Analyzing the Relationship Between Health and Income: A Case Study of the Effect of Dengue Fever on Philippine Economic Growth

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I. Introduction

The association between health and wealth is not a new concept (Weil, 2013). Numerous researchers, economists, and scholars have studied the two-way relationship between health and income, both on a macroeconomic scale and on a household level (Bloom and Canning, 2000; Edillo et al., 2015). Countries with healthier populations, frequently measured in terms of life expectancy, usually have higher national incomes (Weil, 2013). Richer countries are able to afford better healthcare and invest in disease prevention, and thus often have a higher life expectancy at birth than poorer countries. On an individual level, this correlation also holds true. When a person is relatively healthier, they are able to work more productively. Wealthier people are able to afford better healthcare, nutritious food, adequate housing, clean water and bathrooms, and are often more educated than their less wealthy peers, giving them the knowledge and informational access to deal with sickness (Clay and Mirvis, 2008). This relationship is observed in Figure 1, which shows that countries with higher real GDP per capita generally also have higher life expectancy, which is one of the most common proxies for health. Figure 2 also makes a related point; World Health Organization regions with higher GDP per capita in terms of PPP generally have a lower percentage of deaths caused by infectious diseases, consistently showing that richer countries are usually healthier.

While the correlation between health and income is unmistakable, varying views about the exact mechanism of this relationship still exist within current scholarship (Weil, 2013). Much work has been done in analyzing and quantifying the causality running from income to health. However, it is only recently that research has been focused on the reverse relationship, taking health as a driver for economic growth (The Commission on Macroeconomics and Health, 2001). A deeper understanding of the relationship between health and income could have numerous policy implications and influence thinking about long-run economic growth. For example, current understanding about policy issues concerning income redistribution, inequality, and government-provided healthcare could either be validated or questioned based on whether this relationship is simply a correlation or in fact a causal one.

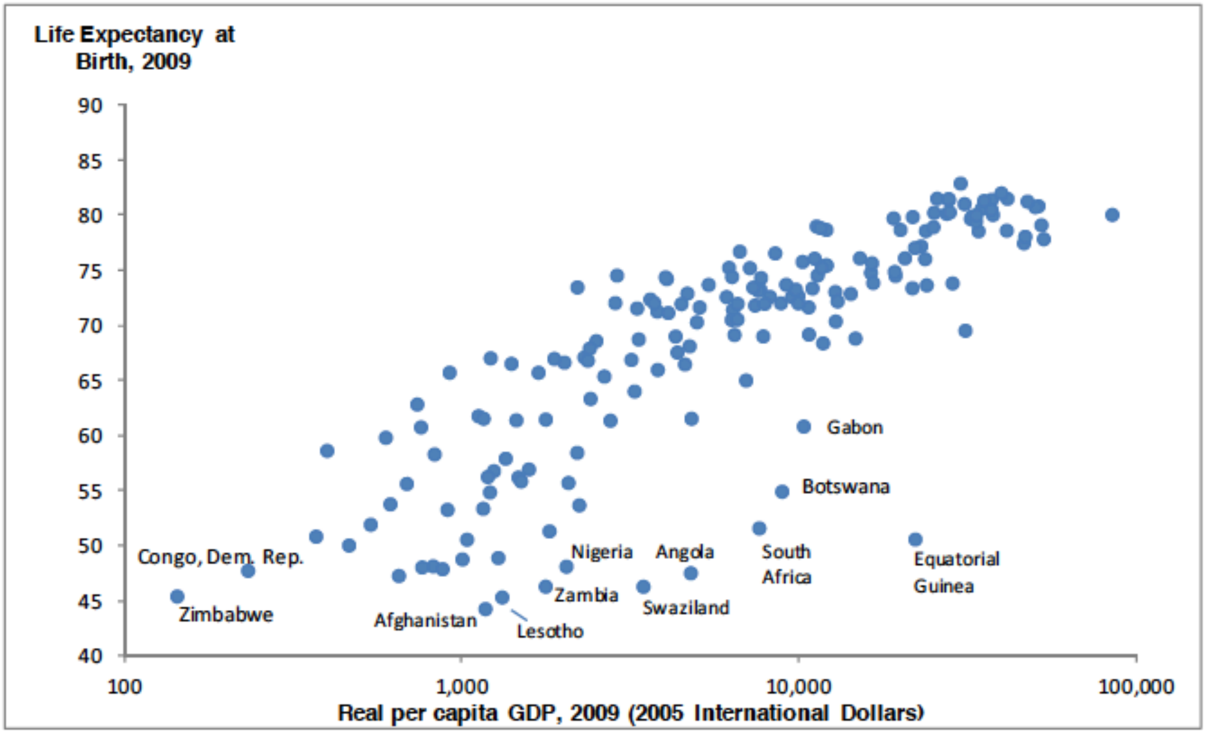

Figure 2: Income and Life Expectancy Across Countries

Figure 1: The Strong Correlation Between Health and Income As Seen Across Countries, from Weil (2013).

This paper will study the mechanism through which good health affects income and acts as an "economic engine", and through which bad health negatively impacts long-run growth in a case study of the dengue disease burden in the Philippines.[1] Although global research exists about the economic burden of disease, there is much work to be done in the Philippine setting. Globally, dengue prevalence and endemicity is rising at an unprecedented rate, with the Philippines reporting

[1] See Clay and Mirvis's discussion about *Health and Economic Development: an introduction to the symposium* in the Journal of Health and Human Services Administration.

more than 169,000 cases in 2015 – a huge 59.5% increase from the reported number in 2014 (Edillo et al., 2015). This paper seeks to synthesize past research that has been published on the economic burden of dengue in the Philippines, and identify gaps in knowledge by comparing, contrasting, and evaluating previous studies that have been done in this field.

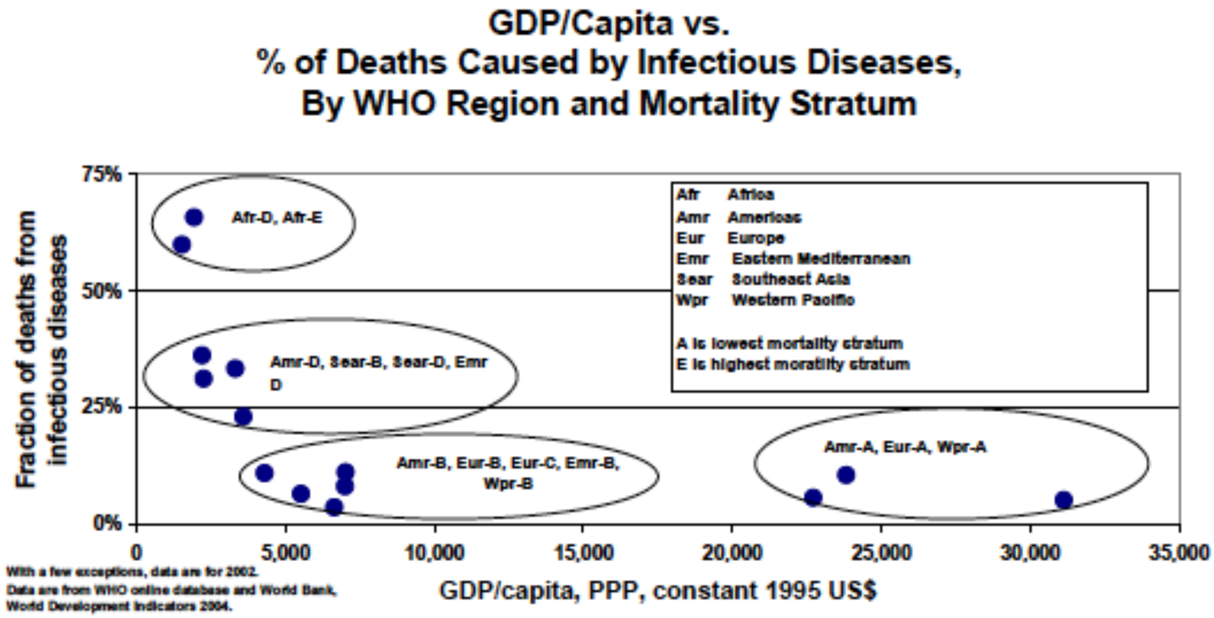

Figure 2: Disease-Caused Deaths and GDP per Capita, from Bloom and Canning (2006)

This paper aims to study the relationship between health and income in the Philippine setting, and determine if the effect of health on income is similar to those found by previous studies. Part 2 of this paper will start by broadly looking at the channels through which health affects wealth, and then will examine the methods through which diseases affect economic development in more depth. Part 3 will discuss dengue biology and provide background about its epidemiology and prevalence in the Philippines. Part 4 makes use of the limited data available in the Philippine setting and discusses what empirical conclusions can and cannot be drawn from these trends. Part 5 concludes and offers some ideas for future studies about the relationship between dengue disease and Philippine economic growth.

II. Health as a Determinant of Wealth

Health can affect income through a number of channels, both at a household level and on a population or countrywide level. Overall, diseases reduce the health status of individuals and their productivity level. From a country level perspective, diseases reduce life expectancy and economic productivity, depleting the quantity and quality of the labor force, which negatively affects GDP and GNI (World Health Organization, 2006).[2]

The first channel through which health can affect income is through education. Healthier children are able to achieve a higher level of human capital in the form of education because they are less likely to suffer from diseases or impaired cognitive development that would prevent them from attending and completing school.[3] This individual effect would then have implications on the countrywide average level of education, which plays an important role in our model of economic growth (Dupas and Miguel, 2016).

Second, healthier people are more productive. The causal effect that runs from good health to labor productivity is evident in poorer countries, where a lot of the work is centered on physical activity. Healthier people are more likely to able to physically go to work, and are also more likely to be effective workers. Because healthier people are not suffering from malnutrition or chronic diseases, there would then be less detrimental effects to their output and productivity (Bloom and Canning, 2006).

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[2] Although reducing quantity of the labor force may affect overall GDP negatively, the effect of a decrease in labor force on GDP per capita is ambiguous, and will depend on the relative effects of labor force size and productivity.

[3] For a deeper discussion about the impact of health on education, see Leslie, J. and Dean Jamison, (1990). "Health and Nutrition Considerations in Educational Planning: The Cost Effectiveness of school-based interventions." *Food and Nutrition Bulletin,* 12: 204-215; Bhargava. Alok (2001).. "Nutrition, Health, and Economic Development: Some Policy Priorities". World Health Organization, Commission on Macroeconomics and Health. CMH Working Paper Series, Paper No. WG1: 14.

