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Climate Change, Dengue and the Economy Ascertaining the Link Between Dengue and Climatic Conditions

by

Agustin L. Arcenas

Associate Professor, University of the Philippines (UP) School of Economics

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Climate Change, Dengue and the Economy
Ascertaining the Link Between Dengue and Climatic Conditions

By

Agustin Arcenas

This paper examines the climate-change related factors that affect the incidence of dengue in the Philippines. Dengue, one of the most high-profile public health problems in Southeast Asia, has been estimated to cost hundreds of millions of dollars in the Philippines and worldwide in terms of treatment, surveillance and control, lost income and other indirect costs per year. The disease has been a burden on the public, especially the poor who are less able to access funds for treatment and more heavily affected by the loss in income due to illness.

The findings indicate that temperature, precipitation and the incidence of La Niña significantly contribute to the cases of dengue in the Philippines by enhancing the breeding, growth and development of the *Aedis aegypti*, the dengue-carrying mosquito variety. The econometric results also indicate that better household sanitation practices also reduce dengue cases, indicating that investments to enhance the public's adoption of hygienic and other health practices do lessen the transmission of diseases such as dengue. The results of the study are consistent with the findings of studies regarding dengue in other parts of the world, and contribute to the growing awareness about the health impacts of climate change. This study should provide Philippine policy-makers some guidance in addressing the dengue problem as regional climate change becomes more pronounced.

Key words: Dengue, climate change, La Niña

JEL Classification: Q54, I18

Climate Change, Dengue and the Economy
Ascertaining the Link Between Dengue and Climatic Conditions

Agustin L. Arcenas

Final Report

Introduction

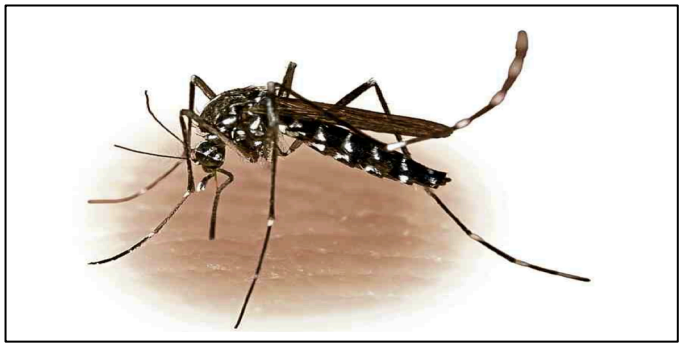
The illness dengue fever (or just dengue) is one the most high-profile public health problems in Southeast Asia, and is considered one of the fastest emerging pandemic-prone viral diseases in many part of the planet. Dengue is normally identified through its distinct symptoms—the rash and fever—and considered not necessarily fatal unless it develops into dengue hemorrhagic fever (DHF), which could lead to circulatory failure that results in death especially among children. The severity of the dengue fever ranges from mild to severe, depending on the age group and overall health of the patient. Other symptoms of the illness include muscle and joint pains, and pain behind the eyes, and in severe cases, febrile convulsions. (http://www.who.int/water_sanitation_health/diseases/dengue/en/).

The world first became aware of dengue in the late 1700s after it was formally identified and named as "breakbone fever" because of its symptoms. Dengue Virus Net (www.denguevirusnet.com), however, reports that dengue fever dates back to the Jin Dynasty (265-420 AD) when it was called insect-related "water poison". How the name 'dengue' came about is unclear, but it is believed that the name may have been derived from the Spanish word dengue – meaning careful – which is how people who have dengue have been described to behave when they walk as a result of the pain in their bones.

It was only at the turn of the 20th century that dengue's viral etiology was understood, and only in the 1950s during the dengue epidemics in the Philippines and

Thailand that severe dengue was completely recognized. Currently, it is considered one of the leading causes of hospitalization and pediatric deaths in Asia and Latin America. It has spread to other regions in the world, including North America, Africa, the Caribbean and the Pacific, affecting more an estimated 100-200 million people a year (Halasa, et al, 2012). Despite awareness regarding the disease and the advancement in modern health care and preventive medicine, dengue remains formidable in terms of incidence and economic impacts, and promises to remain so in years to come.

