# Dengue, Weather and Urbanization in Brazil

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**Abstract**

Since two decades, the population affected by dengue disease is exponentially increasing and dengue is now affecting more than 390 million people in the world. It ranks behind as the second most important vector-borne disease in the world and the first one in Latin America. Despite the important economic and social cost of the uncontrollable growth of the disease, little economic analysis has been devoted to it. In addition to weather, socio-economic factors such as urbanization and sanitary systems play an important role in the proliferation of dengue. In this paper, I measure the impact of weather and urbanization factors on dengue incidence in Brazilian states during the 1992-2012 period, since Brazil is the most affected country in Latin America. I find a positive and statistically significant effect of different weather factors (temperature, vapour pressure, temperature anomalies) and urbanization factors (population density and urbanization rate). I find also statistically significant support for a negative impact of education and wealth on dengue proliferation.

JEL codes: I13, O18, Q54, Q56

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# 1 Introduction

Dengue is a vector-borne viral infection that according to the estimation by Bhatt et al. (2013), affects 390 million people, from which 96 million present symptoms, and causes 22,000 deaths in the world (WHO, 2015). Nowadays, 40% of the world population and 100 countries are at risk against only 9 countries before the 1970's. It is the most frequent vector borne disease in the Americas and the second one in the world, after malaria (Chowell et al., 2011). In many countries, dengue is an endemic and an epidemic disease. Bhatt et al. (2013) analyse the spatial evolution of dengue cases between 1960 and 2012 and they find an exponential increase of dengue case locations over time. In 2012, the Americas represent 50.7% of the dengue locations, followed by Asia with 40.3%.

Despite the huge increase of this disease during the last decades, the failure of the governments to eradicate it and the economic and social cost that it represents, economists of different research areas have rarely analysed this disease. This fact contrasts very much with the number of articles published by economists addressing malaria such as Egbendewe-Mondzozo et al. (2011); Gallup and Sachs (2001); Lucas (2010); Tol et al. (2007) or with the articles on dengue in epidemiological journals (Nature, The Lancet, etc.). Even the literature on the impact of climate change/variability on health is not very developed and it concentrates mainly on health impacts of air pollution (Dell et al., 2014; McMichael et al., 2006).

The few economic articles that have treated the dengue disease have focused on its economic impact[1], but it is also important to understand the mechanisms behind its rapid increase in recent years. In fact, the transmission of dengue is determined by several factors, including social, economic, ecological, climatic and immunity (McMichael et al., 2006)

One of the specificities of the dengue mosquitoes (Aedes Aegypti or Aedes albopictus) is that they proliferate mainly in urban and suburban areas (WHO, Bhatt et al., 2013; Colón-González et al., 2013), while for malaria urbanization is considered to reduce the disease (Gething et al., 2010). Another characteristic of the dengue mosquito is that they are more affluent in tropical and subtropical areas, which suggests an important dependence on climate (Bhatt et al., 2013; Colón-González et al., 2013; Hopp and Foley,

[1]See the exhaustive review of the literature addressing economic issues in Beatty et al. (2011).

2003).

In the epidemiological journals, some publications address the relationship between climate and dengue (Chowell et al., 2011; Colón-González et al., 2011; Hopp and Foley, 2003), but the socio-economic aspect of the disease is less studied (McMichael et al., 2006). Some of the exceptions are Colón-González et al. (2013) and Bhatt et al. (2013). In Colón-González et al. (2013) the authors use a Generalized Additive Model (GAM) to analyse the influence of weather and some socio-economic variables like GDP, urbanization and access to piped water in Mexico during 23 years. They find a non linear effect of temperature and precipitation on dengue incidence, but an unexpected positive effect of piped water access. They explained this last result arging that water supply in Mexico is intermittent, what force people to storage water between each supply. Another surprising result in their paper is that GDP and urbanization are not significant. Bhatt et al. (2013) in a world analysis take into account factors like urban accessibility and poverty to estimate the total cases of dengue in the world and their spatial distribution. Gollin and Zimmermann (2012) develop a theoretical model for "tropical disease" (included malaria and dengue) taking into account preventive behaviour of individuals. They conclude that the impact of preventive behaviour can overcome the impact of climate change on tropical disease prevalence, but that such behaviour is costly. They argue that public policies should focus on population development, what should have an impact on preventive behaviour, instead of focus on climate change impact policies.

