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Impacts of Dengue Epidemics on Household Labor Market Outcomes

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Abstract[1]

Existing research on the economic impact of dengue among households focuses on individuals with clinically confirmed disease and their families. However, caregiving activities, avoidance behaviors, and changes in labor demand may cause the potential labor market impacts of an epidemic to extend beyond households that directly experience illness. I exploit exogenous fluctuations in the timing and scale of dengue epidemics in the Amazonian city of Iquitos, Peru from July 2005 to June 2010 to isolate changes in the work hours of all primary male and female residents in the region. I find that dengue epidemics are associated with large, statistically significant decreases in work hours for those who work positive hours. In aggregate, females reduce work hours more than males, both in levels of the point estimates and relative to mean hours. Furthermore, the decrease in female work hours during epidemics extends beyond households experiencing illness. This research contributes to the infectious disease literature by assessing the impact of epidemics on the labor market outcomes of all households in an affected region and by assessing the differential impacts on the outcomes of male and female residents.

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I. Introduction

Dengue fever is a mosquito-borne, flu-like virus that predominantly affects urban areas of tropical and sub-tropical regions throughout Southeast Asia, the Americas, and the Western Pacific (WHO 2014). Estimates suggest that there were approximately 96 million symptomatic cases of the virus globally in 2010 (Bhatt et al. 2013). The symptoms of dengue include headache, fever, rash, and muscle aches. Severe cases, while only representing a fraction of infections, can result in vomiting, internal hemorrhaging, and potentially death (WHO 2014). Frequently recurring large dengue epidemics are said to overburden health care systems in the developing world (Gubler 2012). However, the economic impact of epidemics at the household level is still largely unknown.

Existing cost estimates of the impact of dengue at the household level focus on the families of individuals who test positive for dengue (see Beatty, Beutels, and Meltzer, 2011 and Shepard, Halasa, and Undurraga, 2014 for reviews). However, the impacts of an epidemic on household labor market outcomes may extend beyond households who experience illness. Individuals may increase their labor supply in anticipation of or in response to increased healthcare costs for their family. Alternatively, individuals may stay home to prevent themselves from getting sick, to care for other family members who stay home, or to take protective measures to control the mosquitoes that spread the disease. Changes in labor demand during epidemics due to decreased tourism rates may also affect work hours regardless of family health. This research contributes to the literature on dengue epidemics as well as the infectious disease literature more broadly by assessing the impact of epidemics on the labor market outcomes of all households in an affected region.

I use irregular fluctuations in dengue transmission that are plausibly exogenous to the household to assess the impact of epidemics on household labor market outcomes in the Amazonian city of Iquitos, Peru. I rely on data from the Peruvian National Household Survey

(ENAHO) carried out by the Peruvian National Institute of Information and Statistics (INEI) from July 2005 to June 2010 (INEI 2015). The repeated cross-sectional data allows for the inclusion of controls for season, district, and year to isolate the impacts of unseasonably large dengue epidemics on labor market outcomes. I also estimate a difference-in-differences model utilizing the fact that epidemics occurred at the same time of year in 2005-2006 and 2007-2008, but not in 2006-2007. I estimate labor market outcomes for all primary males and females (household heads or spouses of heads) in the region.

One identifying assumption of the analysis is that, absent the occurrence of dengue epidemics, the outcomes of males and females surveyed during epidemics would have followed the same trend as the outcomes of males and females surveyed outside of the epidemics. I provide evidence that no change in survey implementation that might impact the results occurred during epidemics. The other identifying assumptions are that no other shock occurred during the dengue epidemics and that the intensity of each epidemic was not the result of a shift in the labor market. I provide evidence supporting these assumptions below.

I find that primary female residents decrease work hours by more than primary males during dengue epidemics, both in terms of point estimates and in percent changes relative to mean work hours. The weekly work hours of males who work more than 7 hours per week significantly decrease by around 3.3 hours, or 6.8% relative to the mean of approximately 48 hours per week, while the work hours of females who work more than 7 hours per week significantly decrease by 6.9 hours, or 15.1% relative to the mean of approximately 46 hours per week. I find no evidence for a change in the probability that males or females work more than 7 hours per week during epidemics. I consider differences in the response of male and female work hours to epidemics based on household structure, illness reports, and economic status in order to isolate various labor supply and labor demand impacts through which epidemics may affect work hours.

The results show that labor market activities are restricted during epidemics, even among households that do not experience illness directly, indicating other mechanisms through which epidemics restrict labor market activities such as avoidance behaviors or labor demand impacts. The results also indicate which members of society may be most susceptible to labor market restrictions during epidemics. I find that in most types of households, women are more affected than men and that individuals in households with lower economic status are more affected regardless of gender. I conclude with a discussion of how the results inform intervention policies aimed at mitigating the negative impacts of dengue. I also discuss the implications of this work on future studies of the impacts of infectious disease epidemics at the household level.

II. Previous Literature on Infectious Disease and Labor Market Outcomes

Much of the recent literature on infectious disease within households pertains to the willingness to pay for, or the uptake of, various treatment or prevention technologies. This literature is reviewed by Dupas (2011) and is discussed in detail in Clayton (2015a). There is also an extensive literature on the impact of exposure to infectious disease in utero, infancy, or early childhood on educational and later life outcomes. The fetal origins literature is extensively reviewed by Bleakley (2010). However, neither the willingness to pay literature nor the fetal origins literature offer insight into the broader household-level impacts of infectious disease.

Many recent studies have attempted to assess the relationship between disease and income or household productivity. Studies assessing the cyclical link between income and health are typically conducted at the macro-level and display mixed results about the magnitude of the causal effect of health on income or vice versa (for example, French 2012; Datta and Reimer 2013). There are a few studies that look at the impact of malaria on agricultural productivity and rural income (for example, Asenso-Okyere et al. 2011; Kiiza and Pederson 2014). However, these studies are not directly applicable to understanding the household-level impact of dengue since dengue is an urban, rather than a rural disease.

There are many existing studies that attempt to measure the economic burden of various infectious diseases, including dengue, at both the national and household level.[2] A key issue with the existing literature is that the inclusion criteria for economic costs of disease vary widely from study to study and typically only focus on households who directly experience the illness in question. For dengue, many studies include medical expenses and lost hours of work or schooling among infected individuals and sometimes caregivers in their direct or indirect costs (Halasa, Shepard, and Zeng 2012). The same is true for literature on Malaria (Kiiza and Pederson 2014). Bleakley (2010) defines the indirect costs of infectious disease as reduced productivity or human capital development in terms of the intensity of labor or ability to achieve cognitive gains from education among infected individuals. All of these definitions of direct and indirect disease costs only assess the economic impacts of disease for infected individuals and possibly their families.

Some studies discuss the importance of additional indirect costs of dengue in terms of the overburdening of healthcare systems or the negative effects of disease transmission on tourism (for example, Shepard, Halasa, and Undurraga 2014; Shepard et al. 2011). However, to my knowledge, no studies have attempted to incorporate broader community-wide impacts into household-level assessments of the economic burden of dengue. The same is true for the economic literature assessing the costs of other infectious diseases like malaria, hookworm, and the flu (for example, Asenso-Okyere et al. 2011; Bleakley 2007; Almond 2006). Studies that do assess the

[2] Beatty, Beutels, and Meltzer (2011) and Shepard, Halasa, and Undurraga (2014) offer detailed reviews of the literature estimating the economic burden of dengue.

costs of disease for broader communities include government costs along with costs for infected individuals and their families, but still do not look at the effects experienced by households in the area who do not experience illness (for example, Halasa, Shepard, and Zeng 2012). By focusing on accurately identifying disease burden from a clinical standpoint rather than an economic standpoint, previous studies have thus failed to capture additional behavioral changes among individuals in an area affected by infectious disease outbreaks that may contribute to the economic burden of disease for households.

III. Research Location and Context: Dengue Transmission in Iquitos, Peru

This research relies on data collected in the city of Iquitos in northeastern Peru. With an estimated population of over 400,000 people, Iquitos is the largest city in the world that cannot be reached by road. It is bordered by the Amazon Rainforest and the Amazon, Itaya, and Nanay Rivers, making it an ecological island. The city of Iquitos comprises four districts (Iquitos, Punchana, Belen, San Juan Bautista) and lies within the Loreto region. **Figure 1** shows a map of the Loreto region and of the location of the city of Iquitos.

The labor market in Iquitos includes both formal and informal sectors. The city has fairly large commercial retail and financial sectors with banks and shopping malls in the city center. International and domestic tourism comprises a large portion of the economic activity in Iquitos, and there are many hotels, restaurants, nightclubs, casinos and travel companies that employ local citizens. At the same time, there is an active informal labor market. It is common in Iquitos for people to provide taxi services with personal vehicles or to sell food or handicrafts at market stalls and within homes. I include both formal and informal labor in my analysis.

Iquitos has a tropical climate with year-round rainfall and warm temperatures, causing dengue to be continually transmitted at low levels. Still, the summer months (November to March) coincide with a significant increase in transmission. Warmer temperatures shorten the extrinsic incubation period that female *Aedes aegypti* mosquitoes undergo before being able to transmit the virus to humans (Scott and Morrison 2010). Dengue is then transmitted from mosquito to human more rapidly, increasing disease density. Stoddard *et al.* (2014) describe dengue transmission in Iquitos from July of 2000 to June of 2010. They define the peak transmission season as September to April with most activity occurring around December.

Although temperatures likely play a role in dengue transmission, Stoddard *et al.* (2014) find that dengue incidence varies both seasonally and across years for a variety of complex reasons. They describe that one likely cause of dengue epidemics is the introduction of a new serotype of the virus into the affected population. Dengue has four separate serotypes, and while contracting one provides lifelong immunity to that serotype, it provides only temporary immunity to the others. The introduction of a new serotype into a population in which very few people are already immune to it can then lead to a larger-than-average dengue outbreak. The introduction of a new serotype can occur when even a small number of infected humans travel into the area and are bitten by local mosquitoes, which then transmit the disease to local human populations.[3] Although not all causes of dengue transmission at epidemic levels are known, it seems likely that the occurrence of a dengue epidemic constitutes an arguably exogenous shock to households.