At the center of the dengue discussion is the vector (transmitter) of the disease which is the female *Aedes Aegypti* mosquito (see photo below). Since there are four types of dengue viruses, complete immunity from dengue is possible if the patient is exposed to all four types. We must keep in mind, however, that sequential exposure to the four dengue viruses could lead to the DHF which could result in death; as such, the possibility of being immune from dengue is—until recently--remote. A few months ago, however, vaccine against dengue has been announced although it use is only at the pilot stage with the Philippines as one of the pilot countries.



Source: newsinfo.inquirer.net/files/2014/03/D_Aedes_aegypti.jpg

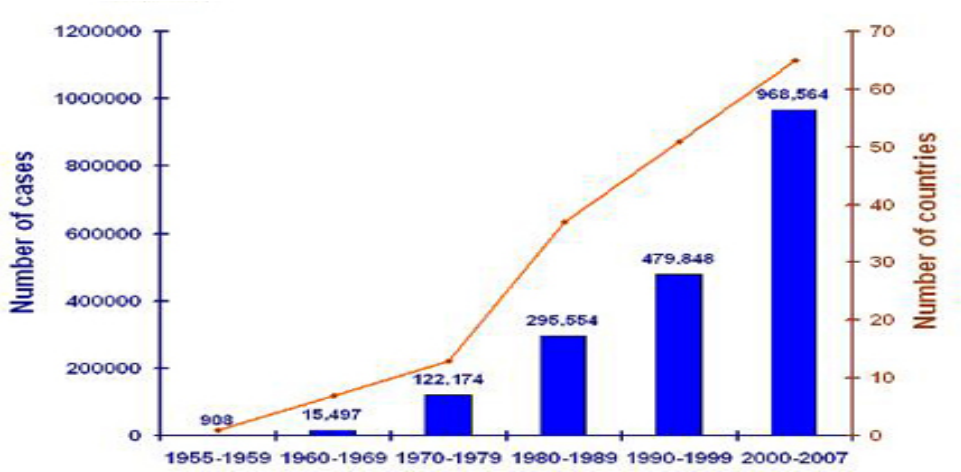
Until the anti-dengue vaccine is fully accepted and used, the most effective dengue prevention method is still the control and elimination of the dengue-carrying mosquito. There are several ways to accomplish this but arguably the most aggressive entails the destruction of the breeding areas for the mosquitos and fogging, or the use of insecticides to kill the mosquito population. Human behavior and living conditions also highly contribute to the potential for dengue infection especially in the urban areas. Recently, there have been studies that indicate that environmental factors also positively impact dengue cases by encouraging the growth and breeding of the *Aedes aegypti* mosquito.

The scientific literature has identified characteristics that impact the breeding of mosquitos such as temperature, rainfall, humidity, and water (the breeding medium) characteristics (e.g., salinity, ph, turbidity, etc.). (http://www.open.edu/openlearnworks/mod/oucontent/view.php?id=89&printable=1; Kenawy et al. 2013). Interestingly, these environmental "factors" that enhance the breeding speed of this *Aedes aegypti* mosquito, the transmitter of the dengue virus, are in fact inter-related and bound together by the thread of weather and climate. In fact, climate change—which is defined to be the long-term change in atmospheric temperature—is said to affect weather patterns and levels of precipitation, which in turn, are believed to directly and indirectly contribute to physical changes in water both in quality and quantity. Both climate-change-related factors that lead to changes in weather cycles and water quality could, therefore, contribute to the changes in the population of dengue-causing mosquitos. The question, however, is if the impact of climate-change is sufficient to encourage dengue cases.

