent variables such as private health care spending and tobacco use and a dummy variable adjusting for differences in developed and non-developed countries. These variables enabled us to gain a holistic view of the effects of water access on health care spending. Our study is founded upon existing economic theory and is thus related to other empirical works. It is unique in the way in which health care spending is explained using distinct variables and data sets.

Keywords: Water access, water, health care, global health, economic welfare policy

I. Introduction

According to a report from the World Health Organization and UNICEF released in 2014, around 748 million people worldwide lack access to clean, drinkable water.¹ Lack of access to clean water is a problem because 3.4 million people die every year from preventable water-related diseases, such as diarrhea.² In fact, around 90% of worldwide cases of diarrhea can be attributed to unsafe drinking water. Diarrhea was the second leading cause of death in the world in 2012 among children under five, causing at least one child death every minute.³ A direct causal relationship between unsafe drinking water and diarrheal deaths is irrefutable.⁴ Unfortunately, water borne illnesses and deaths disproportionately affect people in poor regions of the world who lack access to proper health care facilities.

In developing countries, access to health care services is especially scarce given the low number of health workers as a proportion of the population.⁵ This gap in service raises health care costs, which greatly affects people of lower economic status who must pay a larger share of their total income to receive proper care. The WHO reports that approximately 100 million people every year fall into poverty as a result of the costs associated with illness.⁶ Interestingly, a large share of the health care burden in developing countries comes as a result of completely preventable diseases, such as those caused by unsanitary water. If health care facilities in developing countries are freed from the burden of treating preventable water-related diseases, resources could be redirected to provide better quality and more effective care. Additionally, governmental resources could be redirected to improve infrastructure to help prevent water-borne illnesses.

With such stark statistics, we felt it was crucial to analyze the relationship between a country's overall access to improved water sources and the resulting effect this may have on that country's government health expenditure. The lack of access to clean water may directly place a heavier burden on the overall health care system in a country or it may have little to no effect. Our analysis seeks to identify the relationship between water access and governmental health care expenditure.

II. Hypothesis

Our main hypothesis states that if a country has better access to improved potable drinking

Note: Footnotes are cited sources included in more detail in the References Section of this paper.

¹ Progress on Drinking Water and Sanitation: 2014 Update

¹ Progress on Drinking Water and Sanitation: 2014 Update

² Safer Water, Better Health

³ World Diarrhoeal Diseases

⁴ Water, Sanitation, And Hygiene Interventions To Reduce Diarrhoea In Less Developed Countries

⁵ Poverty and Access to Health Care in Developing Countries

⁶ The World Health Report: Health Systems Financing: The Path to Universal Coverage.

sources⁷, then that country will spend less money on health-related costs⁸ as a percentage of total government expenditures. Our hypothesis is supported by the rationale that, as fewer individuals become sick from water-borne illnesses, there will be less of a financial burden on the health-related spending of a specific country. This hypothesis corresponds to the rationale behind the social welfare economic theory. The social welfare economic theory attempts to analyze the effects of policies on the well-being of a specific community.

Following Adam Smith's teachings of the Invisible Hand, social welfare economics states that the allocation of sums tends to benefit the whole community. We also make use of Pareto's concept of social welfare economics. Pareto found that there is a point (the Pareto Optimal/Efficient point) where afterward, any gains in social welfare efficiencies are contrasted by subsequent losses by another party⁹. In our list of countries, we see a division between developed and developing countries, which corresponds with the points before and after the Pareto Efficiency Point. Therefore, our hypothesis concludes that a successful attempt at improving water access in a developing country will result in a reduction of health care spending.

III. Literature Review

The existing literature proves that there is, in fact, a global water crisis, particularly in developing nations.^{10, 11, 12} One millennium development goal (MDG) is halving the proportion of people in the world without access to safe drinking water (Target 10). While this goal was met in 2010,¹³ there remains a crisis in some countries. In many developing nations, a vast number of people still live without access to improved water sources.