In this paper, I use econometric methods to test the widely claimed but rarely proven effect of urbanization and weather factors on dengue case proliferation. I also try to identify which particular characteristics of urbanization affect dengue. More precisely, I want to answer the questions: Is urbanization a statistically significant factor of dengue proliferation? What are the mechanisms and factors behind this relationship? Which role do weather factors play in dengue proliferation? I take into account all the possible factors that affect dengue, in order to have the most complete model possible.

I do the analysis on Brazilian states for the 1992-2012 period. Brazil is the most affected country in Latin America. In Figure 1 we can see the time evolution of total dengue cases in Brazil and Latin America and the Caribbean (LAC). Brazil count for about 60% of LAC cases and follows the same time trend. Figure 1 shows an upward trend with four main time ascending peaks for Brazil: 535 thousand cases in 1998, 781 thousand in

2002, 1,012 thousand in 2010 and 1,469 thousand in 2013. Brazil is also an interesting country to analyse because it is a world important economic actor and a big country (5th in the world), with a mainly humid and tropical climate (favourable to mosquitoes development), with diverse geographical areas and with still large social and economical inequalities.

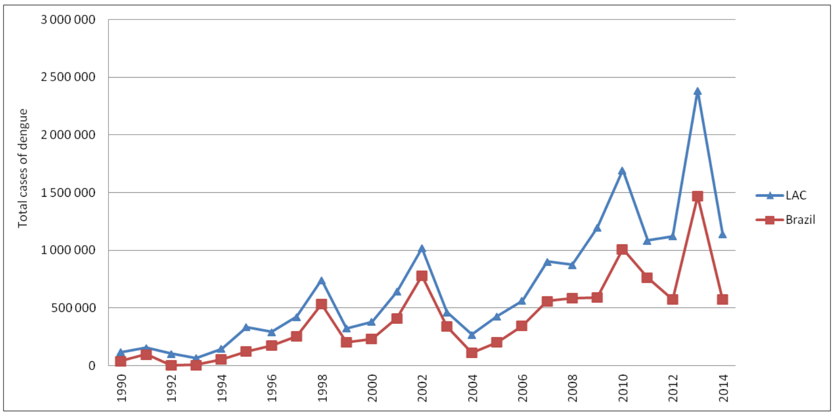


FIGURE 1: Total dengue clinical cases through time in Brazil and Latin America and the Caribbean (LAC).
Source: Author's own graphic representation of data extracted from the Pan American Health Organization (PAHO).

## 1.1 Dengue and weather

Dengue is transmitted via the bite of a female mosquito, infected by one of the five virus serotypes (DENV-1, DENV-2, DENV-3, DENV-4 and DENV-5).[2] After 4-10 days from the virus incubation, the mosquito is infected and can transmit the diseases for the rest of her life ($\simeq$ 3 weeks). Symptoms last for 2-7 days after the incubation period. The infection causes flu-like symptoms and can be lethal. Infected humans are hosts of the virus for uninfected mosquitoes and collaborate in their multiplication. Infected people can transmit the infection during 4-12 days after the bite. There is no specific medical treatment, but early diagnostic and medical care can reduce the fatality rate from 20% to 1% (WHO).

[2] An infection immunizes the person from the serotype caught, but a recurrent infection (with a new serotype) increases the risk of severe dengue. A geographic increase of the 4 serotypes is also observed in the last decades, which is also a measure of increase in severe dengue cases (ref, numbers or graphic needed).

Dengue proliferation is dependent on the productivity of the mosquito and on the availability of host habitat for them. Specific weather conditions like high temperature and relative humidity, are necessary for the development and survival of the mosquitoes and could be favourable to the time necessary for mosquitoes to become infectious. Weather can thus increase the availability of potentially infectious host mosquitoes and their productivity for the disease transmission (McMichael et al., 2006). Carrington et al. (2013) find that fluctuations of temperature can significantly affect the growth rate of mosquito populations. Hopp and Foley (2003) calculate the linear correlation between modelled Aedes aegypti larvae and different weather monthly anomalies, and find a very high positive correlation with the larvae and the temperature or relative humidity, but not necessarily with precipitation. Indeed, precipitation has a more complex effect. Since larva of mosquitoes are developed in stagnant water, frequent precipitation would be likely to increase the number of stagnant water sources and thus availability of the disease. At the same time a drought period will increase the need to stock water and thus will also increase the number of stagnant water sources. Another scenario could be an important flood that is likely to erase all the larva.