The scope of the direct human health impacts of dengue in Iquitos in terms of symptomatic dengue cases is often small. **Figure 2** shows the moving 4-week average of the number of reported dengue cases in Iquitos from 2005 to 2010 as reported in Stoddard *et al*. (2014).[4] The sample probably only captures about 40% of the Iquitos population since only individuals who come to

[3] Amy C Morrison, personal correspondence

[4] I smooth the data on dengue transmission over 4 week increments to account for sharp weekly fluctuations that do not reflect overall transmission patterns. I use the period of 4 weeks to match household survey data on individual illness reports (INEI 2015).

one of six reporting clinics in the area for treatment are observed.[5] Stoddard *et al*. further note that participation was not complete among the sample population. Still, the largest number of annually reported cases during the research period is 825 from mid-2008 to mid-2009, representing approximately 0.55% of the estimated sample population.[6]

Despite the relatively small (in scale) human health impact of dengue in Iquitos throughout the study period, epidemics elicit a large response within the community. The Loreto Regional Health Department (LRHD) often responds to dengue epidemics with widespread intra-household adulticide spraying campaigns to control mosquito populations. Throughout the study period, each campaign reached about 30,000 to 50,000 homes out of the approximately 80,000 homes in the city (Stoddard et al. 2014). The campaigns are highly visible due to their scale and because they entail the LRHD entering each home three times over the course of about three weeks. All households in the area are therefore likely to be aware that a dengue epidemic is occurring regardless of whether or not their members contract the disease.

IV. Potential Response of Labor Market Outcomes to Dengue Epidemics

In this research, I focus on the impacts of dengue epidemics on the labor market outcomes of primary male and female household residents. Dengue epidemics could cause changes in labor demand and labor supply and may differentially affect men and women. For example, gender roles may dictate who is responsible for caring for sick family members (more likely among females)

[5] Clinical data only capture symptomatic cases and Bhatt *et al*. (2013) estimate that symptomatic dengue cases represent approximately 40% of all dengue infections due to the prevalence of asymptomatic cases.

[6] The largest epidemic in Iquitos occurred from October 2010 to February 2011 and is not captured in the data. Over 23,000 cases were reported, representing approximately 14% of the population (assuming 40% of the population was sampled). Over 3,000 of the cases were symptomatic (about 2% of the population), 104 of which were severe (about 0.03% of the population), and 22 of which resulted in death (Amy C. Morrison, personal correspondence). In comparison, during the epidemic of H1N1 flu in the United States in 2009, there were 60.8 million cases, representing approximately 19.82% of the population, 274,304 hospitalizations, or 0.09% of the population, and 12,469 deaths (Shrestha et al. 2011).

or for providing family members with transportation to a health clinic (more likely among males). Gender roles might also determine an individual's employment opportunities and different occupations may be differentially affected during epidemics in terms of labor demand.

Dengue epidemics are likely to decrease tourism rates (Shepard, Halasa, and Undurraga 2014). Labor demand may then decrease during epidemics for those whose occupation is heavily reliant on tourism, including many of those in the services sector like market vendors, restaurant workers, hotel employees, and tour guides. National statistics indicate that females are far more likely to work in the services sector compared to males. The percentage of working females in Peru who reported being employed in the services sector was 61.3% in 2005 and 66.6% in 2010. In contrast, the percentage of working males who reported working in the services sector was only 45.8% in 2005 and 48.7% in 2010 (International Labour Organization 2015). It may therefore be the case that work hours among females who work positive hours are more negatively affected during dengue epidemics compared to males, regardless of potential responses in labor supply.

Regarding the impact of dengue on labor supply, household labor and/or health behaviors may be affected during a dengue epidemic regardless of whether or not their members contract dengue. For example, people may increase their labor supply in anticipation of a health shock to their family. Alternatively, people may stay home as an act of caution to prevent themselves from contracting dengue[7] or to take actions to protect their household from the mosquito that spreads the disease. People may also be more likely to consider the illness of a household member serious enough to require that family members stay home to care for them or to take them to a health care facility during a dengue epidemic. Later in the paper, I analyze heterogeneous responses among

[7] Research has suggested that the entomological risk of contracting dengue is at the household level (Scott and Morrison 2003). However, human transportation is also said to play a key role in dengue transmission (Magori et al. 2009). It is therefore unclear whether staying home would prevent one from contracting dengue or not.

primary male and female work hours to epidemics based on household structure, illness reports, and economic status in order to isolate the various mechanisms discussed here.

V. Data Description

Using data reported in Stoddard *et al.* (2014), I focus on dengue transmission between July 2005 and June 2010 in the city of Iquitos, Peru. I merge the weekly transmission data with household level data from the ENAHO survey carried out by the INEI (2015).[8] The INEI attempts to maintain a representative sample of the national population each year. They survey a random selection of households within pre-defined survey areas to ensure that all geographic areas throughout the country are covered.[9] They randomly select households each year, making the sample a repeated cross-section, rather than a panel.[10]

Table 1 shows the number of household-level observations in the sample, broken down by household type. The full pooled sample includes 1,844 household-level observations. Each observation includes data on all household residents, including the primary male and female resident (when one is present), where the term 'primary resident' refers to either the household head or the spouse of the head. I separately analyze all primary male and female residents in the sample as well as single male and female household heads, and primary male and female residents in dual-headed households. The majority of households in the sample are dual-headed households,

[8] The ENAHO data are available from 2004 to 2013 but the dengue transmission data are only available until June 2010 and there are issues of missing ENAHO data in 2004. There were also issues with the inflation of reported transmission data during 2004 because of a clinic remaining open for extended hours to accommodate a larger number of incoming dengue cases during the 2004 epidemic (Stoddard et al. 2014). I therefore focus my research on data from July 2005 to June 2010.

[9] **Table A.1** in the appendix shows the distribution of household observations across trimesters, fiscal years, and districts. The sample is fairly evenly distributed across trimesters and years. The proportion of the sample from each district is not evenly distributed but generally reflects differences in population level.

[10] There is a limited panel component to the sample, with 112 intentionally repeated household observations that I remove to maintain a random sample. Including the repeated observations does not alter the findings.

comprising 1,288 observations. Single female household heads are almost twice as prevalent as single male heads, with 360 versus 196 observations.

Dengue transmission patterns in Iquitos from July 2005 to June 2010 are shown in **Figure 2** while **Table 2** provides the mean and standard deviation of key independent and control variables for the analysis. The average number of dengue cases reported in the past 4 weeks is about 11. Based on mean reported cases, I determine epidemic levels of transmission to be greater than 12 cases on average over the past 4 weeks.[11] About 24% of observations within the sample are collected during epidemic periods of dengue transmission based on the 12 case threshold. Large epidemics occurred in 2005-2006, 2007-2008, and 2008-2009, with a smaller epidemic occurring in 2009-2010. Dengue transmission decreased for about an 18 month period between the epidemic ending in early-2006 and the one beginning in late-2007.

The ENAHO survey collects household demographic information including the age, gender, and education of all household residents. The average number of household residents in the Iquitos sample is 5.5. 80.5% of households have a primary male resident and 89.4% of households have a primary female resident. 50.8% of households have other income earners and 50.1% of include children under the age of 5. The average age of primary male residents is 46.5 years and the average educational attainment of primary males is 9.5 years. The average age of primary female residents in the sample is about 3 years less than that of primary males and the average educational attainment of primary females is about 1 year less than that of primary males.

[11] The results are fairly robust to altering the threshold for epidemic dengue transmission within 1 to 2 cases per week on average. Altering the epidemic threshold by 3 or more cases per week on average weakens the results since periods of epidemic transmission are lumped with periods of non-epidemic transmission (results available upon request). Based on the strength of the results at various threshold levels and the pattern of transmission provided in **Figure 2**, I conclude that a threshold of 12 cases per week on average is appropriate.

The ENAHO survey also collects detailed information on the number of hours worked for pay in the last week by each resident. Survey respondents are asked about their primary occupation and about whether or not they carry out any other activities to generate income. Total work hours in formal or informal labor market activities are capped at 98 per week. **Figure 3** shows the distribution of primary male and female work hours within the sample. While there are individuals who do not work to generate income at all, the distribution of work hours is relatively normal for males who work more than 7 hours per week and is slightly right-skewed for females, indicating a lower number of weekly work hours on average. Average weekly work hours and the probability working more than 7 hours per week are reported in the results tables for primary males and females. However, **Table 2** does indicate that females are more likely to participate in the informal rather than the formal labor market compared to males. 6.8% of primary females who work report working claim to work in the informal labor market compared to only 1.2% of primary males.

The ENAHO survey collects information on physical housing traits including durable goods ownership and the quality of housing construction materials. I use the physical housing traits to construct an economic index for each household (Clayton, 2015b). The survey also asks whether or not each resident experienced an illness in the past four weeks and, if so, how many days they were unable to carry out their normal activities, although the survey does not specify the type of illness experienced. I use the physical housing traits and household illness data later in the paper to test for variations in the household response to dengue epidemics based on household economic status and illness experiences. The data are discussed in greater detail in **Section VIII**.

VI. Empirical Specification

VI.1. Fixed Effects Estimation

I estimate changes in the paid weekly work hours and the probability of working over 7 hours per week for both primary male and female residents during dengue epidemics in Iquitos between July 2005 and June 2010. I utilize ordinary least squares (OLS) regression and include fixed effects for district, month, and year. The independent variable of interest is an indicator for the occurrence of dengue epidemics.[12] The identification strategy is valid if 1) household labor market outcomes do not affect the occurrence of dengue epidemics, 2) there are no other confounding factors that occur at the same time as the dengue epidemics that may also affect labor market outcomes, and 3) the work hours of males and females surveyed during epidemics would have followed a similar trend as those of males and females surveyed outside of epidemics, where it not for the occurrence of the epidemics.

I have already argued the exogeneity of dengue epidemics at the household level above. At the city level, it may be the case that increases in tourism increase the risk of dengue epidemics occurring as people from outside of the city can bring in new serotypes of the disease. If anything though, this would only dampen results indicating negative labor demand impacts from decreases in tourism during epidemics.

To help address the second identifying assumption, I include controls for potentially confounding factors. I include district-level fixed effects to capture time-invariant differences between household labor market outcomes across districts. I also include indicators for year to account for changes in labor market outcomes over time, and controls for season to capture regular

[12] Results analyzing continuous or count data on the number of dengue cases (available upon request) do not offer additional insight to the effect of dengue transmission on labor market activities as the impacts appear to stem from a threshold effect at epidemic levels of transmission.

fluctuations in labor market outcomes due to seasonal influences (*i.e.,* seasonal employment) external to changes in dengue transmission. I further discuss other potentially confounding factors (weather, labor strikes, and other diseases) in the appendix.

The third assumption is largely addressed by the irregular fluctuations in the occurrence of dengue epidemics throughout the study period and by the included controls for district, season, and year. I also provide evidence in the appendix that there are no changes in survey implementation or participation during epidemics that might cause sampling bias.