The seminal work in the area of water infrastructure and health comes from Annette Prüss-Üstün, Robert Bos, Fiona Gore, and Jamie Bartram of the World Health Organization. In their work titled "Safer Water, Better Health" published in 2008, they concluded that one tenth of the global disease burden could be "prevented by improving water supply, sanitation, hygiene and management of water resources".¹⁴ The

⁷ *Drinking water* is water used for domestic purposes, drinking, cooking and personal hygiene (WHO). *Safe drinking water* comes from a household connection; public standpipe; borehole; protected dug well; protected spring; rainwater and is free from any microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality (WHO).

⁸ Total expenditure on health (THE) is measured as the sum of all financing agents managing funds to purchase health goods and services.

⁹ Welfare Economics, University of Toronto

¹⁰ Discussion Of *Addressing Water Crisis In Developing Countries*

¹¹ Addressing Water Crisis In Developing Countries

¹² Water, Sanitation, And Hygiene: A Global Crisis With Real Solutions

¹³ Global Health Observatory, WHO

¹⁴ Safer Water, Better Health

study was initiated as a progress report on the Millennium Development Goal to improve environmental sustainability, specifically Target 10 as noted above.¹⁵ This work spurred many other researchers to do more in depth, economic research on water access at specific regional levels.

Yongsi (2010) finds that in Cameroon, a statistically high number of cases of diarrhea were caused by poor water quality. This study identifies the health risks associated with the usage of contaminated drinking water, including diarrhea and other water-borne illnesses, in Cameroon. The overall burden of these diseases led to an increase in the burden on health care providers in Cameroon. The results of this study can be applied to many other developing nations. Of particular interest are the specific causes of variability in diarrheal levels between neighborhoods in Cameroon. Once these differences are identified, policy makers can learn how to intervene in communities to lessen the total burden on health care.

We can better see the effects of proper water interventions by looking at Eder, Schooley, Fullerton, and Murguia's research on post-project impacts in Bolivia (2012). Their study looked at the water intervention process by analyzing the \$26 million Development Assistance Program (DAP) that supported water access projects. After six years, DAP communities had better infrastructure for community water systems and household water systems than control communities. Also, DAP sponsored communities were around "30% more likely to be rated good to very good or satisfactory for status of water infrastructure" (2012). The communities were able to improve their health and living standards by investing in water infrastructure, thus reducing the overall health burden.

Other existing sources provided us with good modeling techniques to frame our research. Dinar and Saleth's (2005) study introduces an interesting modeling technique in which countries are grouped according to their level of development to help identify the most common constraints on water systems. They find that these constraints stem from poor resource management and inefficient water use rather than a physical limitation on water access. Typically, countries respond to issues in water access by making institutional changes. Therefore, they stress that improving management infrastructure can solve the water crisis. Dinar and Saleth chose to use the Water Institution Health Index indicators to check for this response. In their study, 43 selected countries were arranged "into three broad groups with countries having good, moderate, or poor performing water institutions" (2005). This grouping helped identify the weaker performing water institutions that need the most help to better allocate resources and perfect inefficiencies. Our analysis will adopt a similarly grouped modeling technique in order to better identify how countries in various stages of development respond when there is improved water access.

This study brings a unique perspective to prior literature and hopefully can serve as a supplement for past work. We focus on a cross sectional analysis of countries around the world to get a holistic

¹⁵ *ibid*

perspective on health care spending. Currently, there is little analysis on the direct effects of improved water access on government health expenditures in a country. Many studies analyze the microeconomic impact of poor water access on an individual or household's health care costs. Macroeconomic studies on water access, however, tend to be limited to specific regions or countries and fail to link water access to a country's health care spending. The research in this paper will provide a broad level, holistic perspective that other research lacks.

IV. Data

This study is primarily interested in the impact a country's access to improved water sources has on its general government health care expenditure. Our dependent variable in this model is general government expenditure on health (GGHE). To measure GGHE, we looked at a country's total government health expenditure as a percentage of its general government expenditure (GGE).