Third, good health causes higher levels of saving and investment, which are forces that drive faster economic growth (Weil, 2013). On an individual level, people are more likely to save for retirement if they have a higher life expectancy. On a national level, healthier countries with more productive workforces are more likely to attract foreign investors and multinational companies. For epidemics in particular, health scares deter a large portion of investors and tourists, as was evidenced by previous epidemics in Asia like SARS that decreased foreign direct investment by an enormous 62%.[4]

Fourth, on a macroeconomic scale, health improvements could lead to a demographic dividend. A change in the demographic composition of society has implications on physical capital availability, labor force productivity, and urbanization—forces that either drive or slow economic growth depending on population effects. In particular, this stage of the dividend has allowed many developing countries to transition from higher to lower rates of mortality.[5] As Bloom and Canning point out, in Asia specifically, "health improvements can … be seen to be one of the major pillars upon which East Asia's phenomenal economic achievements were based, with the demographic dividend accounting for perhaps one third of its 'economic miracle'" (Bloom and Canning, 2000).[6]

Bloom, Canning, and Sevilla have even gone as far as quantifying this causal relationship from health to income, and have found that "each additional year of life expectancy raises per capita GDP by 4%" (Bloom el al., 2004).[7] Furthermore, research shows that the presence of epidemics can decrease economic growth substantially. For example, high malaria prevalence in

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[4] For a more detailed discussion of each channel, see Bloom and Canning (20**). Also, for a discussion about the effect of SARS on FDI inflows, see Tam, J (2003). "SARS slashes FDI inflows by 62 per cent." *The Standard: Greater China's Business Newspaper.* 1 October.

[5] For a discussion on the particular mechanisms associated with the demographic dividend, see Bloom and Canning's *The Health and Wealth of Nations* in Science Magazine.

[6] See Bloom and Canning's article in Science magazine.

[7] For more information on this, see Bloom, David E, David Canning and Jaypee Sevilla (2004). "The Effect of Health on Economic Growth: A Production Function Approach," *World Development,* Vol 32 (January), pp 1-24.

a given area can reduce growth by 1 percentage point annually.[8] Health problems can slow economic growth and set off countries into vicious spirals where poor health can lead to low income levels, and thus creates an even bigger health burden (Bloom and Canning, 2006).

III. Modes of Analysis

Three main methods of analysis have been used to study the relationship between health and income and have shown the aforementioned channels of causality: 1) the cost of burden approach, 2) economic growth models and growth accounting, and 3) full income methods that compute for economic burden by adding the value of health gains to national income (World Health Organization, 2006). This paper will focus on the first two estimation approaches because method (3) deals mostly with economic welfare, which uses a number of complex controversial parameters which is outside the scope of this paper. In addition, the classic theoretical model that has been used to analyze the various channels through which health affects income is the neoclassical growth model – the Solow Growth model combined with the Cobb-Douglas production function.

III. A. The Cost of Burden Approach

It is important to discuss the methodology behind the cost of burden approach and the economic growth model approach because often, papers that use the cost of burden approach overestimate the economic burden of disease (World Health Organization, 2006). The cost of burden approach usually sums the direct and indirect costs of a given disease, and expresses this data in the form of a percent of the total country GDP (World Health Organization, 2006). It is

[8] Commission on Macroeconomics and Health (2001)

often better used for considering the potential benefits of preventing a disease, rather than computing the long-run macroeconomic impact of a disease on economic growth, which is initially what this thesis aimed to accomplish (World Health Organization, 2006).

Moreover, the cost of burden approach also has some limitations that are not as prevalent in the economic growth approach. First of all, many papers that use the cost of burden approach identify direct and indirect costs differently, thus making it difficult to compare research done by various scholars (World Health Organization, 2006). Second, the cost of burden approach runs into problems in the analysis of human capital. Because it only takes into account the production and consumption costs of diseases and injuries, the cost of burden approach implicitly implies that the statistical value of life of retired people is zero. Third, this approach fails to take into consideration many general equilibrium impacts that result from country-wide changes in health, which then leads to a chain of wider economic impacts that could either bias the economic burden of disease upwards or downwards, depending on which effect is stronger (World Health Organization, 2006).

Within the Philippine setting, the approach that has been used most commonly is the cost of burden approach. There are not many studies that quantify the economic burden of dengue using a growth model within Philippine economic literature; therefore I will start this discussion by discussing the paper that has been cited most often by Filipino economists, the Department of Health, and medical academics in this field.

The most well-known paper that deals with the economic burden of dengue in the Philippines is a study done by Edillo et al. The authors determined that the national economic burden of dengue in the Philippines was *substantial*, with direct annual medical costs amounting to $345 million 2012 US dollars, or about 0.0138% of national GDP in 2012 (Edillo et al., 2015).

Their paper estimated the annual number of dengue episodes in the Philippines through an adjustment factor that accounts for surveillance underreporting in a case study of Punta Princesa from 2008 to 2012. In other words, they looked at a case study of Punta Princesa and computed the economic burden of dengue in that city—which, after using an adjustment factor that theoretically should account for country-scale bias, they applied in a macroeconomic analysis.

Edillo et al. estimated the number of dengue episodes nationally, derived the cost of dengue treatment per cause by setting and sector, and, using these two aforementioned components, computed the aggregate direct medical cost of dengue.[9] They used a macro-costing methodology to analyze dengue episodes by ambulatory and hospitalized setting, and by public and private sectors. Although the authors were able to obtain data of dengue incidence according to year, setting, sector, and severity, it is important to note that formal laboratory testing for dengue is rarely done in public hospitals in the Philippines because of the huge financial burden that the patient has to bear to complete the test. Thus, many dengue cases they have identified have not been lab-tested, and have only been confirmed only via presence of symptoms.

Edillo et al. generated an annual average number of 117,065 dengue cases in the years 2008 to 2012. After using an adjustment factor of 7.2, based on the case study done in Punta Princesa, which was used to account for case underreporting, the authors determined that the estimated annual number of dengue cases in the Philippines is 842,867.[10] Although the surveillance system in the Philippines did well in capturing severe cases, results show that less severe manifestations of dengue are substantially underreported, possibly due to the passive nature of the surveillance

[9] Using data obtained from the Department of Health National Epidemiology Center, the authors performed a systematic review of Philippine national and regional dengue surveillance systems "to understand their processes and define their strengths and weaknesses" (Edillo et al., 2015).
[10] By serotype, DENV1 comprised of 20% of the cases, DENV2 was 18%, DENV3 made up a bulk of 54%, and finally DENV4 composed 4%. The authors organized a one-day Delphi panel workshop in Cebu City to "address gaps in knowledge related to some aspects of dengue treatment in the country" (Edillo et al., 2015).

systems.[11] This underreporting of the less severe dengue episodes could impact our understanding of the overall economic burden dengue poses on the country because of its effect on the number of sick-days a person can take, and possibly, if manifested in children, would also affect education levels. Additionally, an analysis of this case study reiterates some of the drawbacks of using a cost of burden approach, as discussed in the previous section—while computing the total cost of dengue disease using direct and indirect costs, it fails to account for equilibrium impacts and effects of dengue on population demographics. Figure 3 summarizes their results, segmenting costs into three groups; public, private, and combined costs.

[11] For fatal and more serious dengue cases, "the weighted average medical cost of a hospitalized case was $565.04 (CI = $351.88 - $673.18) and $120.38 (CI = $61.18 - $157.49) for an ambulatory case" (Edillo et al., 2015). In terms of private hospitals, the total direct medical cost of a treated hospitalization case would be $772.46, as compared to the $387.84 total direct cost in public hospitals. Moreover, results show that treatment costs in private hospitals was almost twice the financial burden in public hospitals. "The weighted average cost of treatment per case was $409, representing 16% of the Philippines' per capita GDP ($2,587 in 2012)" (Edillo et al., 2015). On the other hand, the authors also calculated the financial burden of non-fatal dengue cases by obtaining the "indirect cost by adjusting results of a previous study [by Shephard et al.] for inflation using the US GDP deflator," which turned out to be a higher share of GDP per capita than other countries with comparable data (Edillo et al., 2015). The authors used information on medical bills of hospitalized patients obtained from Philippine Health (PhilHealth) to compute the average cost of a "bed day". From here, they calculated the average length of stay of a hospital patient, again using PhilHealth admission data for four unnamed hospitals, due to privacy reasons.

Table 3

Average annual direct medical cost of dengue cases by setting and sector 2008–2012 (in 2012 US dollars)

Setting	Public	Private	Combined
Ambulatory cases			
Hospital outpatient departments			
Cost per visit	$21.94	$46.50	$33.25
Number of visits	1.3	1.3	1.3
Cost per case in outpatient department	$28.52	$60.44	$43.23
Other ambulatory settings			
Cost per visit	$17.55	$37.20	$26.60
Number of visits	2.9	2.9	2.9
Cost per case in other settings	$50.90	$107.87	$77.15
Total cost per ambulatory case	$79.43	$168.31	$120.38
Number of adjusted ambulatory cases	159,741	136,467	296,208
Aggregate cost of ambulatory cases	$12,688,000	$22,969,000	$35,657,000
Percentage of aggregate medical cost	3.7	6.7	10.3
Hospitalized cases			
Hospitalized episode			
Cost per bed day	$68.57	$145.30	$102.46
LoS	4.37	4.03	4.21
Cost per hospitalization	$299.64	$585.55	$431.36
Ambulatory care for hospitalized cases			
Hospital setting			
Cost per visit	$21.94	$46.50	$33.25
Number of visits	1.7	1.7	1.7
Cost per case	$37.30	$79.04	$56.53
Other ambulatory setting			
Cost per visit	$17.55	$37.20	$26.60
Number of visits	2.9	2.9	2.9
Cost per case	$50.90	$107.87	$77.15
Cost of ambulatory care per hospitalized case	$88.20	$186.91	$133.68
Total cost per hospitalized case	$387.84	$772.46	$565.04
Adjusted number of hospitalized cases	294,805	251,854	546,659
Aggregate cost of hospitalized cases	$114,337,000	$194,548,000	$308,885,000
Percentage of aggregate medical cost	33.2	56.5	89.7
Aggregate direct medical cost	$127,025,000	$217,517,000	$344,542,000
Percentage of aggregate medical cost	36.9	63.1	100.0

Figure 3 Summary of Edillo et al.'s findings: Annual Direct Medical Cost of Dengue Cases in the Philippines (2008-2012), from Edillo et al. (2015). The authors computed this data using a cost of burden methodology.