The Economic Cost of Dengue

The World Health Organization (WHO) reports that dengue cases has increased 30-fold in the last five decades causing millions of infections every years, and costing economies billions of dollars in terms of lost productivity, treatment costs, and opportunity cost of public funds. In the Philippines where dengue is endemic, the 117,065 average number of cases per year from 2008-2012 (total of 585,324 total cases during this period, according to the DOH) has placed the country in fourth place in terms of dengue burden in Southeast Asia. Edillo et al. (2015) estimate that clinically-diagnosed dengue cases has direct medical cost of USD 345 million for the same period.

Figure 1 - Cases of Dengue in the World Through Time



Source: WHO, image copied from http://www.denguevirusnet.com/history-of-dengue.html

Because of its regularity in incidence and the consistent magnitude in cases, the economic costs of dengue has been tremendous, running into an estimated hundreds of millions of dollars a year, based on estimates of individual country-specific studies. In Puerto Rico, for instance, Halasa et al. (2012) calculate that the average economic cost of dengue cases (adjusted to include non-reported cases) in the

island was USD 38.7 million annually, excluding the cost of dengue surveillance and vector control. In other Latin American countries, the economic costs of officially-recorded dengue cases are likewise large : USD 135.2 for Brazil; USD 10.2 million for Venezuela; USD 1.7 million for El Salvador; USD 1.2 million for Guatemala; and USD 0.9 million for Panama (Suaya et al, 2009, as discussed in Halasa et al.). In the Philippines, the direct health cost (using both private and public health care) of an annual average 842,867 dengue cases is estimated to be USD 345 million (in 2012 prices) (Edillo, et al., 2015).

The economic cost of the cases of dengue becomes even more important if we consider the issue of burden. Halasa et al.'s study, for instance, indicated that (for Puerto Rico) the bulk of the cost of dengue falls on the household, followed by government, and insurance firms last. The share of the household becomes larger if its an ambulatory dengue case, as opposed to cases with hospital confinement. While there has been no similar data for dengue cases outside of Puerto Rico, it is imaginable that the same holds true. In the context of poverty, this situation is a cause for concern because poor households do not have the resources for treatment and mostly rely on the public health system; prevention, therefore, is the more logical approach to dengue management, rather than treatment. In this case, understanding the factors that contribute to dengue becomes imperative for the public and for government to do in order to undertake the necessary steps to reduce these factors.

The Environmental, Social, and Behavioral Underpinnings of Dengue

The investigation regarding the relationship between climate change and dengue cases is not a new field of inquiry, and the literature abounds with studies that explain the link between the two. Thomson (1938) and Watts et al. (1987), for instance, found through their laboratory experiments, that the breeding patterns of

mosquitoes were affected by temperature and the level of humidity. They concluded that the these factors change the vector efficiency of dengue-carrying mosquitoes, and that higher temperatures shortened the incubation period of the dengue virus.

Similarly, Bangs et al. (2006), found a correlation between a severe decrease in rainfall and higher temperature, and the incidence of dengue. Their findings, however, were not statistically conclusive, but the direction of relationship was established. What was conclusive were the results of the study by Colon-Gonzalez et al. (2013) in Mexico, wherein, they found that there was a nonlinear relationship between dengue cases and temperature change. The study concluded that dengue cases was positively related to increase in temperature between 18 and 32 degrees Centigrade. They also found that there was a statistically-significant relationship between increases in precipitation (up to 550mm in rainfall) and increase in dengue cases. This led to the conclusion that low to medium amount of rainfall induced the collection of rainwater; and that high amount of rainfall actually washed away the breeding sites, thus reducing dengue-incidence.

It must be pointed out, however, that the literature indicates that incidence of dengue is affected not only by environmental factors (such as climate change), but by a confluence and combination of variables related to behavior, information, urbanization, population growth, congestion, and human travel. While it is true that the probability of contracting dengue increases as environmental factors become more conducive for the breeding of the *Aedes aegypti* mosquito, human response to the threat of the illness blunts the sharpness of the of the possibility. Government programs, for instance, to educate the public regarding the threat of dengue and how to minimize exposure to the dengue-carrying mosquito has proven to be effective in reducing dengue cases in the last few years. This is an important insight to keep in

mind because it highlights the importance of the appropriate government intervention and human behavioral-response in minimizing dengue cases, thus minimizing (if not totally averting) a potential addition to the economic burden of society.