We also incorporated several independent variables in our study. Our primary independent variable is the proportion of the population using improved water sources as a percentage of the total population. Access to an improved water source is the primary independent variable because it has the potential to be the most interesting and revealing statistic related to GGHE. If our hypothesis proves to be true, a country with better access to improved water sources will have a significantly lower GGHE.

Table 1.1 Defining independent and dependent variable

LABELS	VARIABLES	DATA SOURCE
water	Proportion of the population using Improved Water Sources (% of total pop)	United Nations Statistics Division
publichealth	General Government Expenditure on Health (% of Total Government Expenditure)	The World Health Organization
privatehealth	Private Share of Total Health Expenditure (%)	The World Health Organization
tobacco	Smoking Adults (% of pop over age 15)	The World Health Organization
mortality	Infant Mortality Rate (per 1,000 births)	UNICEF
developing	Dummy variable signifying if a country is developing (1) or developed (0)	Worldbank

Variables Included in Simple Regression:

$$\text{publichealth} = \beta_0 + \beta_1 \text{water}$$

1. *Improved Water Sources* - The percentage of the total population who use any of the following types of water supply for drinking: piped water into dwelling, plot or yard; public tap/standpipe; borehole/tube well; protected dug well; protected spring; rainwater collection and bottled water (if a secondary available source is also improved). It does not include unprotected well, unprotected spring, water provided by carts with small tanks/drums, tanker truck-provided water and bottled water (if secondary source is not an improved source) or surface water taken directly from rivers, ponds, streams, lakes, dams, or irrigation channels. This is the standard definition provided by the United Nations site for MDG indicators.¹⁶
2. *General Government Health Expenditure* - GGHE as % of GGE, provided by the World Health Organization Global Health Expenditure Database.¹⁷

Additional Variables Included in Multivariate Regression:

$$\text{publichealth} = \beta_0 + \beta_1 \text{water} + \beta_2 \text{privatehealth} + \beta_3 \text{mortality} + \beta_4 \text{tobacco}$$

1. *Private Share of Total Health Expenditure* - Private share of health spending as given as a percentage of total health expenditure (THE)¹⁸. The WHO Global Health Expenditure Database provided this data set. We included this variable because countries with a larger share of THE funded by private entities (such as individuals, NGOs, etc.) would have a lower percentage of THE come from a public source.
2. *Infant Mortality Rate* – As defined by UNICEF, the probability that a child born in a specific year will die before reaching the age of one, expressed as a rate per 1,000 live births. UNICEF also provided the data for this variable. Infant mortality could affect THE, which is why we included it in our regression. In a country with a high infant mortality rate, public health spending would likely be low because there is inadequate access to proper medical services.
3. *Smoking Adults* - Prevalence of current tobacco use of both sexes aged 15 and over, provided by the World Health Organization Statistical Information System. We felt it was important to include this variable in our research because of the large effect that tobacco use has on health.

¹⁶ Millennium Development Goals Indicators Website: the Official UN site for the MDG Indicators

¹⁷ Global Health Expenditure Database: World Health Organization

¹⁸ Total Health Expenditures includes both public and private sources

For instance, the Centers for Disease Control and Prevention estimate that cigarette smoking causes 1 in every 5 deaths in the United States.¹⁹

Taken as a collective, these independent variables provide the foundation upon which we constructed our statistical model. Ideally, these variables will give us a clear picture of what factors influence total public health spending. For the purpose of the research, we often utilized data compiled by Gapminder but originally available from sources like the WHO, UNICEF, and the UN Statistics Division.

The addition of a dummy variable, *developing*, allowed us to control for different types of countries: both developed and developing nations. *Appendix 1.1* shows a breakdown of the developed nations and developing nations used in this study. Splitting these countries up allowed us to control for the large differences in health care systems and water infrastructure between developed and non-developed countries. Developed nations tend to be richer than non-developed nations and therefore spend more money on health care systems. Additionally, water infrastructure in developed nations far surpasses that in the developing world. The dummy variable gave us deeper insights into the realities for both types of countries.