To determine the direct medical cost of dengue, the authors used macrocasting methodology and the data from the medical bills of hospitalized dengue patients, both in private and public hospitals. They used a three-pronged methodology, first they estimated the number of dengue occurrence in Punta Princesa, then they segmented how much it would cost each person depending on the setting of the disease and sector used for treatment. Finally, they extrapolated from these two portions and combined it with the information from the underreporting adjustment factor to compute the aggregate direct medical cost of dengue in the whole country, which is shown in the table above. In essence, Edillo et al.'s study showed that dengue has a relatively large impact on both households and the public sector in the Philippines.[12]

One thing to note when referring to this paper, as is similar to the study done by Bravo et al., is that because Edillo et al. rely on data coming from disease reporting units and the local government surveillance system, it may be the case that bigger and more urbanized cities have more accurate recording of dengue cases as compared to more isolated and provincial areas—another risk of using solely direct and indirect costs to compute for disease burden. This is exacerbated by the fact that Edillo et al. used national passive surveying, which relies heavily on the "regular reporting of disease data by all institutions that see patients," primarily meaning hospitals and local government units (WHO, 2016).[13]

III. B. Growth Accounting Models

[12] For the data set, see http://www.who.int/immunization/monitoring_surveillance/burden/vpd/surveillance_type/passive/en/

[13] Also, while the authors mention this caveat at the beginning of their paper, it is significant to remember when comparing Philippine Department of Health (DOH) data with World Health Organization (WHO) data that the new dengue surveillance classification system set by the WHO in 2009 has been endorsed in the Philippines DOH, although is not currently being used because a number of hospitals in the country have not yet adopted this classification scheme. Although Edillo et al.'s methodology for computing the annual aggregate economic burden of dengue in the Philippines, further research into a number of issues might be helpful. For one, extrapolating the costs of dengue across the whole country using data mostly obtained from Punta Princesa in Cebu City is problematic. As mentioned in the introduction of this paper, the Philippines is an archipelago whose islands are spread out and distinctive. By using Cebu City as a case study and applying city-specific findings to the rest of the region, and on a larger scale, to the rest of the country, Edillo et al. face the risk of either overestimating or underestimating the economic burden of dengueMoreover, although the authors used an expert Delphi panel to determine the costs of dengue treatment in different settings and sectors, these costs and cases may still be biased given the attendance of scholars in the panel. The lack of detailed systematic and consistent reporting of dengue cases and dengue-caused morbidity across the Philippines again provides a dearth of accurate and reliable data. While Edillo et al. recognize this risk in their analysis and compare their extrapolation model with similar southeast Asian countries, it still does not reduce the uncertainty related to the quantities they ascribe to the costs, occurrence, and aggregate effect of dengue. Despite these limitations to applying microeconomic data on a macroeconomic scale, Edillo et al.'s study still provides an important reference on how researchers have studied the relationship between dengue and income in the Philippines.

Despite these drawbacks, the cost of burden approach has often been used to characterize the effect of disease on economic growth because the data this analysis requires is usually easier to obtain than the data required for economic growth accounting and general equilibrium models. Growth accounting models usually require a meticulous record of data that includes disease-specific epidemiological information, including the prevalence, incidence, mortality effects, and duration of a specific disease (World Health Organization, 2006). Not only is this data difficult to obtain financially, but it is also not always available, and thus cross-country comparisons, which have a high probability of being biased, are often made. Furthermore, because economic growth models account for the general equilibrium effects of diseases, the resulting disease burden is very sensitive to the specific parameters used in a study, and requires a high level of technical expertise to correctly analyze each channel being studied (World Health Organization, 2006).

A paper whose methodology was very instrumental in the analysis of the research question for this thesis is that of Ashraf et al., which discusses the causal relationship between health and GDP. In contrast to the cost of burden approach paper discussed earlier, Ashraf et al.'s research finds that health improvements, including disease prevention, have *a smaller effect on income in the long-run* than previous estimations used to support government policies. Although it is a common belief that improving health in a country will also significantly raise its income, as earlier discussed in this paper, Ashraf et al. find that "large improvements in health lead, in the long run, to modest increases in GDP per capita" through a case study of African countries (Ashraf et al., 2008). Although the data used for this study and that of Edillo et al. differ, both of them generally aim to determine the effects of health on the economy. Ashraf et al.'s growth accounting result then contrasts the result from the cost of burden approach paper previously discussed, which determines that dengue has a significant economic burden in the Philippines.

However, one important thing to note when comparing Ashraf et al.'s study and Edillo et al.'s study is that their approaches to estimate the causal effect of health on income differ in more than just the backbone model they use. While Ashraf et al. utilize the growth accounting model and Edillo et al. use the cost of burden model, the former also focuses on the supply side of the economy while the later looks into the uses of output. Ashraf et al. study the variations of and effects on capital, human capital, and labor input, while Edillo et al look at how much money was spent on hospitals. Although a direct comparison of the monetary costs gives us results that are not too inconsistent, a large part of this stems from the fact that hospitalization costs for treating dengue disease are still considered as part of the Philippine GDP. Despite increased health spending and higher hospital-associated costs, this computation does not reduce GDP.

In Ashraf et al.'s macroeconomic study, they used a simulation to determine the economic effects of an exogenous change in health on per capita income. They look at both the direct and indirect effects of health on output. The three aspects of causality through which they studied the effects of health are the following; labor productivity and human capital, demographic responses and mortality changes, and changes in the aggregate production function. The authors study the "direct effect of health on worker productivity, as well as indirect effects that run through schooling, the size and age-structure of the population, capital accumulation, and crowding of fixed natural resources… [as well as] the dynamic processes of phase-in of health improvements and the adjustment of fertility to a change in mortality," (Ashraf et al., 2008). Like many growth models, the angles of analysis used in this paper allow a better examination of general equilibrium effects.

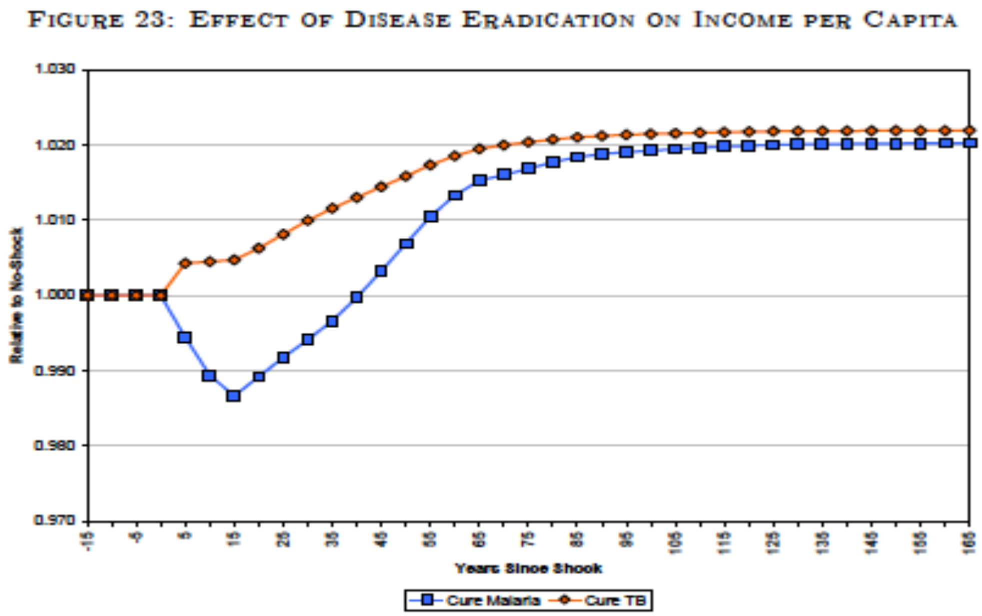

Figure 4: The Effect of Disease Eradication on GDP per Capita, from Ashraf et. al. (2008).

Ashraf et al. determined that the time-lag from the health improvement and the supposedly accompanying increase in GDP per capita could take as a long as 30 years, although most of the long-run gains take twice that amount of time to manifest (Ashraf et al., 2008). The effect of improved health on income per capita are considerably lower than those described in modern policies, and the long time scale in which improvements in health are observed could reach up to three decades or more (Ashraf et al., 2008).

Importantly, Ashraf et al. point out that there may be differences in the findings of macroeconomic versus microeconomic studies, as was pointed out earlier by the World Health Organization (2006). The household and individual level association between health and income is described, on average, by various researchers to have a strong positive causal relationship. Namely, Deaton determines the causal relationship of income on individual level health and vice versa in a study about health and economic status in South Africa.[14] While most of the microeconomic research published in the past, which focused on malnutrition, anemia, exposure to diseases, and similar estimates of health, have shown a very strong positive causal relationship between health and income, this was not always the case with macroeconomic studies. General equilibrium effects of health changes are not always evident or observable in microeconomic studies. Health improvements can lead to large increases in national population, which, based on the Malthusian growth model, can have a negative impact on income. Health improvements also have a large effect on infant mortality, which plays a substantial role in demographic trends. Moreover, not all microeconomic measurements can be mapped directly on to corresponding effects in macroeconomic settings because of the different units and methodologies used to compute health effects. These effects would not have been as accurately accounted for if the cost of burden approach was used for analysis, especially because not all of the general equilibrium mechanisms and long-run effects would have been represented precisely.

Most significant to this thesis is Ashraf et al.'s exploration of disease eradication, as shown in Figure 4. Through a prospective examination of demographic data from Zambia, Ashraf et al. identified the income effects of complete eradication of malaria and tuberculosis, both of which are prominent and endemic in many developing countries including the Philippines.[15] While the elimination of either disease caused an expected increase in life expectancy at birth, "eliminating malaria causes the dependency ratio to increase by about 2.6 percent over the following 15 years, while eliminating tuberculosis causes the dependency ratio to fall more or less continuously for the next 60 years, including on impact" (Ashraf et al., 2008).[16] With regards to the direct effect of

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[14] Deaton, 2003 http://admin.nber.org/reporter/spring03/health.html

[15] http://wwwnc.cdc.gov/travel/destinations/traveler/none/philippines list of diseases that are endemic and epidemic in the Philippines

[16] This calculation for dependency ratios makes sense, because malaria largely affects young children, while tuberculosis occurs in adults who are in their most productive years.[16] In that sense then, eliminating malaria will reduce child mortality more than it

eliminating malaria and tuberculosis on labor productivity, the authors find that the long run effects of eradicating both diseases are similar, resulting with an increase in income per capita of two percent. However, the short-run simulation effects of reducing these diseases differ.[17] In terms of income paths, Ashraf et al. describe the differential effects of disease eradication on income per capita and income per worker. Although malaria eradication is correlated with a higher income per worker in the long-run, income per capita of malaria and tuberculosis eradication is equalized in the same timescale because of the positive effect of tuberculosis eradication on working-age adults.

In terms of human capital, tuberculosis eradication "frees up" more productive labor in the form of working-age adults, as compared to malaria eradication which increases the number of children (Ashraf et al., 2008). However, in terms of schooling effects on human capital, malaria eradication has a much larger increase because of the demographic segment it is most prevalent in. [18] Despite this causal effect, the authors conclude that "the economic benefits of disease reduction are both small and, in the case of malaria, long in coming" (Ashraf et al., 2008).[19] Thus, we see that the results of this particular growth accounting model indicate that the effect of disease eradication is much less than that described by the cost of burden approach used by Edillo et al.,

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will reduce adult mortality, thus explaining the increase in the dependency ratio. On the other hand, eradicating tuberculosis will decrease adult mortality on a larger scale than it will decrease child mortality, thus causing the dependency ratio to fall. In terms of population size, the increase in population caused by malaria eradication was larger than that of tuberculosis eradication, although this finding was not surprising given that a larger portion of the population was affected by malaria than tuberculosis.

[17] While malaria eradication initially causes income to drop about 1.5 percent below its pre-eradication level before increasing after a timeframe of 40 years, tuberculosis eradication causes income per capita to rise immediately. Interestingly, the authors describe two impact points of this observation; divergent income paths and effects on human capital.

[18] Also, because tuberculosis eradication decreases mortality rate among the working-age population who are in their prime and thus likely to be more experienced, the long-run effect on human capital is much greater than that of malaria eradication. Lastly, looking at the indirect effects of disease eradication, Ashraf et al. look at schooling and human capital accumulation, particularly because malaria affects a large portion of children. Eradicating malaria had a positive correlation on years of primary schooling, as supported by the authors' experiment and several other papers they cite that did similar studies (ie. Lucas 2007, Bleakley 2007). "Malaria eradication raises schooling by 0.18 years, which accounts for most of the long-run increase in human capital from eradication. The increase in schooling from eradicating tuberculosis is only 0.09 years" (Ashraf et al., 2008).