The widely-known information about dengue fever is that it spreads through the *Aedes aegypti* mosquito, its principal vector. Open and still water sources—both natural and artificial—serve as the medium by which this mosquito breeds and propagates. As a matter of strategy, dengue management and prevention have included informing the public about preventing water from accumulating in open location (such as uncovered drums, cisterns, septic tanks, or exposed pipes) which could house mosquito eggs. This is paired with aggressive government and private sector initiatives and campaigns to cover or eliminate open and still water sources, and water treatment to kill mosquito eggs and larvae.

The dynamism of society and economic progress, however, have been making dengue management more challenging. With piped-in water, for instance, greater access to piped-in water—a measure of growing urbanization—has aggravated dengue cases in Mexico because of higher incidence of water storage within a dwelling place (Colon-Gonzalez et al. 2013). Higher concentration of economic activities which has led to higher urban population density, has also significantly contributed to dengue cases because population density is positively correlated with the probability of spreading the dengue (Gubler 1998). In fact, it has been observed that dengue seem to flourish in dense and poor areas—most especially urban areas where the urban poor will most likely reside in cramped and highly populated locations—mostly associated with the urban locations where there are higher levels of economic activities.

Managing the Number of Cases of Dengue

Typically, the prevention of the dengue cases entails two types of strategy directions which, in turn, lead to different nodes of policy-responses. The first strategy points to the management of the factors that increases the probability of infection—which directly means placing the dengue-carrying mosquito population in check. Public health strategies along this line have focused mostly on information dissemination and fumigation, as well as the direct control of potential breeding places. Control of the mosquito population, however, spills over to the second strategy of dengue-management, and that is the prevention of transmission. It is not difficult to discern that an increase in the mosquito population—holding other factors constant—increases the probability of infection and transmission.

The prevention of transmission—the second dengue-management type of strategy—is more of a behavior-modifying type of dengue-management which is better directed at inducing members of society to adopt specific practices that would reduce the probability of infection and transmission. This is where public funds as well as private initiatives are normally directed, informing and educating sectors of society—especially those who are most susceptible to infection—on how to eliminate the possibility of contracting dengue.

Dengue cases and Climate Change – The Pathway of Effect

In ascertaining the relationship between climate change—the environmental phenomenon being investigated—and dengue cases, the path of the relationship must first be identified and explained. Climate change impacts weather variables that are significant in enhancing and affecting the breeding of the carrier—the *Aedes aegypti*—and the ability of the human body to respond to exposure to the virus.

Gubler et al. (2001), Rueda et al. (1990), Tun-Lin et al. (2000), Watts et al. (1987) as reported in Morin et al. (2013), found that climatic conditions both directly and indirectly impact the population of dengue-carrying mosquitos by way of temperature and amount of precipitation. Temperature affects the mosquitos' rate of development and behavior, and the dengue virus' replication within the body of the mosquito. In addition, temperature interacting with the appropriate amount of rainfall, provides the breeding and habitat for the insect, affecting the population of the dengue-carrier. Precipitation, on the other hand, influences the availability of breeding and habitat areas for the insect (Morin, et al. 2013). The studies by Troyo et al. (2009) and Van Benthem et al. (2005) also point to land characteristics such as vegetative and tree cover and land cover with dengue cases. Other studies (Chang et al. 1997; Vanwambeke et al. 2005) also point to land use as a contributor to the mosquito population.

The chain of effects from climatic factors leading to dengue vectors is quite complex and difficult to describe in definitive terms—thus, limiting the information needed to determine what policy intervention can be established in order to effectively address dengue cases. According to Morin et al. (2013), "A climate variable may increase dengue transmission potential through one aspect of the system while simultaneously decreasing transmission potential through another."[1], indicating the difficulty in pinning down the net effect of a change in climatic condition such as temperature. They were, however, able to map out a diagram that illustrates and summarizes the interaction of the factors that impact the vector (transmission) of

[1] Morin CW, Comrie AC, Ernst KC. 2013. Climate and dengue transmission: evidence and implications. Environ Health Perspect 121:1264–1272;http://dx.doi.org/10.1289/ehp.1306556

dengue as shown below: (Diagram and description copied directly from Morin et al. (2013)).