Table 2.1 Descriptive Statistics: Breakdown of variables based on 81 surveyed countries' data. Data sources are noted above. Includes data from both developed and developing nations.

VARIABLE	OBSERVATIONS	MEAN	STD. DEV	MIN	MAX
publichealth (% of GGE)	81	11.14	4.55	.97	21.25
water (% of total pop)	81	87.56	16.14	40	100
privatehealth (% of THE)	81	42.28	19.77	.70	89.97
mortality (per 1,000 births)	81	29.46	27.65	1.9	104.5
tobacco (% of tobacco users)	81	24.38	10.51	5.5	51.8
developing	81	0.38	0.49	0	1

¹⁹ Tobacco-Related Mortality, CDC

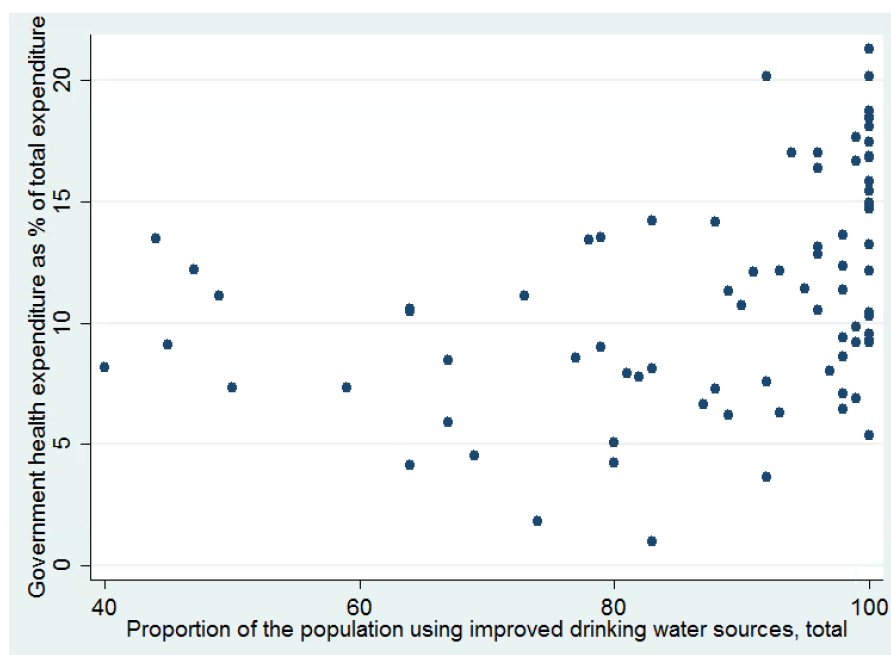
Table 2.2 Descriptive Statistics: Developed Countries Only

VARIABLE	OBSERVATIONS	MEAN	STD. DEV	MIN	MAX
publichealth (% of GGE)	50	12.62	4.46	4.22	21.25
water (% of total pop)	50	96.8	5.18	79	100
privatehealth (% of THE)	50	33.40	15.51	.70	79.71
mortality (per 1,000 births)	50	11.90	10.72	1.9	45.3
tobacco (% of tobacco users)	50	25.51	10.84	5.5	51.8
developing	50	0	0	0	0

Table 2.3 Descriptive Statistics: Developing Countries Only

VARIABLE	OBSERVATIONS	MEAN	STD. DEV	MIN	MAX
publichealth (% of GGE)	31	8.74	3.63	.97	14.20
water (% of total pop)	31	72.65	16.69	40	98
privatehealth (% of THE)	31	56.61	17.47	23.76	89.97
mortality (per 1,000 births)	31	57.77	22.58	16.1	104.5
tobacco (% of tobacco users)	31	22.57	9.83	6.60	42.30
developing	31	1	0	1	1

Graph 1.1 Water Sources and Government Health Expenditures for 81 countries



Gauss Markov Assumptions:

It is just as important to interpret the results of data as it is to verify the reliability of data. The data in the study was verified using the Gauss Markov Assumptions for Multivariate Regression.