The fixed-effects regression for estimating the impact of dengue epidemics on household labor market outcomes is defined in **Equation 1**.

$$(Labor\ Market\ Outcome)_{igst} = \alpha + \boldsymbol{\beta X_{igst}} + \delta\,(DengueEpidemic)_{igst} + \sum_{\tau=2}^{5} \theta_\tau (Fiscal\ Year)_{igst}^{\tau} + \sum_{\sigma=2}^{3} \pi_\sigma (Season)_{igst}^{\sigma} + \sum_{\gamma=2}^{4} \mu_\gamma (District)_{igst}^{\gamma} + \varepsilon_{igst}\ , \quad where \quad (Fiscal\ Year)_{igst}^{\tau} = \begin{cases} 1\ if\ t = \tau \\ 0\ if\ t \neq \tau \end{cases}\ t = 2, \dots, 5\ , \tag{1}$$

$$(Season)_{igst}^{\sigma} = \begin{cases} 1\ if\ s = \sigma \\ 0\ if\ s \neq \sigma \end{cases}\ s = 2, 3\ , \quad and \quad (District)_{igst}^{\gamma} = \begin{cases} 1\ if\ g = \gamma \\ 0\ if\ g \neq \gamma \end{cases}\ g = 2, \dots, 4\,.$$

The dependent variable, $(Labor\ Market\ Outcome)_{igst}$, measures, in different specifications, the paid weekly work hours of primary male and female residents and the probability that each works more than 7 hours per week within household *i* in district *g* during season *s* and year *t*. The vector $\boldsymbol{X_{igst}}$ represents the set of descriptive characteristics for household *i* in district *g* during season *s* and year *t* described in **Table 2**. The independent variable of interest, $(DengueEpidemic)_{igst}$, is equal to 1 if there are more than 12 reported dengue cases per week on average over the 4 weeks preceding the survey date for household *i* in district *g* during season *s* and year *t*.

The dummy variables $(Fiscal\,Year)^{\tau}_{igst}$ control for changes in household labor market outcomes across fiscal year (July-June). The dummy variables $(Season)^{\sigma}_{igst}$ capture regular seasonal fluctuations in labor market outcomes, where seasons are differentiated by calendar year trimesters.[13] The dummy variables $(District)^{\gamma}_{igst}$ control for time-invariant differences in labor market outcomes across the four districts of Iquitos. The variable $(DengueEpidemic)_{igst}$ thus isolates the impact of dengue epidemics on labor market outcomes. Lastly, ε_{igst} is the error term.

VI.2. Difference in Differences Estimation

Although the timing and duration of dengue epidemics varies throughout the study period, there is recurring seasonal variation in transmission patterns. Epidemics also occur with greater frequency in later years. One might then worry that despite the inclusion of controls for season and year in the fixed-effects regressions above, any apparent impact of dengue epidemics on labor market outcomes might actually reflect seasonal variations or changes in labor market outcomes over time. Additionally, there is seasonal variation in survey collection across districts. Even when district controls are included, if districts with lower average labor market participation are more likely to be surveyed during seasons when dengue epidemics are more probable, differences in labor market outcomes during epidemics might also be driven by district-level variation in the sample across seasons.

To further control for potentially contemporaneous effects from variations in season, district, or time, I carry out a difference-in-differences (D-D) regression on the impact of dengue epidemics on labor market outcomes for the Iquitos sample from July 2005 to June 2008. Epidemics occurred

[13] Calendar-year trimesters are used based on climatic variation in Iquitos (Stoddard et al. 2014). Differentiating seasons based on calendar-year trimesters also prevents the season dummy variables from being collinear with the fiscal-year dummy variables. Results are robust to varying the specification of seasonality or to removing the seasonality dummies (results available upon request).

around the same time of year and for similar durations in 2005-2006 and 2007-2008 while transmission remained low throughout 2006-2007. I can therefore compare labor market outcomes among households surveyed during the same time of year in years when there is and is not an epidemic. This differs from the fixed effects estimation above, which assesses differences in labor market outcomes among households surveyed during versus outside of epidemics that occur at various times of year and at varying frequencies and durations.

Figure 4 shows dengue transmission from July 2005 to June 2008. The period of time to be compared across years, about December through March, is outlined in red. The control group is comprised of the households that are surveyed during months when dengue epidemics never occur (April through November). The treatment group consists of the households that are surveyed from December to March of any survey year, since epidemics occurred in the 2005-2006 and 2007-2008 survey years during these months. The treatment is then the epidemics that occur in 2005-2006 and 2007-2008.[14]

In analyzing households surveyed at the same time of year in epidemic and non-epidemic years, I remove concerns that the results are driven by seasonal patterns in survey collection or in the probability of dengue epidemics occurring. Because the non-epidemic period is both preceded by and followed by epidemics, concerns about results being driven by time trends are also alleviated. The specification is valid as long as there are not events that might affect household work hours that occur in either 2005-2006 or 2007-2008 at the same time as the dengue epidemics and that also do not occur in 2006-2007.

[14] The assessed time of year does not perfectly capture epidemic levels of dengue transmission at the beginning and end of the 2005-2006 and 2007-2008 epidemics since the epidemics do not occur over the exact same weeks in each year. If anything though, the fuzzy specification of dengue epidemics should weaken the results, making significant coefficients all the more convincing.

The D-D regression for estimating the impact of dengue epidemics on labor market outcomes is defined in **Equation 2**.

$$
\begin{aligned}
&(Labor\ Market\ Outcome)_{igt} \\
&\quad = \alpha + \sigma\,(Dengue\ Season)_{ig} + \gamma_1\,(FY\ 2005-2006)_{ig} + \gamma_2\,(FY\ 2007-2008)_{ig} \\
&\quad + \delta_1\,[(Dengue\ Season) \times (FY\ 2005-2006)]_{ig} \\
&\quad + \delta_2\,[(Dengue\ Season) \times (FY\ 2007-2008)]_{ig} + \sum_{\gamma=2}^{4} \mu_\gamma (District)_{igt}^{\gamma} + \boldsymbol{X_{igt}}'\boldsymbol{\beta} + \mu_{igt}\,, \\
&\quad where\ \ (District)_{igt}^{\gamma} = \begin{cases} 1\ if\ g = \gamma \\ 0\ if\ g \neq \gamma \end{cases}\ \ g = 2, \ldots, 4\,.
\end{aligned}
\tag{2}
$$

The dummy variable $(Dengue\ Season)_{ig}$ indicates that household *i* in district *g* was surveyed during the months in which there were dengue epidemics in 2005-2006 and 2007-2008, around December to March. The variable captures households surveyed from December to March in every survey year. The dummy variables $(FY\ 2005-2006)_{ig}$ and $(FY\ 2007-2008)_{ig}$ indicate that household *i* in district *g* was surveyed during a fiscal year in which there was an epidemic. The interaction terms $[(Dengue\ Season) \times (FY\ 2005-2006)]_{ig}$ and $[(Dengue\ Season) \times (FY\ 2007-2008)]_{ig}$ capture the impact of being surveyed during a dengue epidemic (December to March of 2005-2006 or 2007-2008) compared to being surveyed during non-epidemic weeks in the non-epidemic fiscal year. The coefficients δ_1 and δ_2 thus estimate the effect of dengue epidemics on household labor market outcomes.

The $(District)_{igt}^{\gamma}$ dummy variables capture time-invariant differences in labor market outcomes across the four districts of Iquitos. The vector $\boldsymbol{X_{igt}}$ represents a set of demographic and economic characteristics of household *i* in district *g* and year *t*. The last term, μ_{igt}, is the error term for household *i* in district *g* and year *t*. I do not include year or seasonal controls, in part because the specification already controls for variations in season and year. Also, Bertrand, Duflo, &

Mullainathan (2002) point out that the error terms in longitudinal D-D analyses are serially correlated, causing the statistical significance of findings to be overstated. They find that, with a small number of comparison groups, the best solution to the serial correlation problem is to pool the sample, ignoring the longitudinal aspects of the data.

VII. Results

VII.1. Fixed-Effects Estimation

Table 3 and **Table 4** provide the main fixed-effects results on the labor market outcomes of all primary male and female residents, respectively. The initial regressions are estimated for all households with a primary male or female resident. The means of each dependent variable are reported at the top of the tables. Primary males work more hours on average and are more likely to work more than 7 hours per week compared to primary females. The average weekly work hours of all primary males in the sample is 39 while the average of primary females is 24. 81.4% of primary male residents in the sample work more than 7 hours per week for pay compared to only 50.9% of primary females. Among those who do work more than 7 hours per week, the average work hours of males is 48 while the average for females is 46.

The results indicate that during a dengue epidemic, primary females decrease work hours by a substantially larger amount than males, both in terms of the point estimate and in percentage terms relative to mean hours.[15] The occurrence of a dengue epidemic is associated with a weakly significant decrease of 3.4 work hours for primary male residents, representing an 8.6% decrease relative to mean hours. Female work hours decrease significantly by 5.1 hours, representing a

[15]Reported results are based on non-clustered standard errors. Results are robust to the clustering of standard errors by district and by year (results available upon request).

21.4% decrease relative to mean hours. Neither males nor females display statistically significant changes in the probability that they work more than 7 hours per week during dengue epidemics.[16]

Among those who do work more than 7 hours per week, the decrease in work hours among primary females during dengue epidemics is over twice that of primary males. The decrease in work hours during epidemics among primary males who work more than 7 hours per week is similar to the decrease for the full sample, at 3.3 hours, but it constitutes a smaller change relative to mean hours, representing a 6.8% decrease. Primary female work hours decrease significantly by 6.9 hours which, compared to mean work hours, represents a change of 15.1%.

Regarding other control variables, the presence of another primary resident who works more than 7 hours per week is associated with significantly fewer work hours and a lower probability of working for both males and females. The presence of other income earners in the household has no significant association with work hours or the probability of working. If anything, the presence of children younger than five is associated with decreased work hours and a lower probability of working for both males and females, although the coefficients are mostly insignificant. Work hours and the probability of working more than 7 hours per week are both quadratic in age for males and females. Years of education are not significantly related to male work outcomes, but are associated with a significantly higher probability of working for females and with fewer work hours for those who work more than 7 hours. I do not report the results of household demographics in the rest of the results tables; they are included in all regressions unless otherwise specified (results available upon request).[17]

[16] Probit regressions of the impact of dengue epidemics on the probability of working more than 7 hours per week confirm the reported results (results available upon request). The findings are also robust to altering the threshold at which primary male and female residents are determined to work positive hours.

[17] Results are robust to altering the inclusion of various household demographic control variables.

VII.2. Difference-in-Differences Estimation

Tables 3.5-3.6 show the same results as **Tables 3.3-3.4**, but with the difference-in-differences specification described in **Equation 2**. The results indicate that work hours are generally increasing over time and tend to be higher during the time of year in which dengue epidemics occur if there is no epidemic. Primary male work hours for those who work more than 7 hours per week decrease by 3.5 hours during the 2005-2006 and 2007-2008 epidemics, with weak statistical significance in both cases. Female work hours for those who work more than 7 hours per week decrease by 6.1 hours and 4.7 hours during the 2005-2006 and 2007-2008 epidemics respectively, again with weak statistical significance in each case. Results are expectedly weaker for all primary males and females, including those who do not work, and dengue epidemics have no significant impact on the probability that males or females work more than 7 hours per week. Although not always statistically significant, the difference-in-differences results support the main fixed-effects results.