Figure 2 – Diagrammatic Representation of the Links Between Climate Variables, The Dengue Virus and Vector.

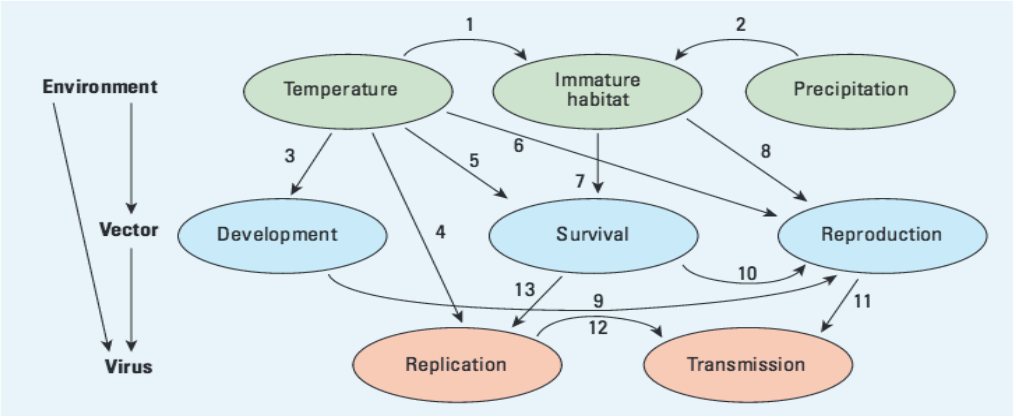


Figure 1. Diagram of biophysical influences on DENV ecology showing the interactions between climate variables, vectors, and the virus. Numbers identify relationships between variables. Habitat availability for mosquito larvae is influenced by temperature through evaporation and transpiration (*1*) and incoming precipitation (*2*). Temperature is a major regulator of mosquito development (*3*), viral replication within infected mosquitoes (*4*), mosquito survival (*5*), and the reproductive behavior of mosquitoes (*6*). Habitat availability is required for immature mosquito survival (*7*) and reproduction of adult mosquitoes (*8*). Faster mosquito development and increased survival will accelerate mosquito reproduction (*9* and *10*). Increased mosquito reproduction enhances the likelihood of transmission by increasing the number of blood feedings (*11*), whereas faster viral replication increases transmission by shortening the extrinsic incubation period (*12*). Last, increased survival of the adult mosquito increases the amount of viral replication (*13*).

Note: DENV refers to dengue vector.

Source: Morin CW, Comrie AC, Ernst KC. 2013. Climate and dengue transmission: evidence and implications. Environ Health Perspect 121:1264–1272; http://dx.doi.org/10.1289/ehp.1306556.

From the information gathered, one can discern that although the interaction between the climatic factors and the conditions that result in a change in vector activity is complex, the stand-alone impacts of each can be ascertained. More scientific inquiries are needed in order to find out how the environmental conditions that are specific for each dengue-stricken country combine and interact, which in turn result in changes in vector activities that affect the number of dengue cases. For now, the detailed technical information is not available; and perhaps, this would be an area for budget considerations by specific countries such as the Philippines. This paper is a

step towards this objective of providing data and insights that could be the start of further inquiries about climate change and dengue cases.

From the information collected, the fundamental question is formed: How does a change in climatic condition influence dengue cases in a tropical country like the Philippines? In order to answer this question, it is necessary to determine the statistical significance of specific climatic variables—temperature and rainfall—in influencing the country's susceptibility to enhanced vector activity which in turn results in higher dengue cases. The results of this inquiry should provide some technical bases and guidance for policy direction regarding the illness.