It is well known and accepted that the atmospheric greenhouse gas concentrations of anthropogenic origin have an impact on climate variability (IPCC, 2014). The surface air temperature is already increasing and will continue to increase, the variability between seasons will decrease and the spatial extension of tropical and subtropical areas will expand. These facts represent a major risk for health, especially as regards vector borne diseases that are sensitive to weather.

## 1.2 Dengue and urbanization

In 2012, more than half of the world population were urban and the UN forecast that 67% of the world population would live in urban areas by 2050 (UN, 2012). As we can see in Figure 2, among the less developed countries, and despite the fact that urbanization in Asia and Africa is growing faster, Latin America has a level of urbanization comparable to Europe or Northern America.

In any scientific article, international organization report or in the press, dengue is associated with urbanization (some examples are Alirol et al., 2011; Daily and Ehrlich, 2008, WHO). But it is harder to find statistics, estimations, and measures of the impact of urbanization on dengue. Colón-González et al. (2013) is one of the exceptions, in that they measure the impact of urbanization on dengue incidence in Mexico, but they do not find statistically significant evidence on the impact of urbanization.

In fact, the effect is not evident. Urbanization increases the number and concentration of human hosts and the reproduction of artificial hosts, like stagnant water, especially in a developing country or in poor areas. Poor urban structure, like a deficient drinking water supply system or only a basic level of waste management is likely to increase the risk of dengue mosquito proliferation. A limited access to drinking water supply is likely to increase the water reservoirs in households and a poor waste management multiply the solid wastes that act as a stagnant water reservoir. Nevertheless, at the same time, urbanization could also imply better sanitary system, better health facilities (in quantity and in quality) and better access to information (government campaigns, network information, etc.). In Cuba for exemple, despite its well developed health system and very early vector surveillance programme, Havana suffered un epidemy in 2001-2002 due to its population size and Santiago de Cuba in 1997, due principally to its irregular supply of drinking water (Bultó et al., 2006). Urbanization is closely associated with development, which at the same time is associated with higher income and better education. More wealthy people are likely to spend more money on preventive measures and are more reactive when they suffer a health problem. More educated people are also likely to be more well informed and to value health more. Hence, how urbanization affects dengue infections is not clear and until now unanswered. There are both positive and negative forces operating simultaneously.

The urban environment is also important. The urban heat island effect, according to which an urban area is warmer than the surrounding rural areas because of industrial activities, infrastructure and human density and transportation, is likely to have a higher impact on mosquito proliferation than a comparable rural area. Urban areas are also frequently developed near a river or in humid regions, which can also increase the risk of dengue disease.

## 1.3 Dengue in Brazil

Brazil is a highly urbanized country compared to other developing countries. Since 1960, the urban population increases exponentially but the urbanization growth slowed down since 2001. Nowadays, 85% of the Brazilian population live in urban areas (see Figure 3). According to the statistic institute

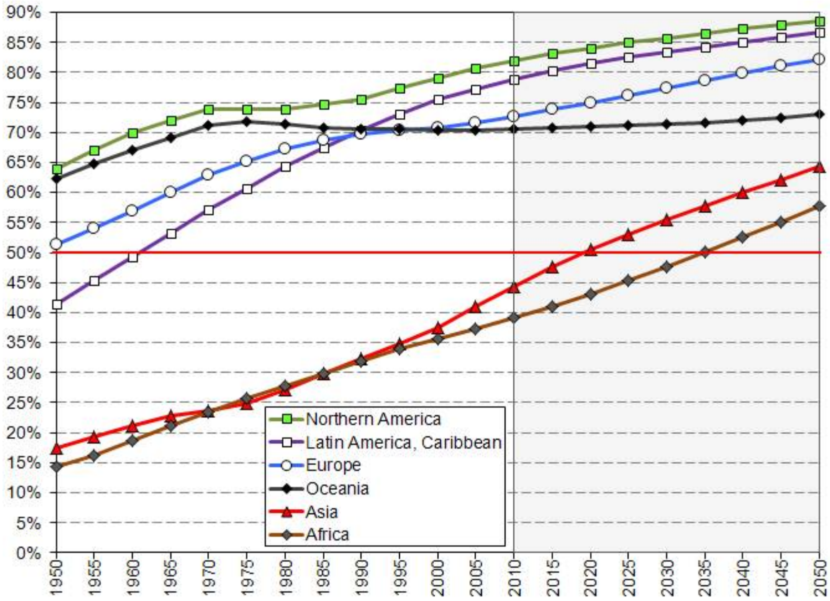


FIGURE 2: Urban population by major geographical area (% of total population).
Source: World Urbanization Prospects, the 2011 Revision.

of Brazil (IBGE), 6% of the population are still living in slums ("favelas"), which represents the important number of nearly 11 million persons. This poor urban environment is especially favourable for dengue proliferation.