[19] The appendix contains some useful figures from Ashraf et al.'s paper. The methodology the authors used in this analysis has been instrumental in the organization of the framework of study for this paper. Their systematic examination of each channel through which health could affect income in the Solow growth model was exhaustive, as was their inclusive study of the dual-direction through which causality can run.

although again, it is important to note that other differences in the authors' computations may affect this result, as mentioned earlier in this section.

On a global scale, another paper that deals with growth accounting estimates of the economic impact of disease is that published by the World Health Organization.[20] Abegunde and Stanciole estimate the economic cost of selected chronic diseases at a national level and identify the potential economic gains that could be made if the global goals for chronic disease prevention are met. The authors find that potential losses from deaths caused by chronic diseases is substantial across their selection of countries, and will cumulatively decrease national accounts, labor supplies, and savings. Moreover, their results indicated that the "burden of chronic disease poses appreciably greater constraints to economic performance in low and middle income countries, [including the Philippines]" (World Health Organization, 2006). What this research has in common with the previous two described in this paper is that it establishes a clear and logical channel of causality from health to income, and does indeed show that the relationship between health and income is not only a correlation, but also a causal one. By using the economic growth model and doing a macro-level analysis of the consequences of "premature mortality" from chronic diseases on the national income of the authors' selected countries, Abegunde and Stanicole quantified the potential economic gains that could be achieved by disease prevention. Their methodology is very similar to that of Ashraf et al., and again are able to account for general equilibrium effects of disease eradication (Abegunde et al., 2006). This approach is coherently organized using the Solow Growth Model and the Cobb-Douglas Production Function, which the authors augmented to include effects of human capital as well as labor input. The gravity and

[20]Abegunde, Dele and Anderson, Stanciole (2006). An estimation of the economic impact of chronic noncommunicable diseases in selected countries. The World Health Oragnization, Department of Chronic Diseases and Health Promotion.

direction of the impact, however, is still debatable, particularly evidenced in the varying magnitudes of the economic burden diseases pose globally and nationally.

In summary, many approaches have been used to evaluate the effect of health on income at both a micro-level and a more macroeconomic scale. This part of the paper began with the studies that focused on dengue economic burden in the Philippines, before moving on to the varying effects of disease on long-run growth in Africa, and finally looking at a more global scale at the effects of disease on economic growth. While the results of these three papers vary by region, time period, and magnitude of result, it is clear that a causal effect runs through the channel of health to income.

IV. Background

IV. A. Dengue Occurrence Around the World

Globally, dengue is currently regarded as the most important arboviral mosquito-borne disease, with 50% of the world's population living in areas that are at risk of the disease, and 50% of the world's population living in countries where dengue is endemic (Murray et al., 2013). The World Health Organization classified dengue as the "'most important mosquito-borne viral disease in the world' [in 2012] due to significant geographic spread of the virus and its vector into previously unaffected areas and the subsequent costly burden of disease it brings" (Murray et al., 2013). According to Murray et al., "significant geographic expansion has been coupled with rapid increases in incident cases, epidemics, and hyperendemicity, leading to the more severe forms of dengue" (Murray et al., 2013).

While the true impact of dengue disease globally is difficult to pinpoint due to poor disease surveillance and the consistent underreporting of dengue cases, historical estimates of the number of infections per year have ranged from 50 million to 200 million people. However, more recent research using cartographic approaches, in particular the work done by Bhatt et al. on dengue's global distribution and burden, has shown that global dengue occurrence is probably closer to 400 million people. Although this estimate is almost three times the initial World Health Organization estimate which are shown in Figure 5, Bhatt et al.'s approach also factors in dengue cases which do not manifest apparently, meaning that they are not at a clinical or sub-clinical severity. While these non-apparent dengue cases are not as severe as the cases reported by the World Health Organization, they still pose a considerable burden on a country (Bhatt et al., 2013). Additionally, difficulties in diagnosing the disease are also common in developing countries in the tropical region, particularly because of the high hospital costs associated with the laboratory testing. Coupled together, these factors lead to a lower level of case fatality rate reporting than the actual number of deaths and cases, and thus makes it more difficult to have cross-country and regional comparative analyses of dengue disease. Thus, currently available data has most likely underestimated the social, economic, and health burden of dengue (Murray et al., 2013).

Accordingly, Bhatt et al.'s work on estimating the frequency of dengue globally identifies a number of variables that affect dengue ecology, or the probability that a particular geographic location's population will contract the dengue virus. These factors include rainfall, temperature, and the degree of urbanization.[21] Consequently, while dengue is a global concern, "almost 75% of the global population exposed to dengue live in Asia-Pacific," particularly in Southeast Asia where dengue is a leading cause of child mortality and hospitalization (Murray et al., 2013). In the Western Pacific region, the number of dengue cases has risen rapidly in the last decade, with the

[21] Bhatt et al. use a formal modeling framework to create a map of the global distribution of dengue risk, and finally analyze the public health burden of dengue disease in 2010.

greatest dengue burden occurring in Cambodia, Lao People's Democratic Republic, Malaysia, the Philippines, Singapore, and Vietnam.[22]

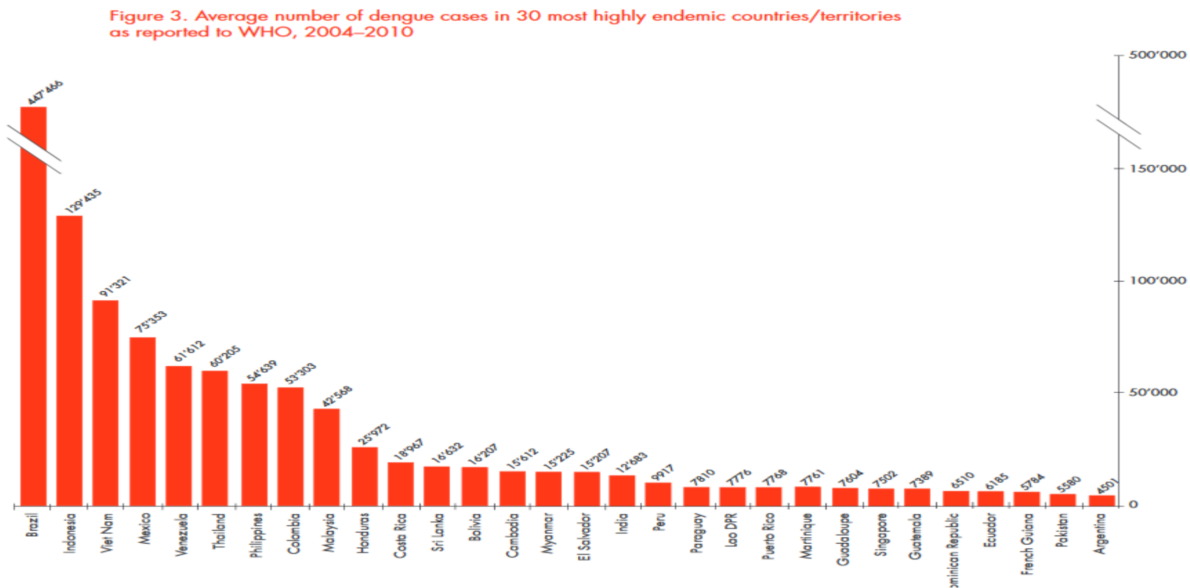

Figure 5 Average number of dengue cases in highly endemic countries from 2004-2010 from WHO. The Philippines has the seventh highest average number of dengue cases in the world.

Aedes aegypti, the mosquito that transmits dengue and zika, originated either from Africa or Asia, and through the use of shipping vessels in 1800 AD, it became endemic throughout urban tropical coastal cities around the world.[23] Tracing its first possible occurrence in the time of the Chin Dynasty in 265-420 AD, dengue virus has spread rapidly through both tropical and subtropical regions. Advancements in modern transportation and rapid urbanization in World War II led to "increased transmission of dengue and hyperendemicity (multiple serotypes present) in most South East Asian countries, with subsequent emergence of the severe forms of dengue"

[22] These region divisions are based on the World Health Organization regions. In the Americas, dengue is now hyperendemic across all countries, while in Africa outbreaks are increasing in size and frequency. In Europe, there is a real and apparent threat of dengue outbreaks given the number of travelers who come in and out of the region, and finally in the Eastern Mediterranean, dengue is now an emerging disease

[23] "These shipping vessels allowed transportation of breeding sites for the vector along with humans to complete the transmission cycle, allowing for slow but evident introduction of the virus and the mosquito to coastal destinations around the world" (Murray et al., 2013). Moreover, during World War II, the epidemic became more far reaching because the troops who began to disperse inland within and between countries served as prolific hosts of the virus.

(Murray et al., 2013). Today, dengue is endemic in more than 125 countries and present in every World Health Organization region of the world, as shown in Figure 6.

The dengue virus is composed of single-stranded ribonucleic acid (RNA) transmitted by *Aedes aegypti* causes dengue and dengue hemorrhagic fever. It has four different serotypes, namely DEN-1, 2, 3, and 4.[24] It comes from the same arboviral disease family as yellow fever, zika, and WN. Interestingly, a person cannot be immune to dengue without getting the disease. Each of the four mentioned serotypes provides serotype specific lifetime immunity and short-term cross-immunity after recovery from the disease. [25] However, all serotypes can cause severe and fatal dengue disease, as well as non-apparent infections. Dengue is transmitted primarily by infected female mosquitos, which bite more frequently in the daytime and live around human habitation. These female mosquitoes lay eggs and produce larvae preferentially in artificial containers.[26]

Some of the risk factors that are associated with dengue hemorrhagic fever include the type of virus strain, kind of pre-existing anti-dengue antibody which can either be present in the form of previous infections or maternal antibodies in infants, host genetics, and the patient's age. There is a higher risk of fatal cases in secondary infections, and also a higher risk in locations with two

[24] These strains are alternatively called DENV-1, 2, 3, and 4

[25] The way the virus is transmitted and infects humans starts when the host is bitten by the mosquito vector. From there, the virus enters the bloods stream and then attaches to a cognate receptor on an immune cell, until finally the cell is taken over for viral replication (Opol, 2016). The virus is transmitted to human hosts in mosquito saliva, then it is replicated in the human body within target organs, infecting macrophanges and monocyte lymphatic tissues, before eventually circulating and spreading in the blood stream.