Methodology and Data

Using Ordinary Least Squares (OLS) with fixed effects, the 2004-2014 data collected from PAG ASA and the Department of Health per region, were econometrically tested to determine possible causal relationship. Since the primary research inquiry of this paper focuses on climatic variables and their effect on dengue cases, the different variables mentioned in the literature were supposed to be included in the empirical model for this study, namely: temperature, humidity and rainfall. These variables were supposed to be tested along with existing policy variables that represent government health programs, but the time and resource limitations did not allow for additional data collection that would have captured these variables. The dummy variable for La Niña occurrence, however, was added to the model in order to determine if this weather deviation could exacerbate dengue cases. The inclusion of La Niña in the model was done upon reflection that this climatic phenomenon (wherein the sea surface water cools down below normal) affects the normal cycles of rainfall and dryness of the seasons in the world, and could affect the development of

the *Aedes aegypti* mosquito. In summary, the basic empirical model is specified as follows:

$$\text{Frequency of Dengue} = f\,(\text{MTemp, RelHum, TotRain, LN, HealthExt, San, HH})$$

where MTemp represents average temperature, RelHum is relative humidity, TotRain is total rainfall, HealthExt is the number of times health stations in the area, San is percentage of households with proper sanitation, and LN is the dummy for years that there were reported La Niña phenomenon. The variables MTemp, RelHum, TotRain and LN were selected based on the scientific literature that identified these climatic conditions as key determinants of the development and breeding of the dengue virus-carrying mosquito. The other variables—HealthExt and San—were selected to represent the government program health intervention and the communities' proactive actions to address health issues such as dengue. The presence of health stations represents the presence of health programs in the communities—presumably one of which would be dengue-prevention—while the percentage of sanitary facilities represents a communities' behavior toward proper sanitation that affect the breeding of the *Aedes* mosquitos. It must be noted that the intent was to use dengue incidence as the dependent variable in order to adjust the model for variations in population which would affect the number of dengue cases in each region. Unfortunately, there were gaps in regional population data which could not be bridged without affecting the results. As an alternative, the variable HH, the total number of households for each region, was added to the model to take into account the impact of population-related influence on dengue incidence.

Assembling the data used for the econometric testing proved to be challenging. The dengue cases was generated from the Department of Health directly,

while the climatic data were collected from PAG ASA. The DOH published data on dengue had gaps, which forced the author to use the raw data from the DOH office. The difference between the two sets was that the published data were already adjusted for underreporting. In order to keep all the data consistent, it was necessary for the raw data on dengue cases to be used. The rest of the data were sourced from the FIES. All data were time series, for each quarter for twenty years. The conduct of this study revealed the continuing difficulty in data collection in the country which, if proper research were to be done, must be addressed.

Results and Analysis

The econometric testing was fairly straightforward, with three out of the four climatic variables registering significant statistical relationships with the dependent variable, regional dengue cases across time. It is also worth noting that the statistical significance of the number of households data indicates that the model has appropriately included and taken account of the possible effect of population on the number of dengue cases. The results are summarized below, reflecting consistency with the scientific information in the literature linking dengue incidence with environmental and weather-related variables.

Table 1 – Summary of Econometric Results

Dengue cases (Frequency of Dengue) = Dependent Variable	Coefficient	Robust Standard Error	T	P > |t|
Number of Households (HH)	0.00754	0.0016758	4.50	0.000
% of Households with Proper Sanitation (San)	337.3841	87.33511	3.86	0.000
Number of Health Stations (HealthExt)	4.089868	1.956504	2.09	0.042
Log San	-3570.131	1187.238	-3.01	0.004
Total Rainfall (TotRain)	1.787017	0.9718536	1.84	0.072
Mean Temperature (MTemp)	4575.233	2124.976	2.15	0.037
Relative Humidity (RelHum)	20.3736	231,1128	0.09	0.930
La Nina Dummy (LN)	3020.929	1086.897	2.78	0.008
Constant	-150040.1	69704.18	-2.15	0.037

The figures above suggest that higher recorded precipitation (perhaps interacting with warmer temperature) does significantly contribute to dengue cases. From these results and the findings of other studies, we can conclude that the Philippines is the same as any case in other parts of the world; and that higher precipitation encourages the proliferation of outdoor breeding sources for the *Aedes* mosquito. Temperature increase also induces more cases of dengue because the higher ambient temperature shortens the development and incubation periods of the *Aedes aegypti* larvae, which in turn increases these insects' population growth rate. Higher temperature also increases the feeding rate of the *Aedes aegypti* mosquito which means that the transmission rate of the dengue virus increases as well.