In fact, according to Torres (2007), dengue in Brazil represented 70% of the total dengue cases reported in the Americas between 1997 and 2007. Figure 4 shows the evolution of reported dengue cases in Brazil for the 1982-2008 period. The geographical borders in the figure are the Brazilian states. We can observe that a total coverage of the states starts in 1999 and since, no state managed to eradicate the disease despite important expenses on information campaign, public health and research against dengue. Figure 5 shows the dengue incidence for the period analysed in this paper (1992-2012). As for the total cases in Figure 1, the trend is increasing with a maximal peak in 2010 from more than 500 cases per 100,000 inhabitants.

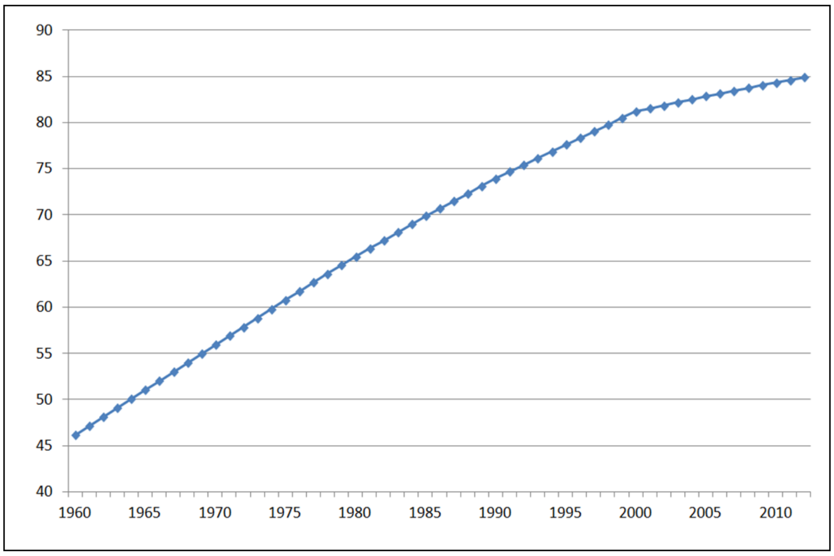


FIGURE 3: Brazil urban population (% of total) across time.
Source: Authors' own graphic representation based on World Bank data.

## 2 Data and variable definitions

The analysis is based on the complete sample of 27 states of Brazil and for the 1992-2012 period, which results in 567 observations. The choice of the state geographical aggregation level is mainly because the publicly available data on dengue cases are at this scale. The dependent variable is defined as the reported dengue cases (normal cases or dengue hemorrhagic fever) per 100,000 inhabitants and are obtained from the statistical and geographic institute of Brazil (IBGE).

The weather variables exploited in this article are daily mean temperature, average daily minimum and average daily maximum temperatures [°C], precipitation [mm], vapour pressure [hPa] and temperature anomalies in state $i$ at time $t$. All the weather data are extracted from the Climatic Research Unit (CRU) Time Series (TS) high resolution gridded datasets, from the University of East Anglia CCRU, NCAS British Atmospheric Data Centre, 2008.

Temperature anomalies is the deviation of actual daily mean temperature from its long run mean. The formal definition is the following:

$$tmp\_anom_{it} = \frac{avg\_tmp_{it} - \overline{avg\_tmp_{LR}}}{\sigma(avg\_tmp_{LR})}$$