[26] Genetic variations do exist within each serotype, with some genetic variants within each serotype more virulent or epidemic than other variations. In terms of transmission, when a second mosquito ingests the dengue virus from the blood of a human host already infected with it, the virus replicates inside the mosquito and infects and replicates within the mosquito's salivary glands. Once this mosquito then bites another human, the virus spreads and is transmitted to another host. The current hypothesis on dengue hemorrhagic fever pathogenesis is that people who have experienced dengue infection develop a type of serum antibody that allows them to neutralize the dengue virus of that same homologous serotype. This means that if a person becomes infected with DEN1, then upon recovery, they will have lifetime immunity from that serotype. It is important to note that the order in which someone gets dengue fever is important, since some orders are deadlier. In particular, the deadliest order someone can get dengue virus in is DEN2, DEN3, DEN4, and DEN1. This order has a higher probability of mortality because of antibody dependent enhancement, which is the "process in which certain strains of dengue virus, complexed with non-neutralizing antibodies, can enter a greater proportion of cells of the mononuclear lineage, thus increasing virus production" (Opol, 2016). This means that the antibodies within the infected person think as if they are fighting the disease, however they are not.

or more serotypes circulating simultaneously at high levels, in other words hyperendemic transmission.[27]

Figure 2. Distribution of global dengue risk (determination of risk status based on combined reports from WHO, the United States Centers for Disease Control and Prevention, Gideon online, ProMED, DengueMap, Eurosurveillance and published literature (Simmons CP et al, 2012).

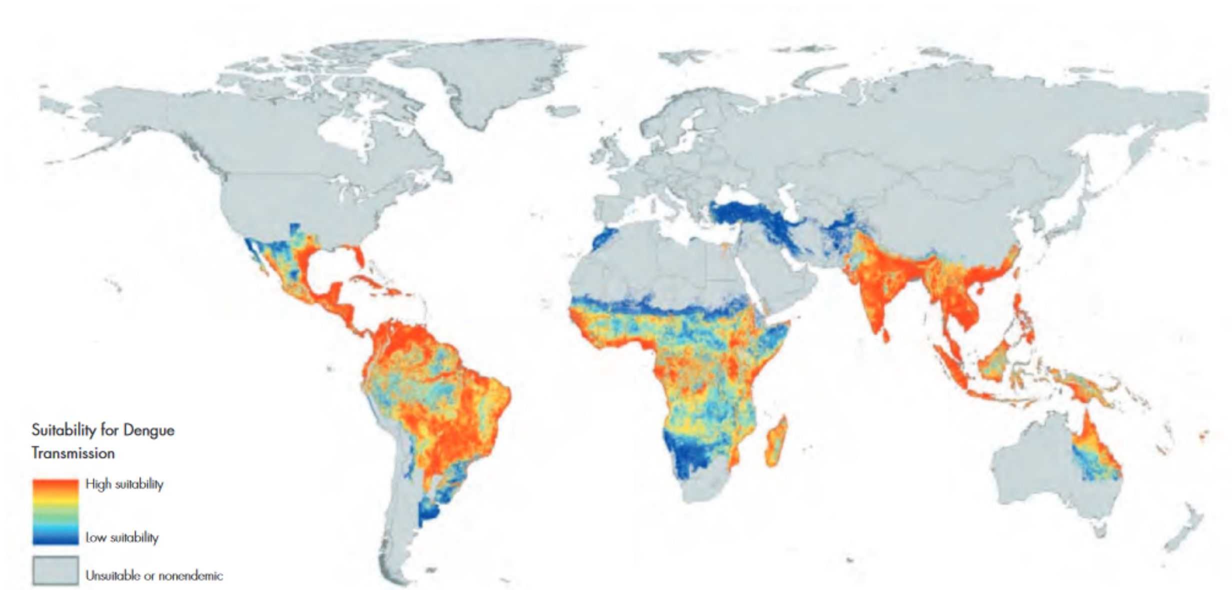

Figure 6 The Global Distribution of Dengue Risk, from the World Health Organization (2012). The Philippines is in red, representing high endemicity.

IV. B. The Philippines and Dengue Philippine Trends

To better analyze the relationship between health and income in the Philippines and understand why it is a good case study for this question, it is important to understand the past dengue disease trends as well as some basic economic and environmental information about the Philippines. The Philippines is a great case study to analyze the relationship between health and income because of the country's regional divisions and dengue ecology. The regional differences are complex enough to be able to make comparisons using different factors like geography, local

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[27] For a succinct discussion on the difference between epidemics, pandemics, and endemics, see Bloom and Canning's work on *Epidemics and Economics*, in the Harvard Initiative for Global Health – Working Paper Series. The full citation for this work can be viewed in my reference page.

environment, and health, yet similar enough to control for some variables like government and political stability.

The Philippine archipelago is a low middle-income country located in South-East Asia between the Philippine Sea and the Pacific Ocean. Comprised of 7,107 islands, The Republic of the Philippines is divided into three major geographical areas namely Luzon, Visayas, and Mindanao. The country consists of 18 regions (although one is autonomous), 81 provinces, and 136 cities, 16 of which are considered as highly urbanized cities.[28]

The Philippines has a tropical and maritime climate, with high humidity and abundant rainfall (Philippine Department of Health, 2016).[29] Located in the Western Pacific typhoon belt and the Pacific Ring of Fire, the country experiences an average of 20 typhoons annually, and heavy rainfall from June through November (Philippine Department of Health, 2016). These varying climatic factors play a role in determining some of the variation in past dengue trends because, as previously mentioned, environmental factors partially determine a location's dengue ecology. The levels of high humidity, increasing rainfall, and tropical climate contribute to creating an environment that promotes exponential breeding rates for dengue-carrying mosquitos. Research led by Agustin Arcenas has studied this particular relationship between dengue-inducing factors in the Philippine setting and the Philippine national economy, taking careful consideration of the link between dengue and climatic conditions. Arcenas focuses on the interrelatedness of the environmental factors that are conducive to increasing the breeding speed of the *Aedes aegypti* mosquito, namely weather and climate. He finds that climate change creates a bigger burden in the

[28] The Philippines is comprised of 18 regions, according the Philippine Standard Geographic Code as of September 2016. Namely, these are: Negros Island Region (NIR), which was just created last 2015, National Capital Region (NCR), Cordillera Administrative Region (CAR), Ilocos Region (Region I), Cagayan Valley (Region II), Central Luzon (Region III), CALABARZON (Region IV-A), MIMAROPA Region, Bicol Region (Region V), Western Visayas (Region VI), Central Visayas (Region VII), Eastern Visayas (Region VIII), Zamboanga Peninsula (Region IX), Northern Mindanao (Region X), Davao Region (region XI), Soccsksargen (Region XII), Caraga (Region XIII), and Autonomous Region in Muslim Mindanao (ARMM).

[29] 2013 – 2016 Medium Term Development Plan: Dengue Prevention and Control Program (DRAFT)

economic costs of dengue. Moreover, the "incidence of dengue is affected not only by environmental factors… but by a confluence and combination of variables related to behavior, information, urbanization, population growth, congestion, and human travel" (Arcenas, 2016).[30]

In 2015, the Philippines had a GDP (in terms of purchasing power parity computation) of $741 billion US dollars, while the GDP real growth rate was estimated to be about 5.8%. National GDP per capita (in terms of PPP computation) was at $7,300 US dollars, while the gross national saving in that same year was 23.4% of the total Philippine GDP. In terms of GDP composition, most of the country's national income comes from the services sector, which contributed about 59% of national GDP in 2015. The industry sector contributed 30.8% of national GDP, and the agricultural sector contributed 10.3% (The CIA World Factbook, 2016).[31] In terms of labor force, the Philippines had 41.76 million people participating in the labor force in 2015, although about 40% of the employed people in the country were working in the informal sector. Following the segmentation of national GDP, the occupations of people in the labor force were mostly focused in the services sector (55%) in 2015, with agriculture (29%) and industry (16%) lagging behind. The Philippines has had relatively high unemployment rate, consistently hovering at 6.3% in 2015 and 6.8% the previous year. About a quarter (25.2%) of the Philippine population survives below the poverty line, and the lowest 10% of the population's households only has about 2.9% of the share of national income. Meanwhile, the highest 10% of the households by consumption, have a 30.5% share.

[30] Moreover, Arcenas concludes that the "econometric results… indicate that better household sanitation practices… 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" (Arcenas, 2016).
[31] https://www.cia.gov/library/publications/the-world-factbook/geos/rp.html

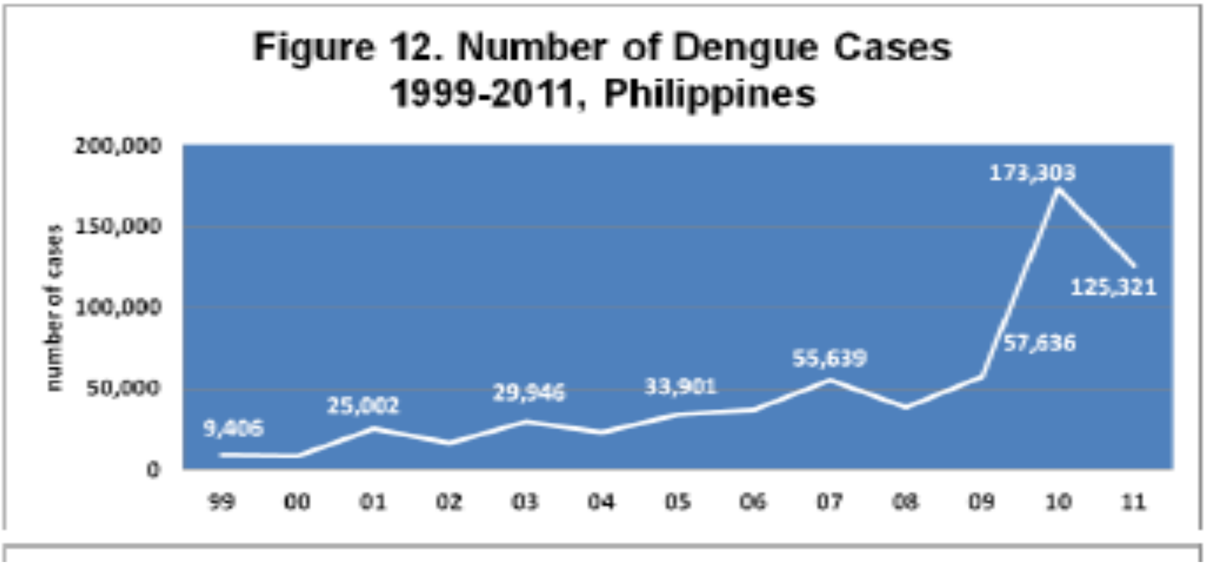

Figure 7: Total Number of Dengue Cases Over Time (Philippine Department of Health)

The average life expectancy in the country is 72 years, according to 2007 data (Philippine Department of Health, 2016). Despite current medical advancements and technological progress, communicable diseases are still a major cause of morbidity and mortality in the country, including infectious diseases like tuberculosis and pneumonia which are leading causes of death (Philippine Department of Health, 2016). Moreover, a comparison of disease indicators and patterns among various socio-economic groups and geographic areas shows that there is a wide disparity between the average level of health between high and low income groups, and that of urban and rural residents (Philippine Department of Health, 2016).

Healthcare in the Philippines is mostly decentralized to private hospitals and independent practitioners, resulting in the private sector having more financial, human, and technological resources than the public sector, and thus causing private insurance companies to cater to 30% of the population. This differential between the private and public sector healthcare thus has quantitative implications on the cost of burden approach and methodologies for computing the direct and indirect costs of dengue. The primary governing agency in the public sector that provides services to communities and individuals is the Department of Health (DOH), although local government units also contribute in part (Philippine Department of Health, 2016).