VIII. Heterogeneous Response to Dengue Epidemics

The initial results show that dengue epidemics correspond with substantially larger and more statistically significant decreases in the paid weekly work hours of primary female residents compared to males. However, the results do not describe how the response of primary male or female work hours to dengue epidemics might vary based on the number of primary residents in the household and their respective work hours. Furthermore, the driving mechanisms for the changes in work hours among males and females are yet to be determined and need to be tested with additional analyses. Here, I analyze the impact of dengue epidemics on male and female work hours for those who work more than 7 hours per week taking into account differences in household structure, illness experiences, and economic status. The theory, data, and results for each analysis are discussed in turn.

VIII.1. Household Structure

It seems likely that primary males and females may respond differently to dengue epidemics in terms of work hours based on the presence of another primary resident and the work hours of that individual. **Table 7** shows the mean of the included control variables for the samples of single male and female household heads and for dual-headed households. Household attributes vary largely based on household structure. Average household size is smaller in households with single male heads, about 3 residents, than it is for households with single female heads, about 5 residents, and for dual-headed households, about 6 residents. Only 17.9% of households with single male heads have children under the age of 5, compared to 45% of households with single female heads and 56.4% of dual-headed households. The average age of single male heads is 2.5 years higher than that of primary males in dual-headed households and the average years of education among single male heads is .5 years lower. The average age of single female heads is over 10 years higher than that of primary females in dual-headed households while the average educational attainment is also .5 years lower.

Primary males in single-headed households and in dual-headed households have nearly the same probability of working more than 7 hours per week, but males in dual-headed households are over twice as likely to work in the informal rather than the formal labor market. In contrast, single female heads are over 10 percentage points more likely to work more than 7 hours per week than primary females in dual-headed households, but are only about 2 percentage points less likely to work in the informal rather than the formal labor market. The probability that other income earners are present is highest among single female headed households, at 66.9%, compared to 47.7% in dual-headed households and 41.3% in single male-headed households.

Table 8 shows the impact of dengue epidemics on work hours for primary males and females who work more than 7 hours per week in various types of households and shows differing changes in work hours during epidemics based on household structure. Single male heads increase work hours by over 8 hours during epidemics, though the coefficient is not significant. The sample of single male heads is small though, at 160 observations. Primary male residents in households with a primary female who works less than 7 hours per week significantly decrease work hours by 5.6 hours. Primary males in dual-earner households where the primary female also works more than 7 hours per week decrease work hours by 3.2 hours, though again the coefficient is not significant.

Work hours among single female household heads display opposite changes during epidemics than those of single male heads, with female work hours decreasing with weak statistical significance by 8.9 hours. This constitutes a decrease of 18.1% relative to mean work hours, which is also almost equal in magnitude to the increase in work hours among single male heads. Primary females in households with primary males who work less than 7 hours per week do not display significant changes in work hours during epidemics. The decrease in work hours among primary females in dual-earner households is substantially larger and more statistically significant than that of primary males. Females significantly decrease work hours by 8.1 hours. Relative to mean hours, this constitutes an 18% decrease, compared to an insignificant decrease of 6.7% among males.

The heterogeneous responses of primary male and female work hours to dengue epidemics based on household structure are intriguing and pose additional questions about the mechanisms through which epidemics affect work hours. Overall, it appears as though primary females decrease work hours by a larger extent than primary males during epidemics. However, the results for males and females who are the only primary earner in a dual-headed household differ, with males decreasing work hours by a larger and more significant amount than females.[18] Because it is common for male residents to work in Iquitos, households with primary males who do not work may be more likely to be experiencing financial difficulties. The work hours of primary females in these households may be more necessary for maintaining family income and may be less able to respond to epidemics. In any case, the results suggest varying labor supply effects among males and females that need to be explored further.

VIII.2. Household Illness Reports

I next consider the influence of household illness reports on the impact of epidemics on work hours. Male and female residents may respond differently to personal illness or to the illness of other household residents during an epidemic. For example, the gender roles of an individual may make them responsible for caring for sick family members (more likely among females) or for providing family members with transportation to a health clinic (more likely among males). I test for different responses by looking at the work hours of primary males and females who have family members who report experiencing illness versus those in households that do not report experiencing any illness at the time of the survey.

The ENAHO survey collects information on whether each resident experienced an illness in the past four weeks and, if so, how many days they were unable to carry out their normal activities. The survey does not specify the type of illness experienced. The lack of specificity regarding illness is not likely to present a problem in the analysis for two main reasons. First, general illness reports will include some dengue illness and may actually capture more dengue cases than

[18] Regressions analyzing the impact of dengue epidemics on the difference between primary male and female work hours in dual-headed households yield insignificant results (results available upon request).

clinically confirmed data since many patients do not seek treatment for non-severe manifestations of the virus. Second, it may be that households respond more strongly to a member contracting a febrile illness during dengue epidemics regardless of whether or not that individual has dengue.

Table 9 shows the probability that various household members report experiencing illness during and outside of dengue epidemics for all primary male and female residents and for dual-earner households. Because of sample size restrictions, I do not assess single male or female-headed households. Illness within households is frequent throughout the study period with between around 69% and 76% of household observations in each sample indicating that at least one resident experienced illness in the past 4 weeks. About 55% to 61% of households report that a dependent resident experienced illness in the past 4 weeks. Primary females are more likely to report experiencing illness than primary males with about 30% of females and about 23% of males reporting experiencing illness in dual-earner households.

The percentage of household members that report experiencing illness does not change significantly during dengue epidemics. The summary probabilities suggest that, if anything, illness reports decrease during epidemics. The apparent decrease in reporting is probably driven by the fact that dengue epidemics occur more frequently in later years of the sample period and illness reports are decreasing over time. OLS and probit regressions confirm that dengue epidemics do not have a significant impact on household illness reports (results available upon request).However, it may still be the case that residents respond differently to household illness during epidemics than they would outside of an epidemic.

Table 10 shows the impact of the interaction of dengue epidemics with reports of household illness on primary male and female weekly work hours. The work hours of males and females do not change significantly in correspondence with household illness reports outside of epidemics. In contrast, both male and female work hours decrease significantly by about 6 and 5 hours respectively for the samples of all primary males and females during epidemics when at least one member of the household reports experiencing illness. Among dual-earner households, work hours significantly decrease by 8.5 hours among primary males and 6.5 hours among females. While primary males decrease work hours more than females in terms of point estimates, the percent changes among males and females based on mean work hours do not differ substantially; the decrease in male hours is larger by about 2 percentage points. The results may contradict the theory that primary female residents are exclusively responsible for caregiving activities when household members are sick. It is also possible that primary male residents provide their family with transportation to healthcare facilities as not many women in Iquitos drive cars or motokars (motorized rickshaws).

Females decrease work hours by about 8 hours during dengue epidemics when no household members report experiencing illness in both samples of working primary females. For all primary females, the result is significant at the 5% level and for females in dual-earner households; the result is significant at the 10.7% level. The decrease in female work hours during epidemics when no household members are sick may indicate avoidance behaviors among females in the form of taking actions to protect their home from mosquitoes. Families keeping their children home from school during epidemics to keep them from getting sick may also explain the results, since primary female residents are more likely to be responsible for childcare. Lastly, the unconditional decrease in female work hours during epidemics may indicate a labor demand effect since females in Peru are more likely to work in the services sector, which is more likely to be negatively affected by epidemics than other labor sectors. Unfortunately, I do not have usable data on regular school attendance or occupation type to further test the labor supply or labor demand hypotheses. Further research on the causes for work hour decreases during epidemics is needed.

VIII.3. Household Economic Status

There may also be heterogeneity in the response of households to dengue epidemics based on economic status.[19] As argued, the occurrence of dengue epidemics is plausibly exogenous to household behavior. Still, households in low or middle economic classes may be more susceptible to contracting dengue during an epidemic. Dengue is spread by the *Aedes aegypti* mosquito, which deposits its eggs in small containers like plastic tubs, flower pots, toilet bowls, and rubber tires (CDC 2014). The mosquito may be more prevalent in households of low or middle economic status as they are more likely to possess discarded items in which the mosquito can lay eggs. Households of varying economic status may also have different responses to illness in terms of seeking medical treatment or changing their labor supply. Lastly, individuals in lower economic classes may be more likely to work in occupations that are heavily reliant on tourism, like transportation, market vending, or restaurant work, and therefore may be more likely to experience decreased labor demand during epidemics.

I test for heterogeneity in the response of labor market outcomes based on economic status by running separate analyses for households in each economic level. I split households into three economic classes using an economic index generated from observable physical characteristics of the home via principal components analysis (PCA) (Clayton 2015b). I then divide households into classes based on the mean and standard deviation of the index scores.[20] **Table 11** shows the summary statistics for household weekly income, asset index score, and the percentage of

[19] I define economic status as the material standing of a household in terms of physical living conditions. See Clayton (Clayton 2015b) for more details on this measure.
[20] Results are robust to altering the thresholds of economic status (results available upon request).

households in each economic class for all working primary males and females and for dual-earner households. About 10% of observations in each sample are missing the physical housing characteristic data needed to construct an asset index. Dual-earner households are the wealthiest on average with a higher average weekly income and asset index score than the samples of all primary males and females.

Table 12 shows the results of separate regressions for all primary male and female residents and for primary males and females in dual-earner households at each economic level. The average work hours of all primary male residents are about 4 to 5 hours higher for males in the middle and upper economic classes compared to the lowest economic class. For primary males in dual-earner households, average work hours are relatively similar across economic classes. Primary females in the highest economic class work about 4 to 5 hours less than females in the middle or lower economic classes among all working primary females and among those in dual-earner households.

The work hours of primary male and female residents are not significantly associated with dengue epidemics for those among the highest economic class in any sample. Primary female work hours among the middle economic class decrease significantly during epidemics by 10.9 to 11.2 hours. Primary male work hours among the same class decrease insignificantly by 3 to 3.5 hours. In contrast, male work hours among the lowest economic class weakly decrease by 7 hours among all primary males and decrease significantly by 23 hours among dual-earner households. Primary female work hours in the same economic class decrease insignificantly by 3 to 5.5 hours.

The results indicate that primary males in the lowest economic class and females in the middle economic class are disproportionately affected by epidemics in terms of lost work hours. The results are consistent with the theory that lower to middle income households may be more susceptible to dengue transmission but could also be driven by changes in labor demand based on the proportion of men and women in each economic class whose work may rely heavily on tourism. Again however, I unfortunately do not have specific data on who contracts dengue or on occupation types in order to specifically test for the potential mechanisms discussed. Future research on the causes of differential impacts of dengue epidemics on labor market outcomes among various economic classes is needed.