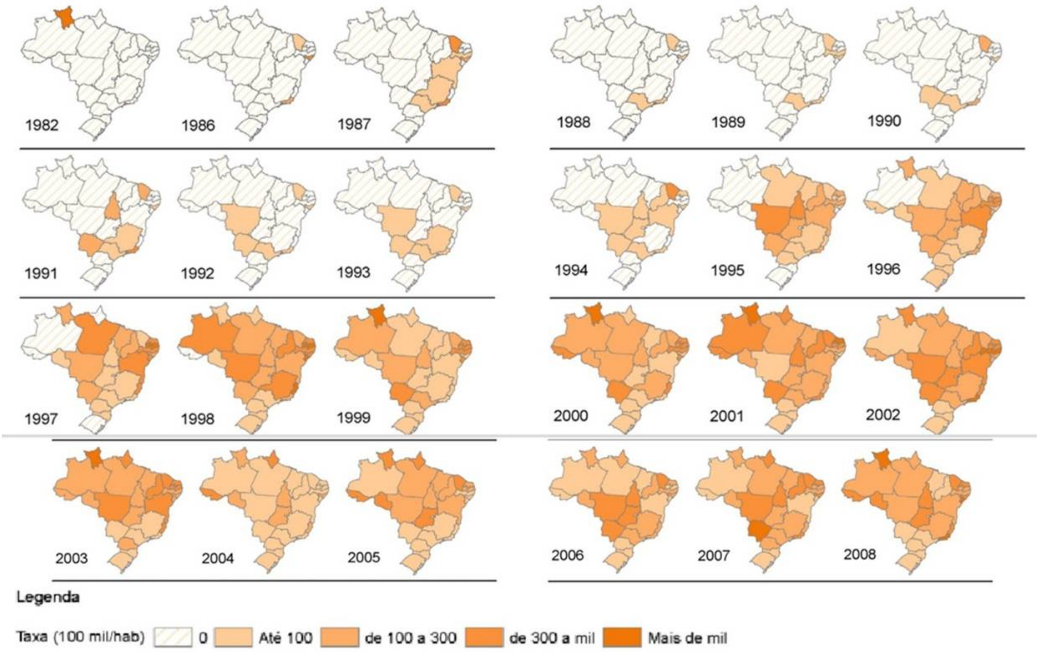


FIGURE 4: Dengue incidence (cases per 100,000 inhabitants) through time in Brazil by states. Darker orange colour means higher incidence rate.
Source: Rede Interagencial de Informações para a Saúde (RIPSA).

where $LR$ means long run, i.e. 1901-1990. This is a *climate* variability measure, since it takes into account the deviation of actual weather from the long run mean.

Socio-economic variables are obtained from the national yearly survey of Brazil, the Pesquisa Nacional por Amostra de Domicilios (PNAD). Urbanization is defined as the % of the population living in an urbanized area and population density as the total population per square kilometre. Concerning the public infrastructure, waste management service is defined as the % of the households that does not benefit from a public or private direct or indirect waste collection system [3] and access to drinking water supply as the % of the population connected to a water piping network. Education is the %

[3] Direct collection system refers to the collection of waste directly from the household. In the indirect collection system, people put their waste in a public container, which is collected afterwards by the waste service.

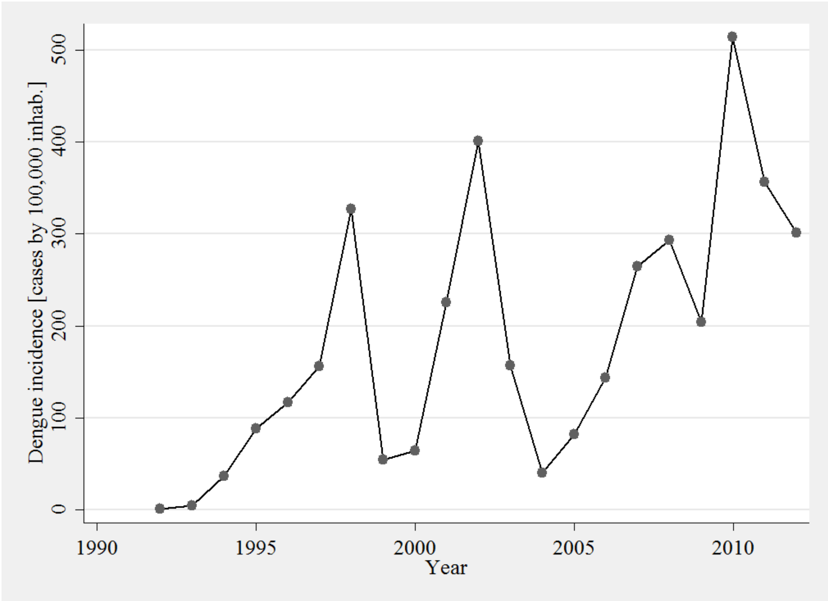


FIGURE 5: Dengue incidence through time in Brazil.
Source: Authors' own graphic representation.

of literate population and income average is the population average income from all sources. All original data from the PNAD is on an individual or household level and then aggregated at the state level.