The results, however, fail to support the conclusion of other studies regarding the positive impact of humidity on dengue cases. As far as the Philippines case is concerned, relative humidity is not a significant contributor in either the breeding and

development of the dengue mosquito, nor does it impact the vulnerability of the members of the communities—perhaps in terms of health resistance—to the dengue virus once bitten by the dengue mosquito. The reason may be due to humidity's interaction with other factors which neutralizes its effects, but this is merely a speculation. Further scientific inquiry is suggested to determine the true reason that humidity is not a factor in dengue cases, even if the literature suggest it should be.

Although there has been only speculation that the presence of La Niña has a direct effect on dengue cases, this study has econometrically linked the La Niña phenomenon with increases in dengue cases. The results indicate that there is a statistically significant increases in dengue cases during the years that La Niña occurred. By definition, La Niña is the worldwide weather phenomenon wherein the amount of precipitation is above the normal level; as such it is logical to conclude that the presence of La Niña induces the development and population of the *Aedes* mosquito.

What is curios among the results is the statistically significant correlation between dengue cases and the non-climatic variables tested, specifically the percentage of households with proper sanitary facilities and the number of health stations in the community. According to the results, there is a negative relationship between the log of percentage of households with sanitary facilities and dengue cases, which is consistent with the WHO advice that proper disposal of solid waste impacts the growth of the population of the dengue-carrying mosquito—the higher the percentage of households that utilize proper sanitary facilities, the less cases of dengue. This suggests that the positive behavioral response to health issues such as investing and adopting hygienic practices does have a significant impact on the control and management of transmittable illnesses such as dengue.

Regarding government health programs, the positive and statistically significant relationship between the number of health stations and dengue cases is curious and counterintuitive. While the relationship is statistically significant, the results show that the direction of effect of the number of health stations on dengue cases is positive, which, at first glance, suggests that building health stations contribute to more dengue cases. There possible explanation to this result is that additional health stations—for treatment and health counseling—were built in response to rising cases of dengue; and that the number of health stations (as a variable in the model) does not represent the government's level of investment to prevent a rise in dengue cases. Unfortunately, more data—which might be primary in nature—would have to be collected and evaluated to replace the number of health stations in the model.

With a fairly high adjusted R^2 of 0.6, the model specified in this study does seem to explain the variability in regional dengue cases across time; and thus, the variables tested—especially the climate and weather-related variables—are then deemed significant contributors to dengue cases. Equally important to note is the result pointing to the public's degree of health awareness is also key in managing total dengue cases in the Philippines.

Summary and Conclusion

This study's main objective is to determine if climate-related factors induce increases in dengue cases in the Philippines. The economic cost of dengue is high with the economic burden being borne most by the poor who have more to lose from lost income due to illness; and as such, every bit of information that can be gathered in order to better manage the incidence of dengue is essential so as to reduce (if not

completely eliminate) these costs. What this research set out to do is not ground breaking because this type of analysis has been done in other countries, but since there has been no known study that looked at this question in the Philippine context, the results of this study frames the problem and "localizes" the problem under specific conditions in the Philippines. This study's results are significant because they have formally verified if the climate-change related variables that have been investigated in other countries are also relevant for the Philippine case. The findings are important in crafting policies and government steps in order to "climate-change proof" the country.