IX. Conclusion

Dengue epidemics correspond to large decreases in the paid weekly work hours of both primary males and females. The results for all primary male and female residents suggest that females disproportionately respond during epidemics compared to males. The work hours of females decrease during epidemics by 15.1% relative to mean work hours compared to only a 6.8% decrease in male work hours relative to the mean. The results are confirmed through multiple fixed-effects and difference-in-differences analyses.

Results disaggregated by the presence of a sick individual in the household potentially indicate that both primary males and females participate in caring for sick family members during epidemics. Perceptions of disease risk also appear to increase during epidemics. While the probability of reporting illness does not change significantly during epidemics, both male and female work hours decrease largely and significantly in response to reports of household illness during epidemics and not in response to reports of household illness outside of epidemics. Primary female residents also significantly decrease work hours during epidemics when no household members report illness. The decrease in female work hours outside of household illness is potentially caused by labor demand impacts since females are more likely to work in the services sector, including jobs that depend on tourism, which are more likely to be negatively affected by dengue epidemics.

For both men and women, work hours decrease the most during dengue epidemics for those in the middle and lower economic classes. There may be increased risk of dengue contraction among households in low or average economic classes due to differences in home construction. There may also be different caregiving expectations of males and females in different economic classes. Lastly, the results may be driven by labor demand impacts as poorer individuals may be more likely to work in jobs that depend on tourism.

I find that primary male and female work hours decline during dengue epidemics, potentially due to changes in both labor supply and labor demand. Additional data could help disentangle the various mechanisms through which dengue affects household labor market outcomes. More detailed information on illness experiences and child school attendance could enhance the analysis of caregiving activities. Avoidance behaviors could be observed using data on the presence of containers capable of holding standing water, which are viable egg deposit sites for *Aedes aegypti* mosquitoes. A reduction in the number of risky containers in a household while male and/or female residents also report work hour reductions could indicate that residents take off work to protect their homes from mosquitoes. Labor demand impacts due to tourism reductions could be assessed with more detailed information on occupation types. Airline data could also indicate reductions in tourism to the city.

This research offers a substantial contribution to the existing literature on the economic burden of infectious disease by looking at changes in the labor market outcomes of all households in an area where epidemic disease transmission has occurred rather than focusing exclusively on the families of individuals who contract illness. The results suggest that ignoring changes in the labor market activities of other households in an affected area underestimates the economic burden of infectious disease epidemics.

The findings also have important implications for policymakers attempting to mitigate the negative impacts of dengue. The results suggest that mitigation efforts may have the greatest impact among females and among low-income households, as these individuals are most likely to experience large decreases in labor market activities during epidemics. The results further suggest that current government interventions aimed at reducing dengue transmission during epidemics may be detrimental to household labor market activity. Intra-household spray campaigns during epidemics are highly visible and, it has been argued, not highly effective at reducing dengue transmission (Esu et al. 2010). While spray campaigns offer a visible form of government intervention that might assuage the concerns of local citizens, they might also increase panic about epidemics, leading to greater labor market disruptions.

Researchers studying dengue transmission suggest that long-term interventions, such as those that encourage households to control mosquito egg deposit sites, would be more effective at keeping dengue transmission below epidemic levels (Morrison et al. 2008). My research, which finds that labor market impacts extend beyond those affected by illness during epidemics, suggests that mechanisms such as avoidance behaviors or labor demand impacts caused by increased perceptions of disease risk during epidemics play a key role in labor market reductions. The results then suggest that continuous interventions, which are less likely to insight panic during epidemics, might also reduce disruptions in household labor market activities during epidemics.

X. Works Cited

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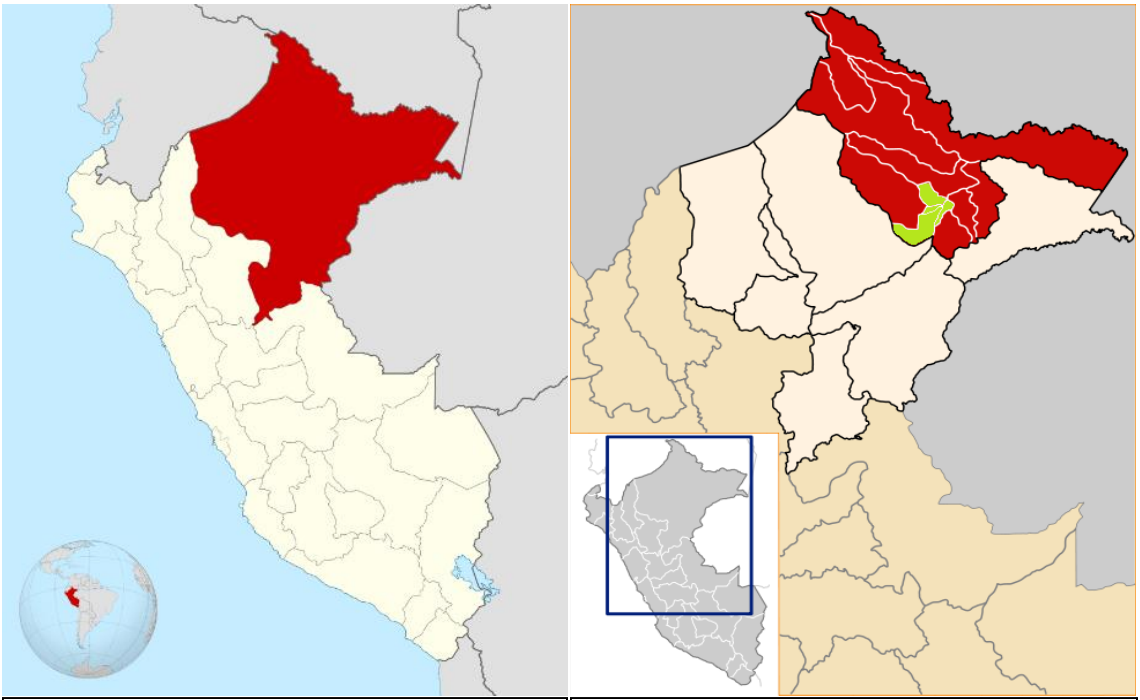
XI. Tables and Figures



The Loreto Region of Peru	The Maynas Province in the Loreto Region of Peru (City of Iquitos highlighted in green)

Figure 1: Maps of the City of Iquitos, the Maynas Province, and the Loreto Region in Peru. The City of Iquitos lies within the Maynas Province which lies within the Loreto Region.
Image Source: Wikipedia

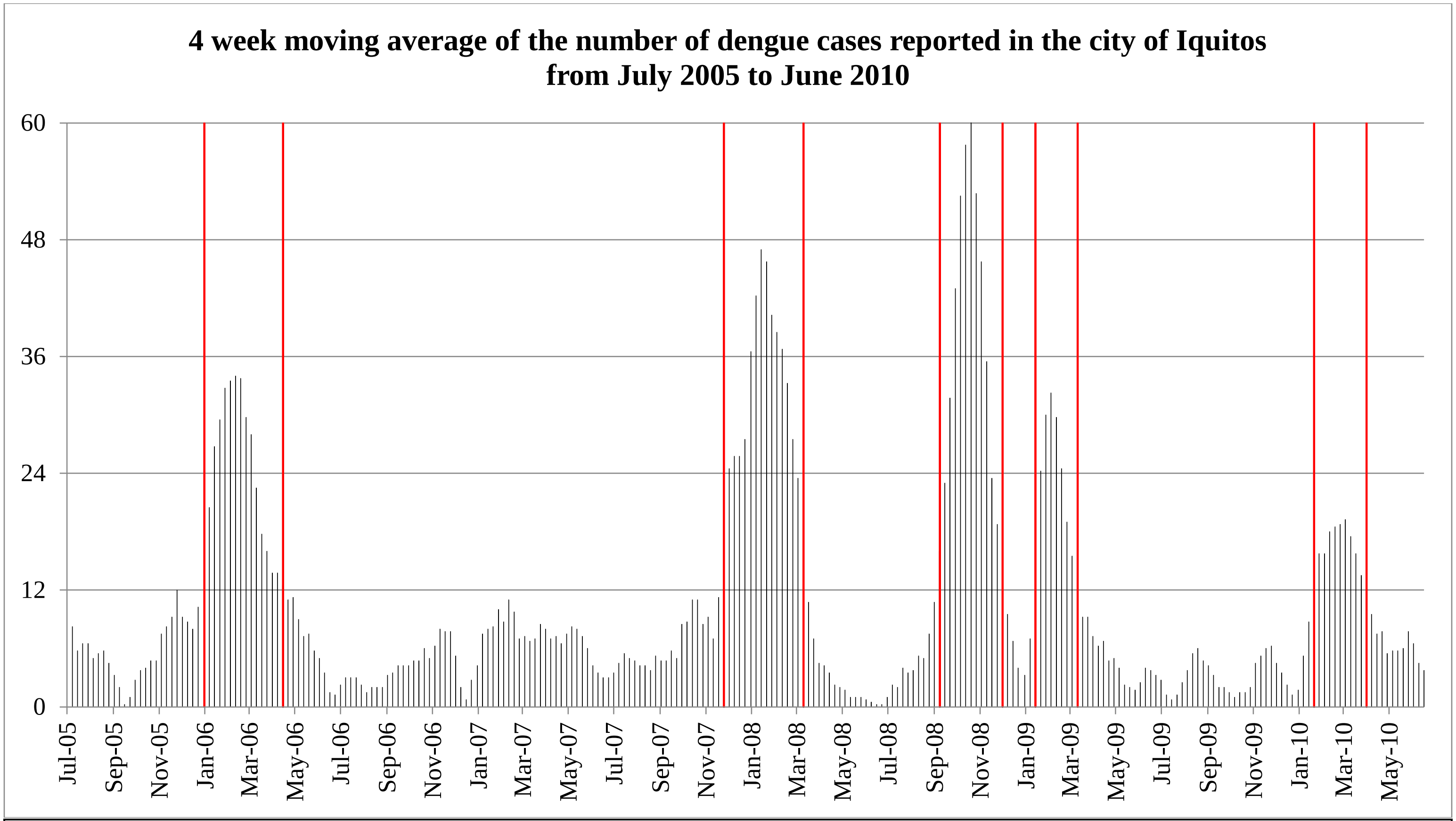


Figure 2: This figure shows the 4 week moving average of the number of reported dengue cases in Iquitos from July of 2005 to June of 2010. I consider more than 12 reported cases on average per week to indicate epidemic levels of transmission. The weeks are indicated in red. Data on reported dengue cases are from Stoddard, *et al.* (2014).