All original data from the PNAD is on household level and then aggregated at the state level.

# 3 Empirical method

## 3.1 Econometric specification

To estimate the impact of urbanization and weather on dengue incidence, the estimating reduced form equation is the following:

$$DengueRate_{it} = \alpha_0 \cdot UrbFactor_{it}^{\alpha_1} \cdot Weather_{it}^{\alpha_2} \cdot X_{it}^{\alpha_3} \cdot \exp(D_i + D_t + \varepsilon_{it}) \quad (1)$$

In this specification, I regressed the reporting dengue incidence rate in state $i$ at year $t$ on urbanization factors $UrbFactor_{it}$, weather $Weather_{it}$

and other control variables $X_{it}$ uncorrelated with the error term $\varepsilon_{it}$. Urbanization factors could be urbanization rate or population density for example. Weather include temperature, precipitation and vapour pressure and/or temperature anomaly (climate measure). Given that temperature and precipitation could be correlated and result in an omitted variable problem [4] (Auffhammer et al., 2013), I always include these two weather factors together. Vapour pressure is already a measure of the combination of temperature and precipitation, nevertheless, only for purpose of robustness, I add also precipitation to the estimations with vapour pressure. Other control variables include socio-economic variables like education and income or public infrastructure factors like drinking water supply and waste management service, discussed in section 1.2.

The ex ante hypothesis for $\alpha_1$ is ambiguous, since as explained before, two type of forces, positive and negative could be operated when analysing urbanization. Concerning the weather coefficients, I expect $\alpha_2 > 0$ for temperature and vapour pressure. The sign for precipitation is more difficult to predict and I test a linear and quadratic relationship for it. Higher temperature as well as highest vapour pressure are likely to increase the mosquito productivity and thus increase the quantity of people potentially affected. Precipitation can either increase the number of stagnant water recipients and thus increase dengue cases, or wash out mosquito larva and thus decrease dengue incidence.

Between the control variables, a better access to sanitary system, represented by access to waste management service and to drinking water supply, should reduce the mosquito larvae reproduction and, all else equal reduce the part of the population affected by dengue.

I include state fixed effects $Di$ that are invariant in time to take into account the heterogeneity between states. This dummy can capture the impact of specific geographic zones on dengue incidence, like forest, wet and dry lands, rivers and coasts. Mosquitoes have a more suitable habitat in wet zones, and thus they can develop easier. Wet land and river zones are also more vulnerable to flood, witch can also increase the propensity to mosquito proliferation. Time fixed effects $Dt$ control for time specific shocks like changes in prices that could affect the disease preventive behaviour of individuals and thus infection rates.

[4] This is true specially when the weather variables are measured over a long period, i.e. climate measures.

### 3.2 Estimation method

Equation 1 is an exponential function. I use Pseudo Maximum Likelihood estimator (PPML) to avoid for heteroskedasticity problems, as explained in Silva and Tenreyro (2006). This method has since been frequently used in trade and migration analysis. This estimator allows also to include zero values of dengue rate incidence, what in our sample correspond to 14% of the observations. I thus report the results with the PPML estimator.

## 4 Results

I present three groups of estimations, Table 1 presents only the weather variables, in Table 2 I add the socio-economic variables and finally in Table 3 I add urbanization and density. All results presented here are done with the PPML estimator and include state and time fixed effects. The dependent variable is dengue cases per 100,000 inhabitants. All the coefficients must be interpreted as elasticities, since a 1% change in the independent variable corresponds to a percentage change of the dependent variable equal to the coefficient. Column (1) in Table 1 presents only the average temperature and in column (2) I add precipitation. In the two estimations, average temperature has a positive and statistically significant impact on dengue incidence rate at a 5% level. Adding precipitation lowers a little the coefficient of temperature average from 15.5 to 13.7, that suggest a correlation between temperature and precipitation to take into account. I thus include precipitation in all the estimations, even if its effect is non statistically significant. [5] As expected, minimum and maximum temperature follow the same result as for average temperature, with the maximum temperature having the higher impact on dengue incidence: an increase of 1% in the average monthly maximum temperature increases the dengue rate by almost 16%. The climate measure, measured as temperature anomaly, is also positive and statistically significant. Vapour pressure has the higher significance level (1%) between the weather/climate variables. I thus do the next estimations only with vapour pressure and precipitation.