Assumption 1: Linear Parameters

We checked that our regressions were linear in parameters, meaning our model could be written as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_k X_k + u$$

Assumption 2: Random Sampling

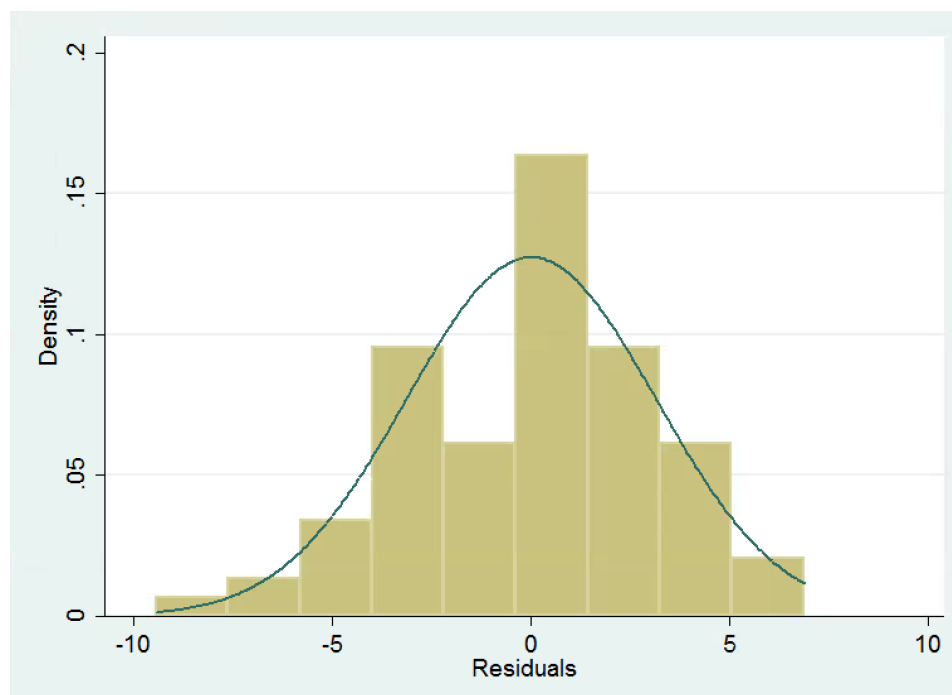
The data we used included every country that had information for our desired variables. The equation for a random sample of the population can be shown as:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_k X_{ik} + u_i$$

Assumption 3: Zero Conditional Mean

Based on our regression equation, the residuals for all our countries were plotted in the histogram below. While *Graph 2.1* shows a slight rightward skew in our data, it is not enough to violate the normality assumption.

Graph 2.1 Histogram Verifying Zero Conditional Mean



Assumption 4: No Perfect Collinearity

We carefully selected independent variables to ensure that there was no perfect collinearity and that the dependent variable, *publichealth*, was related to the independent variables in a predictable manner. A correlation matrix is produced to demonstrate that there is no perfect collinearity:

Table 3.1 Correlation Matrix Verifying No Perfect Collinearity

	water	mortality	privatehealth	tobacco
water	1.0000			
mortality	-0.8005	1.0000		
privatehealth	-0.4027	0.5397	1.0000	
tobacco	0.0537	-0.1612	-0.2703	1.0000

Assumption 5: Homoskedasticity

Finally, we had to make the assumption of homoskedasticity which means that variance in the error term is the same for all combinations of our explanatory variables. Our variety of independent variables should control for unknown errors in homoskedasticity. Although these last three assumptions are rather all encompassing, they are key to utilizing the multivariate regression model assuming best linear unbiased estimators.