The scientific literature already mapped-out the link between temperature, humidity, and precipitation, and dengue cases. This basic connection between these climatic factors and cases of dengue is the mosquito known as the *Aedes aegypti,* whose breeding and development are affected by environmental factors. Although the chain of effects that climatic factors trigger can be quite complex (the impact of one climatic condition could either be negated or enhanced by the presence of another factor), the individual effects on specific stages of the *Aedes aegypti'*s larval development and breeding phase have been identified, *ceteris paribus*.

Temperature has been found to affect the behavior of the dengue-carrying mosquito as regards its breeding, and the dengue virus' replication inside the mosquito. Temperature, combined with the amount of rainfall (where has been heavily linked with climate change), also provides the enabling conditions for the habitat of mosquitos. The result of this study which points to increases in temperature as indeed a significant factor in inducing more dengue cases in the Philippines, is consistent with the what the literature say.

The amount of rainfall that accumulates has also been a significant contributor to the number of cases of dengue in the Philippines. As explained by the literature, more and prolonged rainfall episodes increases the possibility of accumulated and still water; which serves as the breeding ground for the *Aedes aegypti*. The scientific literature, however, also points to low and moderate (and prolonged) rain as positively associated with the growth in the population of the dengue-carrying mosquito, and not the strong and heavy rainfall. Rainfall associated with storms, for instance, will most likely destroy the breeding grounds and habitat of the *Aedes aegypti*. This is the reason why the La Niña phenomenon is positively (and significantly) associated with dengue cases. La Niña, as widely known, is "cooling" of surface water temperature, inducing an abnormal cycle and intensity of dryness and wetness in different parts of the world. Although La Niña does happen naturally, its increasing frequency is attributed to general global warming even if more scientific investigation still need to be conducted in order to ascertain if these two occurrences are causally related.

The results suggest that as more households become proactive in preventing dengue by way of better managing solid waste, the higher the likelihood that dengue cases will decline. Solid waste management, after all, is really a function of households' cooperation and participation in government sanitation programs.

The overall conclusion of this paper is that the factors that affect the incidence of dengue in the world are very similar to the factors that impact the severity of dengue in the Philippines. The study has ascertained as well that climate change does have health implications and that this suggests that the adaptation to climate change and global warming must include health-related considerations such as heightened exposure to the dengue virus.

General Policy Recommendations

From the results of this study, there is now sufficient evidence to suggest policy directions in order to address the issue of dengue cases in the Philippines. But is apparent that the environmental factors that contribute to dengue cases are beyond the capacity of the government to modify and neutralize; and unless significant strides in greenhouse gas emission mitigation are attained, government action, in this regard, would have to be in the form of climate change-proofing the country.

Climate change-proofing the Philippines means that country would have to take specific steps in order to blunt the negative impacts of climate change on the population or on society in general. In the case of dengue, this means that policy makers must put in place initiatives and programs that will more aggressively combat the heightened opportunity and ability of the *Aedes aegypti* mosquito to breed and develop as a result of rising temperature and increase in precipitation. This might be in the form of heavier fogging and increase in dengue monitoring during periods when the Philippines experiences longer rainfall due to La Niña. Fogging, however, should only be one "point of attack" as far as dengue management is concerned. From the results of this study, it is apparent that the involvement of the community in preventing dengue is a very important piece of the dengue solution. With proper sanitation and pro-active efforts to prevent the breeding of the *Aedes aegypti* mosquito, the community and individual households have much to contribute to minimize and perhaps to eliminate completely, the dengue threat. As far as policy is concerned, it is recommended that the government strengthens its initiatives in empowering the public to become pro-active, by helping communities have access to proper sanitation. Information dissemination is also key, and with changing

demographics, it is best to keep in mind that the means by which to communicate is essential in informing the public.

On the science side, it is recommended that there be more public funds allocated for research and experimentation to gather more information about the disease and the vector, and to develop new methods of prevention and (cost-effective) treatments. The country also needs more scientific information about dengue and the impacts of environmental factors on its spread in order to better map out plans of action and determine how technology could be included in these plans. Recently, there are reports that the country is one of the pilot sites for the dengue vaccine, but the efficacy and sustainability of the vaccine's use still needs to be verified, which monitoring and testing can achieve.

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