[5] I also estimated a quadratic relationship between dengue and precipitation, but the results were not statistically significant.

Table 1: Dengue and weather

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ln($avg\_tmp_{it}$) | 15.552** | 13.707** | | | | |
| | (5.307) | (5.406) | | | | |
| ln($pre\_it$) | | -0.295 | -0.293 | -0.306 | -0.328 | -0.189 |
| | | (0.284) | (0.278) | (0.292) | (0.289) | (0.272) |
| ln($min\_tmp_{it}$) | | | 11.061** | | | |
| | | | (4.190) | | | |
| ln($max\_tmp_{it}$) | | | | 15.669** | | |
| | | | | (6.708) | | |
| ln($tmp\_anom_{it}$) | | | | | 0.206** | |
| | | | | | (0.104) | |
| ln($vap\_pressure\_it$) | | | | | | 17.462*** |
| | | | | | | (4.681) |
| State Fixed Effects $D_i$ | | | | | | |
| Year Fixed Effects $D_t$ | | | | | | |
| N | 567 | 567 | 567 | 567 | 567 | 567 |
| $R^2$ | 0.419 | 0.418 | 0.419 | 0.416 | 0.413 | 0.429 |

Robust standard errors in parentheses.
*p<0.10, **p<0.05, ***p<0.001

In column (1) of Table 2 I add education to the estimation. The effect is negative and statistically significant at a 1% level as expected. More educated people are more likely to take more preventive actions since they could be better informed and give a higher value to health. For wealthier people the reasoning is the same and the results expected are shown in column (2) where the coefficient on income is negative and statistically significant. Nevertheless, when putting these two variables together, income is not more significant because of the high correlation between income and education (0.73). In column (4) I add the part of the population which has access to drinking water supply and no access to waste management service. None of these variables are statistically significant but they are important factors to control for.

In column (1) of table 3, I regress dengue incidence only on population density and weather. A 1% increase in the population density increases the dengue incidence rate by 3.2%, and the effect is significant at a 5% level. This positive effect on dengue incidence is maintained when controlling for the other socio-economic and public infrastructure factors, but certainly because of the high correlation between all this control variables with popula-

Table 2: Dengue, weather and socio-economic factors

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\ln(education_{it})$ | -5.734*** | | -4.799** | -5.329** |
| | (1.609) | | (1.903) | (2.370) |
| $\ln(income_{it})$ | | -1.484** | -0.774 | -0.824 |
| | | (0.628) | (0.746) | (0.773) |
| $\ln(drinking\_water_{it})$ | | | | 0.371 |
| | | | | (0.939) |
| $\ln(no\_waste\_serv_{it})$ | | | | 0.001 |
| | | | | (0.162) |
| $\ln(vap\_pressure\_it)$ | 13.352** | 16.285*** | 13.424** | 13.302** |
| | (4.652) | (4.555) | (4.644) | (4.658) |
| $\ln(pre\_it)$ | -0.269 | -0.153 | -0.240 | -0.237 |
| | (0.270) | (0.267) | (0.268) | (0.268) |
| State Fixed Effects $D_i$ | | | | |
| Year Fixed Effects $D_t$ | | | | |
| N | 567 | 567 | 567 | 567 |
| $R^2$ | 0.461 | 0.446 | 0.465 | 0.467 |

Robust standard errors in parentheses.

*p<0.10, **p<0.05, ***p<0.001

tion density, the statistical power and the level of the impact decrease. In column (3) I add an interaction variable between density and the weather variables. The hypothesis is that the effect of weather on dengue incidences is higher in denser zones, but as we can see in the results, I do not find such an effect. Finally, in columns (4) and (5) I run estimations with urbanization rate separately and interacted with the weather variables. When urbanization rate is introduced on its own, we can observe a positive and statistically significant effect but not very large. An augmentation of 1% of the urbanization rate will increase the dengue incidence by 7.13%. When interacting the urbanization rate with the weather variables, we find a positive effect for the two interactions variables. If I calculate the total impact of urbanization on dengue, puting the average values of temperature (24.5°C) and precipitation (110mm) in the calcul, I obtain 7.16%, which is comparable to its isolate impact (7.13%). After calculating the estimated urbanization under each couple ot temperature and precipitation observations, the maximal urbanization impact founded is from 11.3% (with temperature of 27.8°C and precipitation of 227mm).