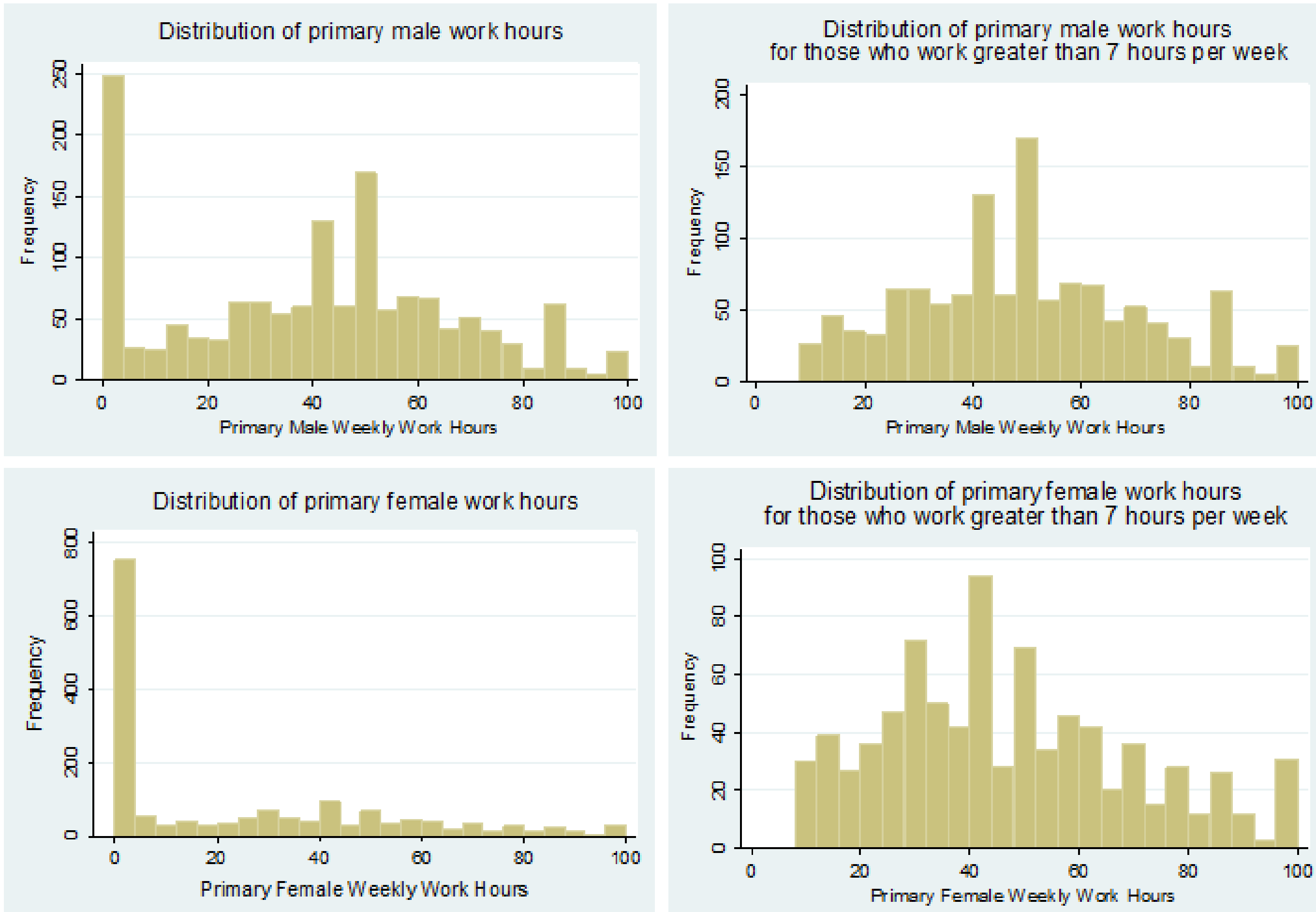


Figure 3: This figure shows the distribution of weekly work hours for all primary males and females and for primary males and females who work more than 7 hours per week for the sample of Iquitos from July 2005 to June 2010. The data are from the INEI ENAHO survey (INEI 2015).

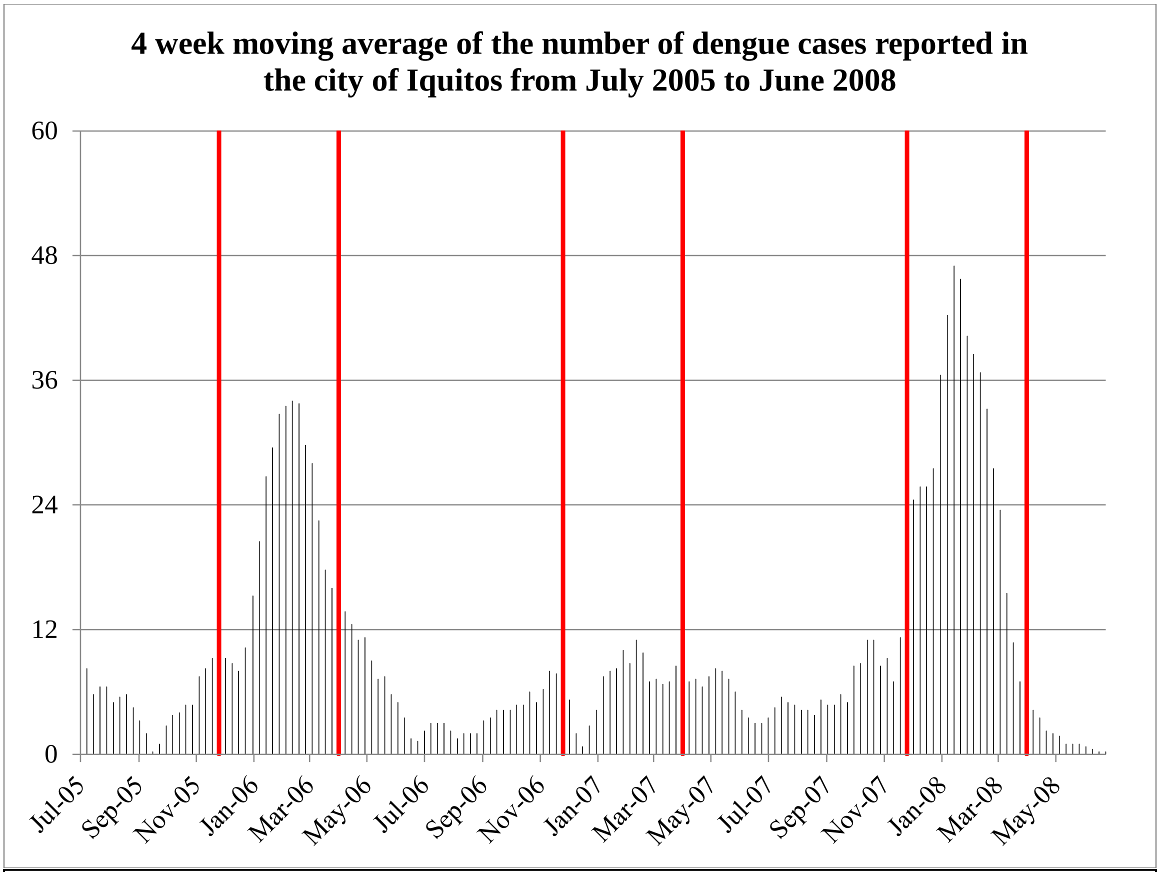


Figure 4: This figure shows the 4 week moving average of the number of reported dengue cases in Iquitos from July of 2005 to June of 2008. The weeks during which there were epidemics in 2005-2006 and 2007-2008 are indicated in red and are adjusted to cover the same time span in each year. Households surveyed during the span of weeks within red can be compared across epidemic and non-epidemic years via difference-in-differences regression. Data on reported dengue cases are from Stoddard, *et al.* (2014).

Table 1: Number of household observations for the sample population of Iquitos from July 2005 to June 2010

Type of Household	Number of Household Observations
All (including panel)	1,956
All (no panel)	1,844
With Both a Primary Male and Female	1,288
Single Female Head	360
Single Male Head	196

Data are from the INEI ENAHO survey from 2005-2010 (INEI 2015).

Table 2: Summary statistics of key independent and control variables for the sample of Iquitos from July 2005 to June 2010

	Full Sample	
	Mean	Stand. Dev.
Key Independent Variables		
Moving Weekly Average Number of Reported Dengue Cases in the Past 4 Weeks	10.952	(11.939)
Dengue Epidemic (1=Yes) (Threshold > 12 cases)	0.240	(0.427)
Control Variables		
Household Demographics		
Number of Household Residents	5.490	(2.811)
Primary Male Present (1=Yes)	0.805	(0.396)
Primary Female Present (1=Yes)	0.894	(0.308)
Other Income Earners Present (1=Yes)	0.508	(0.500)
Household has Children under the Age of 5 (1=Yes)	0.501	(0.500)
Primary Male Age (Years)	46.650	(13.941)
Primary Male Education (Years)	9.609	(4.263)
Primary Male Has Formal Occupation (1=Yes)	0.648	(0.478)
Primary Male Has Informal Occupation (1=Yes)	0.008	(0.087)
Primary Female Age (Years)	43.613	(14.025)
Primary Female Education (Years)	8.332	(4.505)
Primary Female Has Formal Occupation (1=Yes)	0.424	(0.494)
Primary Female Has Informal Occupation (1=Yes)	0.031	(0.175)
Observations	1844	

The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 3: Fixed-Effects regressions of the impact of dengue epidemics on primary male paid weekly work hours in Iquitos from July 2005 to June 2010

Sample:	All Primary Males	All Primary Males	All Primary Males who Work More than 7 hours per Week
Observations:	1,484	1,484	1,208
Dependent Variable:	Primary Male Weekly Work Hours	Primary Male Works More than 7 hours per Week (1=Yes)	Primary Male Weekly Work Hours
Mean of Dependent Variable:	39.373	0.814	48.228
Dengue Epidemic (1=Yes)	-3.370+	-0.016	-3.302+
	(-1.77)	(-0.58)	(-1.90)
Household Demographic Controls			
Number of Household Residents	-0.580+	-0.006	-0.387
	(-1.74)	(-1.33)	(-1.27)
Primary Female Works (1=Yes)	-2.898*	-0.069***	0.400
	(-2.12)	(-3.49)	(0.32)
Other Income Earners Present (1=Yes)	0.913	-0.013	2.086
	(0.56)	(-0.58)	(1.42)
Children Under Age 5 Present (1=Yes)	-0.758	-0.040+	1.358
	(-0.48)	(-1.74)	(0.95)
Primary Male Age (Years)	1.013***	0.023***	0.108
	(3.59)	(5.57)	(0.35)
Primary Male Squared Age (Years)	-0.015***	-0.000***	-0.002
	(-5.33)	(-7.72)	(-0.71)
Primary Male Education (Years)	-0.193	-0.002	-0.160
	(-1.07)	(-0.72)	(-0.96)
Included Controls			
Fiscal Year (July-June)	x	x	x
Season (Annual Trimester)	x	x	x
District	x	x	x
R^2	0.081	0.133	0.021
Adjusted R^2	0.070	0.123	0.007