A recent publication by Bravo et al. written in 2014 provides a comprehensive literature review of the epidemiology of dengue disease in the Philippines from the years 2000 to 2011.[32] Of 253 relevant papers and datasets identified by the literature review group, 34 were reviewed. According to Bravo et al., dengue has been a major health concern in the Philippines throughout the study period, and the incidence of dengue disease is seen to be rising. This rise in the number of declared dengue cases may be related to "a growing population, increasing urbanization, improvements in surveillance, and the limited success of vector control measures" (Bravo et al., 2014). Importantly, the authors also identified gaps in the relatively scarce Philippine data. These include but are not limited to; more "comprehensive national and regional data that describe the proportion of severe dengue disease, including hospitalizations and mortality… incidence data per 10,000 population… age, serotype, and seroprevalence on both national and regional levels" (Bravo et al., 2014). Of particular importance to this paper are the data graphs included by Bravo et al. in their study and cited by the Philippine Department of Health, as shown in Figure 7 and Figure 8.

[32] bravo et al 2014

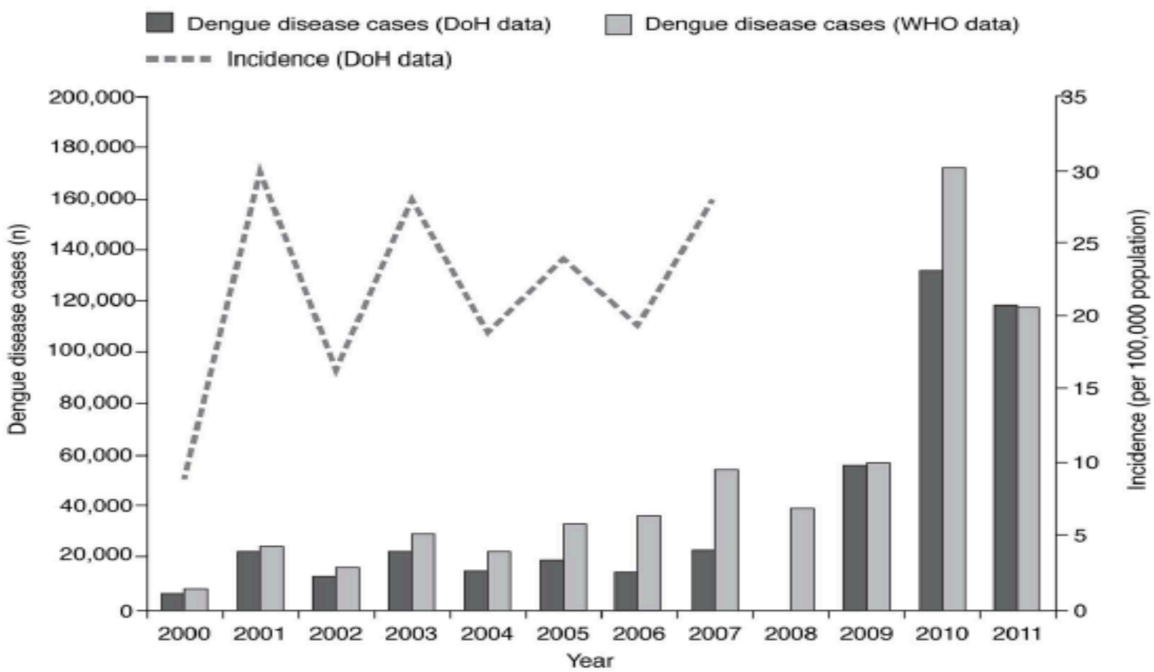

Figure 8: The Epidemiology of Dengue Disease in the Philippines from 2000-2011 as reported by the Department of Health and the World Health Organization, from Bravo et al., 2014.

Bravo et al. have generated a graph showing nationwide dengue epidemiology, as reported by both the Philippine Department of Health (DOH) and the World Health Organization (WHO) from the year 2000 to 2011. Although WHO data consistently over-reports the number of dengue disease cases relative to the DOH, it is clear that the similar trends of dengue incidence have consistently risen from 2000 to 2011. In both data sets, it is evident that there was a huge jump in dengue disease reporting in 2010. This is primarily caused by the global dengue outbreak that happened early in 2010, and which was exacerbated by urbanization, population growth, increased international trade, and global warming (Whitehorn and Farrar, 2010). Bravo et al. provide a succinct starting point for scholars who want to study dengue epidemiology in the Philippines, although the risks associated with underreporting and inaccurate disease identification in the

Philippines should not be ignored.[33] Despite the unpredictability associated with data recording, it is evident that the number of dengue disease cases has risen over the past two years.

V. Data

V. A. Data and Descriptive Statistics

Three main data sets were used for the analysis.[34] First, after very helpful conversations with representatives from the Department of Health, in particular Dr. Clarito Cairo who leads the team that deals with dengue in the Disease Prevention and Control Bureau, I was gratefully able to obtain data for the number of dengue cases and deaths (in terms of case fatality ratio), segmented by region. This data runs from the year 2012 to 2014, and can be found on the publications of the Philippine Department of Health. Another data set that is available is the one that has been used by Bravo et al. (2014), which lists the total number of *reported* cases and incidence in terms of

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[33] Bravo et al.'s methodology takes advantage of the little available data available on dengue occurrence in the Philippines from the time period of 2000 to 2011, especially given their aforementioned limitation that they would not provide an exhaustive historical picture of dengue disease in the Philippines. In particular, the authors mentioned that the data they used were inconsistent on a number of issues including; complete and comparable data across the 2000-2011 review period and severity of dengue cases over the review period. However, their decision not to perform a meta-analysis across the resulting articles that they have identified may be questionable. Their assumption that "the resulting articles would be heterogeneous with respect to data selection, and classification of cases, and would not be methodologically comparable" may not hold true, given that there are only a few reliable data sources that consistently record and monitor dengue occurrence globally and within the Philippines (Bravo et al., 2014).[33] A closer inspection of Bravo et al.'s references shows that many of their data sources are either from the World Health Organization or from the Philippine Department of Health. Moreover, many of the authors who they identify as sources have published under the Department of Health, and would have probably also used Department of Health data. A number of sources also focus on studying dengue occurrence and epidemiology in cities with bigger populations like Cebu City. Thus, it would have been possible and extremely useful if the authors had decided to conduct a meta-analysis given the data and papers they identified through their search strategy and selection criteria.

Also, while Bravo et al.'s literature review shows that the highest reported incidence of dengue cases was among the more populated urban areas like the National Capital Region, this observation might be due to the fact that reporting in bigger cities is more accurate and consistent than it is in more rural provincial areas. For example, the authors state that the number of reported dengue cases in Quezon City was higher than that in Rizal city, despite their population densities being similar. While both of these cities are heavily populated, Rizal is on the outskirts of Manila, and thus in a more provincial and somewhat mountainous area while Quezon City is located at the heart of the capital. Although this issue is related to the data reporting rather than the methodology used by Bravo et al. in their study, it is important to keep in mind the aforementioned reporting issue when looking at the trends described by the authors. Although it is generally accepted that dengue incidence increased over time, the same issue can be said about the general increasing trend of reported dengue disease cases over time in each age group, and cross-regionally – an undefined part of it may be a reflection of better reporting methods in the country.

[34] As previously mentioned in this paper and by other scholars in the field, one of the major challenges encountered in this independent study was the lack of clean, consistent, and reliable data. Despite this, efforts have been made to analyze the available data and identify whether or not a causal effect can be concluded from it.

case fatality ratio of dengue disease by region, running from the years 2000 to 2010. It is important to note that the data used in this paper is highly dependent on how accurate dengue reporting is in each particular region and health center, since most of the numbers were obtained through passive reporting methods.

Data about national-level GDP and per capita GDP has been taken from the International Monetary Fund data set, and runs from 1960 to 2015. Regional per capita GDP has been obtained from the Philippine Statistics Authority, and data for this runs from 2012 to 2014. Thus, the period of study for this paper will be through the years 2012 to 2014. These data sets have been used to answer the question: Do regions with higher rates of dengue cases cause those same regions to incur lower incomes? Does the hypothesis that the prevalence of dengue disease decrease a region's income per capita hold? To do this, I begin with descriptive data—going through the variables and data points I was able to obtain, as well as those I would have liked to have in an ideal situation. Then, I continue by summarizing some ordinary least squares estimates (OLS) to study the conditional expectation function. Afterwards, I try to use some other methods to determine if there is a causal relationship between dengue case percentage and population. Namely, I use the fixed-effects method, although looking at this data through the instrumental variables method would also have been useful, if not constrained by data, time and personal expertise. This analysis is based on the regional dengue data obtained from the Philippine Department of Health for the years 2012 to 2014.

Table 1 provides descriptive statistics for the key variables of interest. Column (1) is for the whole country, and Column (2) is for our base sample, limited to the 17 regions in the Philippines. The GDP per capita for Column (1) is reported at the national level in terms of Pesos, using the year 2000 as a base year. The average is computed over a scale of 10 years, from 2000 to 2010. The regional GDP per capita for Column (2) is computed in terms of Pesos, using the year 2000 as a base year, and over the scale of 2012 to 2014.

The main variable reported in the second row is a measure of dengue disease. This number was obtained by using the total number of reported cases and dividing it by the total population—the first data point was obtained from the Philippine Department of Health and the second data point was obtained from the Philippine Statistics Authority. The proportion of dengue cases in the population is generally very small, but it is important to note that the total number of dengue cases is of a relatively large magnitude when compared with other countries globally. We can see from Table 1 that there exists some variation among regions, although generally the regional data is higher than national data.

The next two rows give measures of variables that are used as controls in my regression model, which is described in the next section. The third row measures the level of sanitation in a given area, as reported by the World Health Organization. This is used as a control for government intervention. In an ideal situation, I would have used additional information regarding the workshops and dengue-specific sessions the Department of Health has held in each region, as well as government spending on dengue disease prevention and monitoring in each region. However, due to time and data constraints, this information is not available. Moreover, data on the level of sanitation was only available at a national scale, as recorded by the World Health Organization. Unfortunately, I was not able to find a similar data set that describes sanitation levels on a regional scale.

The fourth row measures the average level of education in each area, as described by the World Health Organization. Mean education level is described as the cumulative percentage of the population who have completed at least lower secondary education. Again, this information was only available at the national level, and not at the regional level. In an ideal setting, I would have used information such as the total number of years of education completed, as well as national examination scores like the National Achievement Tests (NATs) which are given to students in their 6th, 10th, and 12th years of education.

Another useful data set which should have been included in this paper would be malaria ecology. This would have controlled for environmental factors, since environmental settings that are conducive for malaria prevalence are also conducive to dengue prevalence. However, this data set was again not available, so I am limited by the data I was able to find over the last three months. Aside from malaria ecology, a more accurate measure for environmental factors would have been dengue ecology, which is the probability of an area being endemic in dengue disease. Unfortunately, this data was not available to me as well. It is then highly probable that there will be omitted variable bias in my succeeding OLS analyses. It is also important to note that the data set I am using is relatively small, as I only have 3 data points for each region—representing information in the years 2012, 2013, and 2014.