Table 3: Dengue, weather and urbanization

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $\ln(education_{it})$ | | -4.007 | | | |
| | | (2.489) | | | |
| $\ln(income_{it})$ | | -0.651 | -0.895 | -0.754 | 0.176 |
| | | (0.768) | (0.777) | (0.785) | (0.841) |
| $\ln(drinking\_water_{it})$ | | 0.274 | -0.662 | -1.771** | -2.465** |
| | | (0.926) | (0.776) | (0.873) | (0.938) |
| $\ln(no\_waste\_serv_{it})$ | | -0.118 | | | |
| | | (0.173) | | | |
| $\ln(density_{it})$ | 3.225** | 2.320* | 3.819 | | |
| | (1.280) | (1.390) | (8.818) | | |
| $\ln(urb_{it})$ | | | | 7.131** | -207.232** |
| | | | | (3.626) | (76.147) |
| $\ln(vap\_pressure\_it)$ | 15.593*** | 13.342** | 16.002* | 14.741** | |
| | (4.612) | (4.686) | (8.400) | (4.552) | |
| $\ln(pre\_it)$ | -0.268 | -0.278 | 0.195 | -0.161 | 1.944** |
| | (0.272) | (0.269) | (0.816) | (0.276) | (0.731) |
| $\ln(avg\_tmp_{it})$ | | | | | 18.248** |
| | | | | | (7.190) |
| $\ln(density_{it}) X \ln(avg\_vap_{it})$ | | | -0.222 | | |
| | | | (2.409) | | |
| $\ln(density_{it}) X \ln(avg\_pre_{it})$ | | | -0.129 | | |
| | | | (0.213) | | |
| $\ln(avg\_tmp_{it}) X \ln(urb_{it})$ | | | | | 54.104** |
| | | | | | (23.690) |
| $\ln(urb_{it}) X \ln(avg\_pre_{it})$ | | | | | 8.850*** |
| | | | | | (2.401) |
| State Fixed Effects $D_i$ | | | | | |
| Year Fixed Effects $D_t$ | | | | | |
| N | 567 | 567 | 567 | 567 | 567 |
| $R^2$ | 0.458 | 0.474 | 0.464 | 0.455 | 0.474 |

Robust standard errors in parentheses.

*p<0.10, **p<0.05, ***p<0.001

# 5 Conclusion

In this paper, I searched to better understand the factors behind the increase in dengue incidence in the states of Brazil during the period 1992-2012 by analysing the principal determinants of dengue mosquito proliferation: weather factors, urbanization, public infrastructure and the socio-economic characteristics of the population. Using a PPML estimator and taking into account the heterogeneity of states and structural changes, I find a positive and statistically significant effect of different temperature measures and vapour pressure. I do not find an effect across estimations of precipitation. Not only actual weather has an impact on the dengue incidence, but also the long run climate variation is likely to increase dengue rate, as shown by the significant positive impact of temperature anomalies.

I find also that population density and urbanization have a positive impact on dengue incidence, even when controlling for socio-economic variables. When I interacted urbanization with temperature and precipitation, I find a positive and statistically significant impact for both weather variables. Under particular weather conditions, the impact of urbanization on dengue incidence can reach until 11%. An augmentation of 1% in the urbanization rate will increase dengue incidence of 11%. This result is an empirical proof and quantitative estimation for the widely affirmed but rarely proven impact of urbanization on dengue incidence. I also control for important geographic characteristics like wet land areas, coastal and mountain zones by adding state fixed effects. Nevertheless, a possible important geographic factor for which I do not control is the forest land areas that are variant in time and could impact dengue incidence.

These first results present already important public policy messages. It is clear that a policy against urbanization is not an option, even less in a country like Brazil, with 85% of the population living in urban areas already. But policy should focus on warmer, humid and more urbanized zones.

Future research should aim at including geographical factors like forest land varying in time. Access to health services and public dengue eradication programs are factors that are also important and until now difficult to take into account because of limited data access. Finally, a more disaggregated analysis would allow to increase its statistical power and to distinguish dengue cases in urban and rural areas.

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