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 4: Fixed-Effects regressions of the impact of dengue epidemics on primary female paid weekly work hours in Iquitos from July 2005 to June 2010

Sample:	All Primary Females	All Primary Females	All Primary Females who Work More than 7 hours per Week
Observations:	1,648	1,648	839
Dependent Variable:	Primary Female Weekly Work Hours	Primary Female Works More than 7 hours per Week (1=Yes)	Primary Female Weekly Work Hours
Mean of Dependent Variable:	23.674	0.509	46.044
Dengue Epidemic (1=Yes)	-5.076**	-0.039	-6.938**
	(-2.68)	(-1.15)	(-3.17)
Household Demographic Controls			
Number of Household Residents	-0.492	-0.007	-0.320
	(-1.51)	(-1.29)	(-0.86)
Primary Male Works (1=Yes)	-8.738***	-0.156***	-2.158
	(-5.81)	(-5.87)	(-1.31)
Other Income Earners Present (1=Yes)	1.525	0.027	-0.098
	(0.94)	(0.93)	(-0.05)
Children Under Age 5 Present (1=Yes)	-1.378	-0.013	-0.886
	(-0.86)	(-0.46)	(-0.49)
Primary Female Age (Years)	2.218***	0.041***	1.116*
	(7.90)	(8.27)	(2.58)
Primary Female Squared Age (Years)	-0.025***	-0.000***	-0.012*
	(-8.64)	(-9.05)	(-2.57)
Primary Female Education (Years)	0.060	0.014***	-1.036***
	(0.36)	(4.49)	(-5.44)
Included Controls			
Fiscal Year (July-June)	x	x	x
Season (Annual Trimester)	x	x	x
District	x	x	x
R^2	0.086	0.107	0.085
Adjusted R^2	0.077	0.098	0.066

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 5: Difference-in-Differences regressions of the impact of dengue epidemics on primary male weekly work hours in Iquitos from July 2005 to June 2008

Sample:	All Primary Males	All Primary Males	All Primary Males who Work More than 7 hours per Week
Observations:	886	886	722
Dependent Variable:	Primary Male Weekly Work Hours	Primary Male Works More than 7 hours per Week (1=Yes)	Primary Male Weekly Work Hours
Mean of Dependent Variable:	39.916	0.815	48.853
Interactions			
Dengue x FY 2005-2006	-2.528	0.008	-3.562
	(-0.99)	(0.23)	(-1.55)
Dengue x FY 2007-2008	-3.426	-0.010	-3.714
	(-1.35)	(-0.27)	(-1.59)
Dengue Season			
(omitted April-November)			
Yes (December-March)	1.043	-0.021	2.534
	(0.56)	(-0.79)	(1.50)
Fiscal Year (July-June)			
(omitted FY 2006-2007)			
FY 2005-2006	-1.559	0.034	-3.865
	(-0.56)	(0.86)	(-1.55)
FY 2007-2008	-0.257	0.002	-0.746
	(-0.10)	(0.05)	(-0.31)
Included Controls			
Household Demographics	x	x	x
Fiscal Year (July-June)			
Season (Annual Trimester)			
District	x	x	x
R^2	0.083	0.133	0.033
Adjusted R^2	0.067	0.119	0.013

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015). Included demographic controls are as in **Table 2**.

Table 6: Difference-in-Differences regressions of the impact of dengue epidemics on primary female weekly work hours in Iquitos from July 2005 to June 2008

Sample:	All Primary Females	All Primary Females	All Primary Females who Work More than 7 hours per Week
Observations:	984	984	478
Dependent Variable:	Primary Female Weekly Work Hours	Primary Female Works More than 7 hours per Week (1=Yes)	Primary Female Weekly Work Hours
Mean of Dependent Variable:	22.257	0.486	45.464
Interactions			
Dengue x FY 2005-2006	-4.274+	-0.041	-6.106+
	(-1.71)	(-0.91)	(-1.88)
Dengue x FY 2007-2008	1.252	0.065	-4.663
	(0.50)	(1.46)	(-1.62)
Dengue Season			
(omitted April-November)			
Yes (December-March)	1.085	-0.038	6.460**
	(0.60)	(-1.15)	(2.93)
Fiscal Year (July-June)			
(omitted FY 2006-2007)			
FY 2005-2006	-2.005	-0.006	-4.115
	(-0.74)	(-0.13)	(-1.33)
FY 2007-2008	0.267	0.008	-0.372
	(0.10)	(0.17)	(-0.13)
Included Controls			
Household Demographics	x	x	x
Fiscal Year (July-June)			
Season (Annual Trimester)			
District	x	x	x
R^2	0.100	0.126	0.107
Adjusted R^2	0.086	0.113	0.078

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015). Included demographic controls are as in **Table 2**.

Table 7: Summary statistics of control variables for various household types in Iquitos from July 2005 to June 2010

	Single Male Heads Mean	**Single Female Heads** Mean	**Dual-Headed Households** Mean
Control Variables			
Household Demographics			
Number of Household Residents	3.158	5.358	5.882
Other Income Earners Present (1=Yes)	0.413	0.669	0.477
Household has Children under the Age of 5 (1=Yes)	0.179	0.450	0.564
Primary Male Age (Years)	48.918	---	46.305
Primary Male Education (Years)	9.158	---	9.678
Primary Male Has Formal Occupation (1=Yes)	0.811	---	0.804
Primary Male Has Informal Occupation (1=Yes)	0.005	---	0.010
Primary Female Age (Years)	---	51.744	41.340
Primary Female Education (Years)	---	8.008	8.422
Primary Female Has Formal Occupation (1=Yes)	---	0.564	0.449
Primary Female Has Informal Occupation (1=Yes)	---	0.031	0.036
Observations	196	360	1288

Standard errors suppressed for the sake of space. The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 8: Fixed-Effects regressions of the impact of dengue epidemics on primary male and female paid weekly work hours for those who work more than 7 hours per week in various types of households in Iquitos from July 2005 to June 2010

	Primary Males who Work More than 7 hours per Week		
Sample:	Male Single Household Heads	Dual-Headed Households: Primary Female Works 7 or Less Hours per Week	Dual-Headed Households: Primary Female Works More than 7 hours per Week
Observations:	160	557	491
Dependent Variable:	Primary Male Weekly Work Hours	Primary Male Weekly Work Hours	Primary Male Weekly Work Hours
Mean of Dependent Variable:	47.175	48.282	48.511
Dengue Epidemic (1=Yes)	8.311	-5.560*	-3.238
	(1.47)	(-2.20)	(-1.20)
R^2	0.069	0.046	0.036
Adjusted R^2	-0.035	0.018	0.003

	Primary Females who Work More than 7 hours per Week		
Sample:	Female Single Household Heads	Dual-Headed Households: Primary Male Works 7 or Less Hours per Week	Dual-Headed Households: Primary Male Works More than 7 hours per Week
Observations:	214	134	491
Dependent Variable:	Primary Female Weekly Work Hours	Primary Female Weekly Work Hours	Primary Female Weekly Work Hours
Mean of Dependent Variable:	48.444	47.030	44.729
Dengue Epidemic (1=Yes)	-8.906+	0.877	-8.055**
	(-1.87)	(0.18)	(-2.80)
R^2	0.172	0.200	0.088
Adjusted R^2	0.105	0.091	0.057
Included Controls (All Regressions)			
Household Demographics	x	x	x
Fiscal Year (July-June)	x	x	x
Season (Annual Trimester)	x	x	x
District	x	x	x

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. Data on the number of dengue cases are from Stoddard *et al.* (2014). Data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015). Included demographic controls are as in **Table 2**.

Table 9: Summary statistics of household illness reports for samples of all primary males and females and for dual-earner households in Iquitos from July 2005 to June 2010

	All Primary Males		
	Full Sample	**No Dengue Epidemic**	**Dengue Epidemic**
Any Residents Reported Illness in Past 4 Weeks (1=Yes)	0.690	0.704	0.645
Dependent Residents Reported Illness in Past 4 Weeks (1=Yes)	0.550	0.571	0.481
Primary Female Reported Illness in Past 4 Weeks (1=Yes)	0.232	0.233	0.226
Primary Male Reported Illness in Past 4 Weeks (1=Yes)	0.231	0.237	0.213
Observations	1208	921	287

	All Primary Females		
	Full Sample	**No Dengue Epidemic**	**Dengue Epidemic**
Any Residents Reported Illness in Past 4 Weeks (1=Yes)	0.741	0.746	0.725
Dependent Residents Reported Illness in Past 4 Weeks (1=Yes)	0.614	0.625	0.575
Primary Female Reported Illness in Past 4 Weeks (1=Yes)	0.308	0.299	0.337
Primary Male Reported Illness in Past 4 Weeks (1=Yes)	0.181	0.176	0.197
Observations	839	646	193

	Dual-Earner Households		
	Full Sample	**No Dengue Epidemic**	**Dengue Epidemic**
Any Residents Reported Illness in Past 4 Weeks (1=Yes)	0.758	0.766	0.727
Dependent Residents Reported Illness in Past 4 Weeks (1=Yes)	0.609	0.630	0.536
Primary Female Reported Illness in Past 4 Weeks (1=Yes)	0.303	0.302	0.309
Primary Male Reported Illness in Past 4 Weeks (1=Yes)	0.226	0.223	0.236
Observations	491	381	110

The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 10: Fixed-Effects regressions of the impact of dengue epidemics interacted with household illness reports on primary male and female paid weekly work hours among various household types in Iquitos from July 2005 to June 2010

Sample:	All Primary Males who Work More than 7 hours per Week	All Primary Females who Work More than 7 hours per Week	Dual-Earner Households: Primary Male and Female Work More than 7 hours per Week	
Observations:	1208	839	491	
Dependent Variable:	Primary Male Weekly Work Hours	Primary Female Weekly Work Hours	Primary Male Weekly Work Hours	Primary Female Weekly Work Hours
Mean of Dependent Variable:	48.228	46.044	48.511	44.729
Household Illness Outside of Dengue Epidemics				
(omitted: no illness reports within the household)				
Some Residents Report Illness	-2.573	1.524	-3.439	1.541
	(-1.63)	(0.72)	(-1.33)	(0.56)
Household Illness During Dengue Epidemics				
No Residents Report Illness	-2.368	-8.122*	2.944	-8.136
	(-0.89)	(-2.17)	(0.63)	(-1.62)
Some Residents Report Illness	-6.358**	-4.997+	-8.536*	-6.572+
	(-2.83)	(-1.74)	(-2.46)	(-1.77)
Included Controls				
Household Demographics	x	x	x	x
Fiscal Year (July-June)	x	x	x	x
Season (Annual Trimester)	x	x	x	x
District	x	x	x	x
R^2	0.025	0.086	0.051	0.089
Adjusted R^2	0.009	0.065	0.015	0.054

t-statistics in parentheses: + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household survey participation are from the INEI ENAHO survey from 2005-2010 (INEI 2015). Included demographic controls are as in **Table 2**.