Table 1---Descriptive Statistics

	National	Regional	By Region 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Average GDP per capita	53060.79671	53995.55	193744.1	74427.59	42132.5	35823	57046.02	84304.92	38952.27	23560.32	36328.3	59654.35	34432.15	38341.2	55257.57	54818.2	41733.25	32895.93	14472.69
(Standard Deviation)	5398.600929	5504.231	10571.26	1659.098	2450.004	1550.648	3066.061	2572.259	921.2978	1312.026	880.2956	3588.126	964.5957	1367.848	2240.573	3267.338	1988.609	2177.945	198.1726
Dengue Cases as a Share of the Population	0.00000571	0.0007968	0.0007578	0.0017559	0.0008399	0.0009332	0.0008035	0.0007738	0.0004779	0.0002444	0.0010694	0.0008585	0.0004515	0.000881	0.0006665	0.0010716	0.0010025	0.0007865	0.0001715
(Standard Deviation)	0.00000114	0.0000847	0.0007381	0.0012751	0.0005727	0.0006264	0.00065	0.0005078	0.0003478	0.0001727	0.0009184	0.0005728	0.0002665	0.0003806	0.0002075	0.0005915	0.0006777	0.0002558	0.0000804
Mean level of sanitation	68.8																		
(standard Deviation)	7992705																		
Mean level of education	63.15142																		
(Standard Deviation)	3.35451																		
Number of Observations	16	51	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Notes:

*National GDP per capita is computed over 10 years

**Regional GDP per capita is computed from 2012 to 2014

***sanitation and malaria ecology are used as a proxy for environmental factors

****Reverse causality may exist in education

~Average is followed by SD in each case

V. B. Ordinary Least-Squares Regressions

I will work with a few variations of the following regression, looking at the conditional correlation of dengue cases as a percentage of population on regional GDP per capita, and also looking at the possible effect of dengue deaths and dengue cases on overall regional GDP. The regression equation I am currently working with is the following:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i$$

where Yi = regional GDP per capita in 2000 prices (in thousands of pesos); X_1 = the proportion of dengue cases over regional population; X_2 = level of government intervention in terms of sanitation practices; X_3 = education in terms of the percentage of the population that has completed lower secondary education; X_4 = environmental factors in the form of malaria ecology; and ε_i = the error term. The coefficient of interest here is β_1, which will tell us the effect of dengue disease on regional GDP per capita, if any.

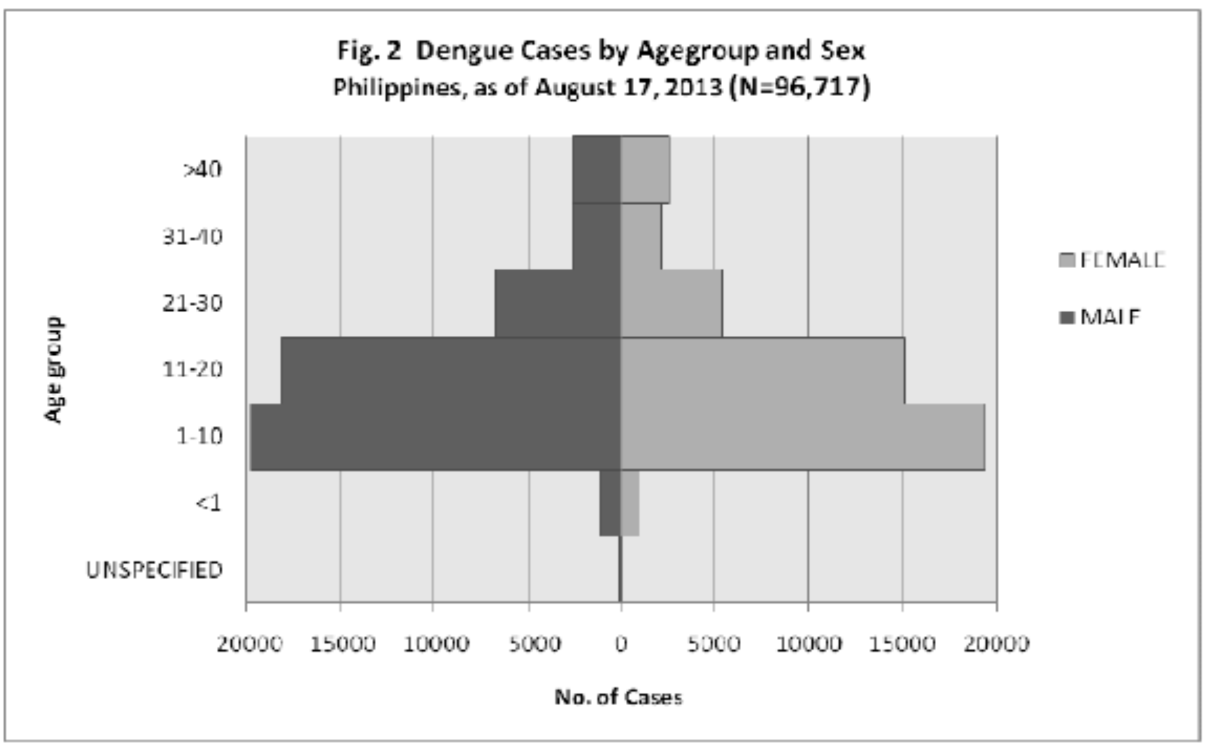
Table 2--OLS Regressions

	National (Years 2000 to 2010)	Regional (Average)	National (Years 2000 to 2010)	National (Years 2000 to 2010)	Regional (Year 2012)	Regional (Year 2013)	Regional (Year 2014)
	Dependent variable is average GDP per capita*						
Dengue Cases as a Proportion of Population	154000000	38900000	7644423	-6125589	-6964238	-503312	-34100000
	46300000	14700000	37600000	15400000	16900000	16000000	50100000
Level of Sanitation			211.9224	-90.07437			
			45.75977	67.31764			
Health Spending per Capita				27.15754	19.66236		
				5.82322	1.741476		
Level of Education					**collinearity		
R-Squared	0.688	0.3172	0.951	0.9941	0.9905	0.0001	0.03
Number of Observations	7	17	7	7	7	17	17
Notes:							
*For national data, information is incomplete for 2012, so the average from 2000 to 2010 is used.							
*For regional data, GDP per capita is reported for 2012 in column (2); 2013 in column (3); and 2014 in column (4)							

Column 1 shows that nationally, there is a strong correlation between my measure of dengue disease and income per capita. Column 2 shows that the direction of the impact of dengue disease in my regional sample is quite similar to that on a national level, however the R-squared for the average of my regional data is much lower than that of my national data. The R-squared of the regression in Column 1 indicates that almost 70% of the variation in income per capita is associated with variation in this index of dengue disease.

However, looking more closely regionally in columns 5, 6, and 7, the correlation between dengue and income seems rather unclear. While Column 2 shows a positive relationship between dengue and income on average, Columns 5, 6 and 7 show a negative relationship. Looking at the R-squared of Columns 5, 6, and 7, only Column 5 for the year 2012 seems to show a significant relationship.

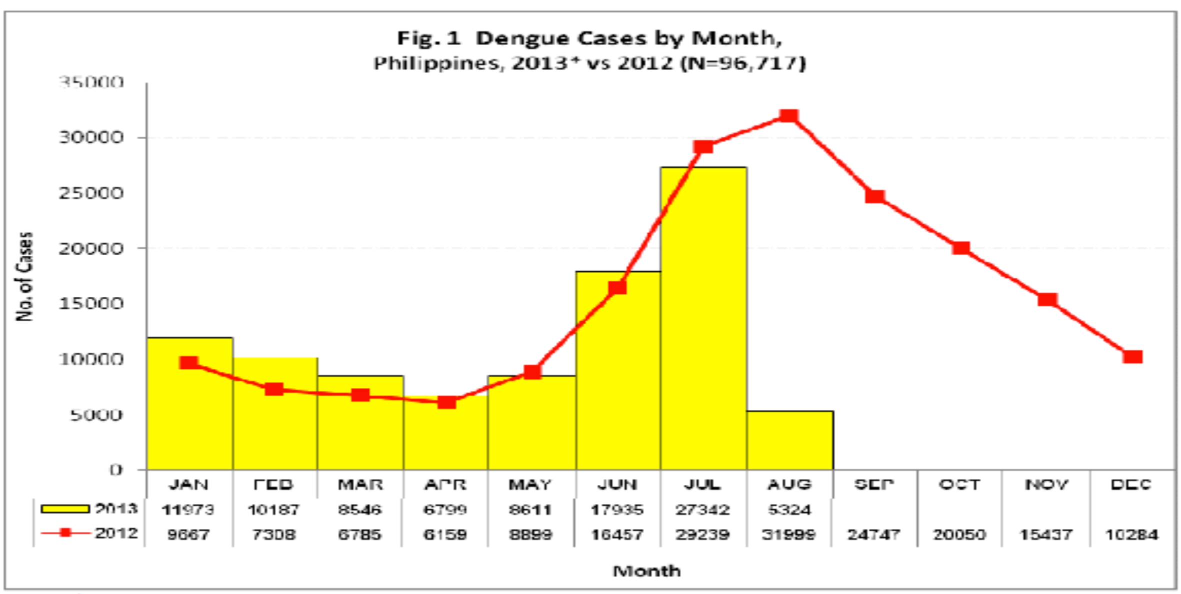
Figure 1: Affected Demographics of Dengue Disease (Philippine Department of Health, 2013)



I chose to control for education because higher education is usually correlated with better health, as discussed in Section II. Ideally, I would have liked to measure regional education levels in terms of average years of schooling. But, because this data is not available or I have not been able to find this data set, I instead use enrollment in public schools.

Figure 1 shows the demographics of the affected population in August 2013. Most of the people who were diagnose with dengue disease were in the age bracket of 1-10, and 11-20. Dengue thus plays a role in determining education levels within a population. If many children are sick and diagnosed with dengue disease, they may be prevented from attending a certain number of days of school—or they may not be able to complete school in general. This leads to one of the caveats of my proposed model. Although I wanted to account for the effects of schooling on dengue disease, it may be that an inverse relationship exists and that dengue also affects level of schooling.