V. Results

Table 4.1 Simple Regression: STATA Results, water regressed on dependent variable publichealth

INDEPENDENT VARIABLE	SIMPLE REGRESSION
water	.101*** (3.42)
Intercept	2.26 (0.86)
Number of Observations	81
R-Squared	.1292

** denotes significance at the 10% level ** denotes significance at the 5% level *** denotes significance at the 1% level*

In the initial simple regression, the relationship between improved water access and public health care spending was positively correlated for the 81 surveyed countries. From an economic standpoint, the coefficient of .101 shows that there is an increase in the value of *publichealth* by .101 when *water*

increases by one unit. Because this coefficient is significant at the 1% level, it shows us that there is a statistically significant correlation between access to improved water sources and public health care spending. Additionally, based on the coefficients, the correlation is also economically viable. However, this relationship violates our hypothesis. Instead of a negative correlation like we initially predicted, there was a positive correlation between improved access to potable water sources and public health care spending. Put simply this means that, as a whole, countries with better access to water spend more money on health care. Our initial explanation for this result is that countries with better access to water are typically richer. Presumably, rich countries would also spend more public money on health care, rather than relying on outside, private sources for support. So rich countries with better water systems also spend more money on healthcare. Since this regression includes both developed and non-developed nations, future regressions that split developed and non-developed nations may have different results. We ran an additional regression using dummy variables in *Table 6.1* to test this hypothesis. First, though, we looked at a multivariate regression without the dummy variables to serve as a baseline for the dummy variable regression.

Table 5.1 Multiple Regression: STATA Results without Dummy Variables

INDEPENDENT VARIABLES	UNRESTRICTED MULTIPLE REGRESSION	RESTRICTED MULTIPLE REGRESSION
water	.023 (.64)	
privatehealth	-.165*** (-7.44)	-.172*** (-9.20)
mortality	-.0001 (.04)	
tobacco	-.077** (-2.15)	-.079** (-2.25)
Intercept	17.86*** (4.33)	20.36*** (14.92)
Number of Observations	81	81
R-Squared	.526	.520

When *water* is included in a multivariate regression with the other independent variables, it is no longer statistically significant. Instead, *tobacco* becomes significant at the 5% level and *privatehealth* becomes significant at the 1% level. This result does not fit our initial hypothesis. However, the resulting

significance of *privatehealth* would logically have a strong effect on public expenditures when looking at the data as a random sample of 81 countries. Our findings suggested that water access is not the most integral component of GGHE. However, this makes sense logically as other factors in our analysis overwhelmed the effects of *water*. Certain variables, like *privatehealth* and *tobacco*, were significant in both the unrestricted and restricted regressions. The significance of these variables could have easily disguised the subtle yet important effects that *water* has on GGHE.

Furthermore, our variable *mortality* is not individually significant. An F-test was conducted to determine if *mortality* and *water* were jointly significant. The F-statistic of .44 was significantly lower than the critical value at a 5% significance level. Thus, we failed to reject the null hypothesis, which indicates the two variables are not jointly significant.

When thinking logically about *water* and GGHE, it is important to look at the countries being analyzed. For this reason, we attempted to split the group of countries into developed and non-developed countries as defined by the World Bank.²⁰ We split our sample of 81 countries from the multivariate regression into smaller samples of developed and non-developed countries as indicated in *Appendix 1.1*. To perform a better regression using a dummy variable, we added the development dummy variable and labeled it *developing*. Developing countries were marked (1) and developed countries were marked (0). We also added the slope interaction dummy variable, d_1 , to analyze how *developing* interacts with the variable *water*. In this new regression, we once again found *mortality* to be insignificant and therefore dropped it from our multivariate regression model.

²⁰ Developing countries are classified as countries with a Gross National Income per capita per year of less than 11,905 USD.