Table 11: Summary statistics of economic control variables for samples of all primary males and females who work more than 7 hours per week and for dual-earner households in Iquitos from July 2005 to June 2010

	All Primary Males who Work More than 7 hours per Week		**All Primary Females who Work More than 7 hours per Week**		**Dual-Earner Households**	
	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
Household Economic Information						
Total Weekly Income (Soles)	228.114	(323.398)	254.966	(296.339)	295.365	(323.211)
Asset Index of Economic Status*	0.764	(0.219)	0.808	(0.225)	0.818	(0.227)
Low Economic Status (1=Yes)	0.137	(0.344)	0.118	(0.323)	0.098	(0.297)
Middle Economic Status (1=Yes)	0.571	(0.495)	0.616	(0.487)	0.615	(0.487)
High Economic Status (1=Yes)	0.140	(0.347)	0.182	(0.386)	0.183	(0.387)
Observations	1,208		839		491	

*Fewer observations due to missing data. Index generated via PCA on physical household attributes. See Clayton (2015b) for more details on index construction. The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015).

Table 12: Fixed-Effects regressions of the impact of dengue epidemics on primary male and female paid weekly work hours among various household types in Iquitos from July 2005 to June 2010 separated by economic status

Sample:	All Primary Males who Work More than 7 hours per Week	All Primary Females who Work More than 7 hours per Week	Dual-Earner Households: Primary Male and Female Work More than 7 hours per Week	
Dependent Variable:	Primary Male Weekly Work Hours	Primary Female Weekly Work Hours	Primary Male Weekly Work Hours	Primary Female Weekly Work Hours
Economic Status:	Low Economic Status			
Observations:	165	99	48	
Mean of Dependent Variable:	44.036	46.626	46.479	45.688
Dengue Epidemic (1=Yes)	-6.993	-3.118	-23.019*	-5.798
	(-1.54)	(-0.44)	(-2.34)	(-0.52)
R^2	0.124	0.217	0.492	0.477
Adjusted R^2	0.022	0.052	0.229	0.207
Economic Status:	Average Economic Status			
Observations:	690	517	302	
Mean of Dependent Variable:	48.207	47.456	48.526	46.281
Dengue Epidemic (1=Yes)	-3.443	-10.932***	-3.097	-11.183**
	(-1.48)	(-3.77)	(-0.91)	(-2.95)
R^2	0.023	0.102	0.033	0.116
Adjusted R^2	-0.001	0.071	-0.021	0.066
Economic Status:	High Economic Status			
Observations:	169	153	90	
Mean of Dependent Variable:	49.243	42.817	47.156	41.311
Dengue Epidemic (1=Yes)	-5.149	6.676	-0.424	7.109
	(-1.01)	(1.33)	(-0.06)	(1.00)
R^2	0.145	0.146	0.204	0.233
Adjusted R^2	0.049	0.038	0.030	0.065

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015). Included controls are as in **Table 2**.

XII. Appendix

XII.1. Potentially Confounding Factors

One might be concerned that results indicating a significant impact of dengue epidemics on labor market outcomes are confounded by changes in weather concurrent with changes in dengue transmission. However, Iquitos is hot and rainy year-round so that changes in temperature and rainfall tend to be minor. The weekly average high temperature ranges from approximately 82.5 to 94.5 degrees Fahrenheit throughout the study period. Similarly, it rained approximately 50.5% of the days covered in the study and rained at least 2 days of the week in over 91% of the weeks covered in the study (Weather Underground 2016). Neither weekly average high temperature nor weekly rainfall occurrence is strongly correlated with weekly dengue cases. Unsurprisingly, regression results are unchanged when measures of weekly or monthly average temperatures or rainfall are included (available upon request).

One might also worry that dengue transmission fluctuates contemporaneously with other diseases. The INEI offers regional transmission data aggregated annually on Malaria, Leishmaniosis, Yellow Fever, and Tuberculosis (INEI 2015). Malaria only seriously impacts the rural areas in the Loreto region that are located outside of Iquitos. Malaria transmission in Loreto steadily decreases throughout the study period, with small peaks in 2005 and 2009. Leishmaniosis and Yellow Fever each display little to no transmission in Loreto. Tuberculosis is a problem in Loreto in general and in the city of Iquitos. While transmission in Loreto steadily decreases throughout most of the study period, there is a large peak in 2009 that only partially subsides in 2010. However, the period of peak Tuberculosis transmission is not covered in the diff-in-diff specifications that confirm the main results.

Finally, labor strikes are common in Iquitos, though generally short in duration, and could potentially confound the results on labor market outcomes if strikes occur concurrently with dengue epidemics. The Peruvian Ministry of Labor and Employment Promotion (2016) collects annual data on labor strikes carried out throughout the country. A manufacturing strike was reported in September 2006 that affected 111 workers for an average 16 hours each. Transportation strikes, mostly among airline workers and taxi drivers, are more common. A strike occurred in November 2006 that affected 80 workers but only for an average of 8 hours each. A smaller strike was reported in April 2008, affecting only 12 workers for an average of 9 hours each. Two more strikes were reported in 2010: one in July, affecting 11 workers for an average of 24 hours each, and another from September to October, affecting 18 workers for an average of 40 hours each. None of the reported strikes correspond to periods of epidemic dengue transmission. Incorporating an indicator for the occurrence of a labor strike does not alter the results of either the main empirical specifications or the difference-in-differences estimations (available upon request).

XII.2. Survey Validity

One might be concerned that the results are affected by the identity of the survey respondent. For example, if primary females report their spouses' work hours, primary male work hours might be systematically under-reported. In that case, the impact of dengue epidemics on work hours would be over-stated for males compared to females. **Table A.2** shows the identity of the survey respondent for both work and health information. The majority of primary males and females report their own information, with both residents responding in the same household. One might also wonder if work hours vary significantly based on whether individuals work in the formal or informal labor market. **Table A.3** shows the impact of dengue epidemics on male and female work hours for the initial samples reported in **Tables 3-4**, for those who work in the formal labor market, and for those who report their own work hours. The results are nearly identical across all regressions, indicating that neither of the above concerns alters the main findings.

Another concern may be that survey participation varies during a dengue epidemic based on household health or work outcomes, introducing endogeneity into the analysis. **Table A.4** shows survey participation during and outside of epidemics. There is no significant difference in the percentage of approached households who complete the survey based on the occurrence of a dengue epidemic. There is also no significant difference in the percentage of households who do not participate for the indicated reasons. OLS and probit regressions of the impact of dengue epidemics on survey participation confirm that epidemics do not affect survey participation (available upon request).

XIII. Appendix Tables and Figures

Table A.1: Percentage of the sample population of Iquitos from July 2005 to June 2010 that is surveyed at each trimester or year and is from each district

Variable	Percentage of Sample
Trimester	
1st (January-June)	32.38%
2nd (May-August)	32.97%
3rd (September-December)	34.65%
Fiscal Year	
2005-2006	19.69%
2006-2007	17.08%
2007-2008	22.51%
2008-2009	21.31%
2009-2010	19.41%
District	
Iquitos District	41.21%
Punchana	15.13%
Belen	22.29%
San Juan	21.37%
Observations	1,844

Data are from the INEI ENAHO survey from 2005-2010 (INEI 2015).

Table A.2: Number of observations for which each type of resident was the survey respondent for each type of survey information in Iquitos from July 2005 to June 2010

	Survey Respondent			
Survey Information	**Primary Male**	**Primary Female**	**Other**	**Total**
Primary Male Health	1,388	86	10	1,484
Primary Male Work	1,384	86	14	1,484
Primary Female Health	29	1,595	24	1,648
Primary Female Work	28	1,594	26	1,648

Data are from the INEI ENAHO survey from 2005-2010 (INEI 2015).

Table A.3: Fixed-Effects regressions of the impact of dengue epidemics on primary male and female paid weekly work hours in Iquitos from July 2005 to June 2010 for the samples of those who work in the formal labor market or who report their own work hours

Sample:	Primary Male Works Positive Hours	Primary Male Works Positive Hours in Formal Labor Market	Primary Male Works Positive Hours & Reports Own Work Information
Observations:	1,208	1,194	1,135
Dependent Variable:	Primary Male Weekly Work Hours	Primary Male Weekly Work Hours	Primary Male Weekly Work Hours
Mean of Dependent Variable:	48.228	48.312	48.127
Dengue Epidemic (1=Yes)	-3.302+	-3.395+	-3.135+
	(-1.90)	(-1.95)	(-1.74)
R^2	0.021	0.021	0.021
Adjusted R^2	0.007	0.007	0.006
Sample:	Primary Female Works Positive Hours	Primary Female Works Positive Hours in Formal Labor Market	Primary Female Works Positive Hours & Reports Own Work Information
Observations:	839	781	818
Dependent Variable:	Primary Female Weekly Work Hours	Primary Female Weekly Work Hours	Primary Female Weekly Work Hours
Mean of Dependent Variable:	46.044	46.261	45.988
Dengue Epidemic (1=Yes)	-6.938**	-6.760**	-6.944**
	(-3.17)	(-3.08)	(-3.11)
R^2	0.085	0.087	0.084
Adjusted R^2	0.066	0.067	0.065
Included Controls (All Regressions)			
Household Demographics	x	x	x
Fiscal Year (July-June)	x	x	x
Season (Annual Trimester)	x	x	x
District	x	x	x

t-statistics in parentheses: + p<0.10 * p<0.05 ** p<0.01 *** p<0.001. The data on the number of dengue cases are from Stoddard *et al.* (2014). The data on household information are from the INEI ENAHO survey from July 2005 to June 2010 (INEI 2015). Included controls are as in **Table 2**.

Table A.4: Survey participation by presence of dengue epidemic for the Iquitos sample population from July 2005 to June 2010

	Dengue Epidemic					
	No		**Yes**		**Total**	
Survey Result	Observations	Percent	Observations	Percent	Observations	Percent
Complete	1,205	75.22%	417	76.94%	1,622	75.65%
Incomplete	167	10.42%	55	10.15%	222	10.35%
Refused	24	1.50%	8	1.48%	32	1.49%
Not Home	26	1.62%	7	1.29%	33	1.54%
Abandoned	58	3.62%	22	4.06%	80	3.73%
Other	122	7.62%	33	6.09%	155	7.23%
Total	1,602		542		2,144	

Data are from the INEI ENAHO survey from 2005-2010 (INEI 2015). Both complete and incomplete observations are included in the sample if the necessary variables are available.