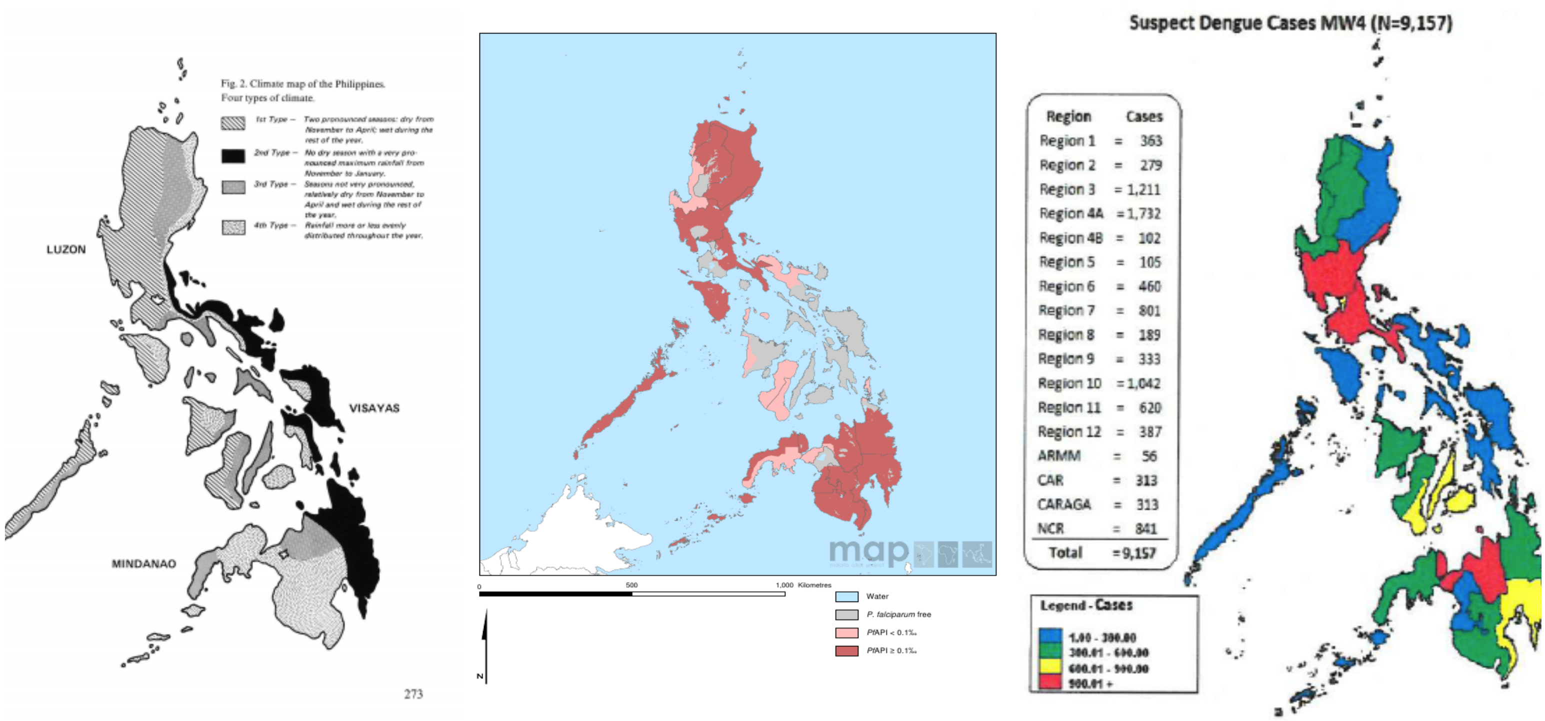
Figure 2: Dengue Trends by Month (Philippine Department of Health, 2013)



*partial data

Figure 2 shows dengue cases by month, for the years 2012 and 2013. As shown, dengue cases peak in July and August, the months of the rainy season and monsoon. This increase in dengue cases for both 2012 and 2013 may show how environmental factors affect dengue prevalence within the Philippines. It then follows that nationally and regionally, environmental falctors like humidity, precipitation, temperature, and rainfall affect dengue prevalence—a finding that is aligned with those mentioned in the literature review.

Figure 3: General Climate in the Philippines, (Cabrera and Arambulo, 1977), Malaria Transmission Map in 2010 (Malaria Atlas Project, 2016), and Dengue Prevalence in January 2016 (Department of Health Philippines, 2016)



I choose malaria ecology as a control for the environment because many of the factors that are conducive to malaria prevalence are similar to those that stimulate dengue disease. This is in part because the mosquito that transmits the dengue vector is of the same species as the mosquito that transmits malaria.

Figure 3 depicts the Philippine archipelago and its relative climates, as segmented by climate type, alongside another map of the Philippines that shows malaria prevalence over time. The third map, which is the most important one in this sequence, shows dengue prevalence across the country, as segmented by region. It is clear that malaria prevalence occurs the most in areas that have high levels of rainfall and experience a long period of wet and rainy season. It is also evident that most areas with high malaria prevalence also correspond to areas with a high number of dengue cases, although there are some outliers like Palawan Island that have high malaria prevalence but a low number of dengue cases. As mentioned in the background section, there is a strong relationship between environmental factors and dengue occurrence, which is supported by this evidence.

V. C. Fixed-Effects Analysis and Identification Strategies

Since the OLS estimator does not give a causal effect, and since the regression analysis omits many variables, I attempt to use other identification strategies to control for and reduce this bias. In an ideal world, I would have used the fixed-effects methodology to control for unobserved characteristics within each region, assuming that this is randomly assigned. My model would then look like the following:

$$Y_{it} = \alpha + \lambda_t + \rho D_{it} + X_{it}\,\delta + \varepsilon_{it}$$

where Yit = regional GDP per capita in region i at time t; α = fixed effects and the parameter to be estimated; λ_t = year effect; Dit = dummy variable of dengue outbreak; and ε_{it} = the error term of region i in time t. This analysis will be useful if I had data about dengue outbreaks because it helps control for some of the bias that was present in the OLS model. This analysis then is not possible at this point in time for a few reasons. First, I do not currently have data on *regional* dengue outbreaks, mostly because these occur frequently and most regions have had outbreaks in the time period—thus this analysis may not yield much new information if these regional outbreak data points are used. Often, outbreaks are either better measured by city or by province, but this is beyond the scope of my paper, and due to data constrains, will not be dealt with here. Second, for the fixed-effects analysis to be valid, we need to assume that the selection of dengue outbreaks is based on unobserved, fixed regional characteristics over time. Inherently, although dengue disease outbreaks may be random, it may still be affected by the environment of a given region—a variable which I tried to control for in the OLS regression. Thus, even the use of fixed-effects methods in this analysis may not yield a causal effect.

V. D. Empirical Conclusions

Overall, the results in Table 2 show inconclusive results about the correlation between dengue and income. Furthermore, aside from showing ambiguous results at the regional level, there are a number of important reasons for *not* interpreting this relationship as causal. First, there may be a problem of reverse causality and selection bias. Richer regions may be able to afford better health, and thus may essentially have lower percentages of dengue cases as a portion of population. Richer regions may also be more educated, and more educated regions are more likely to know how to prevent and treat dengue disease. Richer regions may also have better recording methods, and so may report a higher percentage of dengue cases. Richer regions may have more political influence, and thus may be able to sway government interventions to prioritize their regions rather than poorer regions.

Second, more important than this reverse causality problem is the issue of omitted variable bias which I briefly mentioned throughout this paper. There are many omitted determinants of income differences that will be correlated with health—many of which are both endogenous and exogenous to this model.

Third, the measurements and proxies used in this paper are imperfect, especially the measure of reported dengue cases. As discussed in the prior sections, these cases are reported by hospitals and local government units; the quality of which is greatly affected by the relative wealth of the region. Moreover, most of these cases are not laboratory confirmed but instead provided based on presence of symptoms.

These problems may be solved if I had an accurate and ethically sound method of randomizing and measuring dengue disease across the 17 regions within the Philippines, holding everything else constant. It would also be useful to have measurements for the government intervention, education, and environmental controls I had envisioned to include in my regression.

VI. Concluding Remarks

The idea that good health acts as a driver of economic growth is not an unfamiliar concept. Much research has been done to study how good health increases income. However, considerable debate remains about how much good health increases income, and how the various environments and factors this relationship is observed in affects the correlation between health and income. Historically, it has also proven challenging to study the relationship between health and income because of the issue of reverse causality, making it difficult to isolate exogenous sources of variation in the models as well as to study the effects of some endogenous variables. In this paper, I support the hypothesis that bad health in the form of dengue arboviral disease decreases regional income and slows economic growth.

My findings were inconclusive. I encountered three main issues in my analysis: 1) lack of data; 2) reverse causality; 3) omitted variable bias; 4) technical expertise. First, I spent a tremendous amount of time and effort trying to find data suitable for this analysis, however most of the available data sets were incomplete, unreliable, or not available to the public. Second, the issue of reverse causality also made it difficult for me to create a model, because the direction of the causal relationship between health and income ran in both directions. Third, the data issues I had increased the effect of omitted variable bias—other than the possibility of omitting factors which I did not know were correlated with income, I also unfortunately yet unintentionally omitted variables which I knew were correlated with income. Lastly, although I used the best of my abilities and sought advice from professors who are experts in this field to analyze the question of whether or not the prevalence dengue disease in the Philippine setting caused regions to have lower GDP per capita, there is much I need to learn within the field of econometrics. There are many questions and facets of the relationship between health and income that my paper does not address, and the methodology I used is limited to those of which I have an understanding.

Despite these caveats, this independent research has been extremely useful for allowing me to explore the current issues when conducting economic analysis. This paper also sheds much light on the gaps in Philippine scholarly literature about the economic implications of dengue disease.

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Appendix

Additional Information on Dengue Disease

Dengue is one of the most significant viral mosquito-borne diseases in the Philippines. Transmitted primarily by the *Aedes aegypti* mosquito and sometimes the *Aedes albopictus*, the reported incidence of dengue in the Philippines has increased in recent years (Bravo et al., 2014).[35] Made up of two genotypes, Asian 2 and Cosmopolitan, dengue takes humans as their main hosts and circulates the virus in the human blood stream from two to seven days, usually manifesting in a fever (Philippine Department of Health, 2016). In 2011 alone, the reported number of dengue cases has risen to 125,975 (Philippine Department of Health, 2016). There are four strains or serotypes that cause dengue, namely DENV1, DENV2, DENV3 and DENV4, all of which are present and endemic in the Philippines. One becomes immune or protected from the other three dengue serotypes after they have been infected by a given serotype. Usually, this protection lasts for two to three months, but afterwards, one can be infected by any of the remaining three serotypes (Nature, 2016).

Historically, dengue occurrence was first recorded in Manila City in 1953, originating as a rural disease, although it is now more endemic in urban areas rather than provinces (Philippine Department of Health, 2016). In 1966, the morbidity rates due to dengue were as high as 28/100,000 of the population, and the mortality rate was 0.7/100,000 of the population.[36] In the next 20 years, from 1974 to 1993, the morbidity rate increased almost 12-fold, while the mortality rate stayed somewhat constant at 0.54/100,000. In 1998, the Philippines experienced the highest number of reported dengue epidemic cases, with almost 32,000 cases and 500 deaths nationwide. Regionally, the National Capital Region, Region III, and Region IVA have the highest reported

[35] bravo et al
[36] DOH

occurrence of dengue virus nationwide, which is possibly associated with their relatively higher populations and densely-urbanized cities. Seasonally, the number of reported dengue cases peaks in the rainy months of July through October, with the highest spike in August.[37] Demographically, 63% of the dengue cases reported occur in children ages one through ten years old.

As of today, there is no dengue vaccine for prevention and no definitive treatment regimen for those who suffer from the disease, so the early diagnosis, management, and prevention of the infectious airborne disease are crucial. The most common form of prevention encouraged by the Philippine Department of Health and other government agencies would be through the control of the mosquitos that can transmit the virus by removing the breeding-places of these mosquitos. (Philippine Department of Health, 2016).

Map of the Philippines, Showing Regions (Numerical Names and Expanded Names)

37 page 3 philippine DOH