Table 6.1 Multiple Regression: with Slope Changing Dummy Variables

INDEPENDENT VARIABLES	MODEL
Developing	24.98*** (2.88)
Water	.262*** (3.05)
d ₁ (water*developing)	-.263*** (-2.82)
Privatehealth	-.160*** (-7.21)
Tobacco	-.083** (-2.46)
Intercept	-5.25 (-0.62)
Number of Observations	81
R-Squared	.573

The regression with a slope changing dummy variable on *water* has quite a different result than the one with no distinction between the development statuses of countries. For this model, we found *water* to be statistically significant. The effect the variable has on GGHE can be described by saying there is a $(.262 - .263 * \text{developing})$ unit change in *publichealth*, when *water* increases by 1 unit. That means as a developed countries' improved water access increases by 1%, GGHE (as a proportion of GGE) also increases by .262%. However, as developing countries' improved water access increases by 1%, GGHE (as a proportion of GGE) decreases by only .001%. While this result does not seem like a substantial effect in developing countries, the remainder of the effect is captured by a shift in the intercept caused by the dummy variable *developing*. For developing countries, the intercept is shifted upward 24.98 units, showcasing the difference between developing and developed countries. Both the water and dummy variable coefficients are significant at the 1% level. This statistical significance shows us that there is a correlation between access to improved water sources and public health care spending when a country's development status is taken into account. Furthermore, our multivariate regression analyzes other variables, such as private health care spending and tobacco use. These variables are also statistically significantly at a one and five percent level, respectively.

VI. Conclusions

Put simply, access to improved water sources in developing countries does affect the amount of public health spending. As water access increases, government expenditure on health decreases. We verified our hypothesis, but only in instances where we looked at developing countries. In developed nations, the amount of water access also affects public health spending. However, the relationship is positively correlated, negating our hypothesis. Overall, the impact of water access on public health spending is rather minimal. It is apparent that there are other, more influential factors that determine the level of government expenditure on health.

It is important to note that we also performed an analysis on other variables, such as GDP, mortality, the number of physicians in a country, private health care spending, and tobacco use. Our analysis on GDP showed that there was a small, positive correlation between GDP and health care spending. This correlation was statistically insignificant. Subsequently, we recognized the importance of analyzing the number of physicians in a country. However, the data available would have cut our sample size greatly. As noted above, mortality was also removed from our regression due to lack of significance. Private health care spending and tobacco use showed significance in our model. Therefore, these variables also affect GGHE.

The analysis of water access on GGHE in this study showed us two distinct scenarios. One in which a developing nation with better water access spent less public money on health. Another scenario showed a developed nation with better water access and more government expenditure on health. The issue of water access is relevant and has an impact on countries and individuals worldwide. We plan to use the results from this study to guide further research before the Georgia Tech Research Symposium in Spring 2015.

VII. Appendix

<i>Appendix 1.1 List of Developing Countries</i>
Armenia
Bangladesh
Bolivia
Burkina Faso
Cambodia
Cameroon
Central African Republic
Congo, Dem. Rep.
Cote d'Ivoire
Djibouti
Ethiopia
Gambia
Guinea
Guinea-Bissau
Haiti
Indonesia
Kenya
Kyrgyz Republic
Lao
Lesotho
Liberia
Malawi
Mali
Mauritania
Moldova
Mozambique
Myanmar
Niger
Pakistan
Papua New Guinea
Philippines

<i>Appendix 1.2 List of Developed Countries</i>	
Algeria	Ireland
Andorra	Israel
Australia	Italy
Azerbaijan	Jamaica
Barbados	Japan
Belize	Kazakhstan
Bosnia & Herzegovina	Kuwait
Botswana	Latvia
Brazil	Lebanon
Canada	Luxembourg
Chile	Malaysia
China	Maldives
Colombia	Malta
Croatia	Marshall Islands
Cyprus	Mauritius
Czech Republic	Montenegro
Denmark	Namibia
Fiji	Netherlands
Gabon	New Zealand
Germany	Niue
Greece	Norway
Hungary	Oman
Iceland	Russia
Iran	South Korea
Iraq	St. Lucia

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