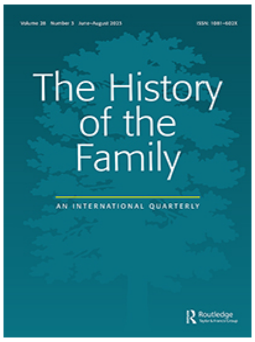
Hurricanes, fertility, and family structure

Elliott, Robert J.R.; Strobl, Eric A.; Tveit, Thomas

DOI:
10.1080/1081602X.2023.2256507



The History of the Family

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rhof20

Hurricanes, fertility, and family structure: a study of early 20th century Jamaica

Robert J R Elliott, Eric A Strobl & Thomas Tveit

THE HISTORY OF THE FAMILY
https://doi.org/10.1080/1081602X.2023.2256507

Hurricanes, fertility, and family structure: a study of early 20th century Jamaica

Robert J R Elliott [a], Eric A Strobl [b] and Thomas Tveit [b]

[a]Department of Economics, Birmingham Business School, University of Birmingham, Birmingham, UK; [b]Department of Economics, University of Bern, Bern, Switzerland

ABSTRACT
This study investigates the impact of hurricanes on fertility and the role of family structure in early 20th century Jamaica. Importantly, this was a time period in which there were no storm warnings or other formal disaster mitigation policies in place, allowing one to arguably identify the causal effect of storms on births without any policy interference. To this end, historical hurricane tracks and an exhaustive register of births are used to create a parish level monthly data set on births and hurricane destruction for the period 1901 to 1929. The regression analysis reveals that hurricanes impact excess births for close to 2 years after the event, with the average damaging storm causing a reduction in births of around 13%. Most of the negative effect is due to lower post-storm fertility rather than a fall in births by women affected while pregnant. There is no evidence that the fall in births was driven by fertile females dying as a result of the hurricane. Similarly, there was no discernible differential impact between single mother and two parent registered births, where the impact on the latter appears to be driven by non-marital conjugal unions.

ARTICLE HISTORY
Received 4 January 2023
Accepted 23 August 2023

KEYWORDS
Fertility; hurricanes; Jamaica; Family

1. Introduction

While the number of deaths due to tropical cyclones generally receives a lot more attention, subsequent reproductive health and fertility decisions, potentially affecting both short- and long-term population growth, could have far greater implications. However, the nature of the relationship between fertility and tropical cyclones is not yet fully understood.[1] Rather, the number of studies is limited and those that have been published tend to provide mixed results.[2] Importantly, as noted by Grabich et al. (2015), one of the challenges for researchers, and perhaps a reason for the widely differing results, is the difficulty in identifying the effect in the face of a large possible set of hard to measure confounders, such as storm anticipation and disaster mitigation policies.

This study examines the impact of hurricane strikes on regional birth outcomes in early 20th century Jamaica. To examine the impact of hurricanes in this context, a hurricane

CONTACT Robert J R Elliott r.j.elliott@bham.ac.uk

destruction index is constructed from historical storm tracks and is combined with comprehensive digitalized birth records from the Jamaican birth register to generate a monthly longitudinal parish-level data set covering nearly 30 years. Arguably, the Jamaican setting has several key factors that can help correctly identify intrinsic non-policy related adaptive behaviour.

More specifically, while Jamaica during this period was, as it is today, frequently exposed to damaging hurricanes, at the time there was essentially no hurricane warning system in place, which as shown by Evans et al. (2010) has a significant impact on fertility rates in the US.[3] Hence, it can be argued that hurricanes were largely unanticipated outside of a general knowledge of when the hurricane season usually occurs. Moreover, no formal disaster mitigation policies were in place during the period, since hurricane relief was seen as an essentially charitable act rather than a government responsibility (Schwartz, 2005). There was also little by way of social welfare programs that individuals might have had access (Jones, 2013). Thus, one need not worry about generally hard to measure differences in confounders related to government ex-ante and ex-post intervention. In essence, our setting can be considered a series of quasi-experiments that allow us to isolate the impact of hurricanes on births without any policy interference.

There are a number of ways in which one may expect hurricanes to affect fertility. First, there may be a relatively short-term effect on potential births that were conceived before the event by either directly or indirectly causing the death of already pregnant women or causing them to subsequently miscarry. Fertility may also be affected after the event in different directions. On the one hand, attachment theory from the psychology literature suggests that during times of elevated stress, couples seek support and physical closeness, leading to greater coital frequency (Davis, 2017). Likewise, Davis (2017) also notes that replacement theory, according to which couples' near term desire for more children in the aftermath of an increase in death rates, would similarly suggest a positive relationship between hurricanes and fertility. Empirical evidence of such a positive effect of hurricanes on births has thus far been found for the case of South Carolina after Hurricane Hugo in 1990 by Cohan and Cole (2002) and, after low severity hurricane warnings, for the US by Evans et al. (2010).

On the other hand, and contrary to replacement and attachment theory, the conservation of resources theory suggests that a loss of resources, both tangible and non-tangible, after a hurricane could lead to psychological distress and hence to lower birth outcomes (Costa et al., 2019). In this regard, Hamilton et al. (2009) found a 19% decrease in births following hurricane Katrina. An additional reason for a negative effect might be that people temporarily postpone child bearing until they have recovered from the damages and disruption due to a hurricane (Evans et al., 2010). Such a phenomena would be related to the tempo-effect of births proposed by Bongaarts and Feeney (1998) and implies a potential increase in births after an initial fall. However, the only study to explicitly examine this, Evans et al. (2010), did not find any evidence of a temporary effect. A negative birth effect could also stem from physical or mental health effects through temporal or permanent infertility due to the added stress and economic hardship following a hurricane. Indeed, it is well known that stress can cause problems with conception, pregnancy and birth (Agarwal et al., 2005; Herrenkohl, 1979).

The Jamaican birth register that we use in this paper also records the gender of the child for each birth, allowing us to investigate whether there is evidence for the existence of the Trivers-Willard (TW) phenomena derived from evolutionary biology (Trivers & Willard, 1973). Accordingly, natural selection should favour adaptive variation in the offspring sex ratio if alterations maximise the offspring's potential reproductive success. The assumption is that in 'good' conditions a male will out-reproduce a female and hence parents are more likely to have a male child during good times and a female during hard time. The period immediately following a hurricane would qualify as a bad time. However, Grech and Scherb (2015) found that the male-female birth ratio increased following hurricane Katrina in states that experienced heavy rainfall.

Finally, Hung et al. (2016) showed how family demographics affected vulnerability to a natural disaster with two-parent families shown to be less vulnerable than single-parent families and single person households following storm surges in Florida. One might hypothesise that it would be more difficult for people with no spouse or domestic partner to be able to support a new child, financially or emotionally, after a hurricane. For example, Zahran et al. (2011) found that after Hurricane Katrina single mothers had poorer mental health outcomes than others and did not deal as well with life events as mothers with partners. The added stress and trauma coupled with fewer resources might lead to single people having fewer children, either by choice or due to stress or health-induced infertility, than people in stable relationships. In this regard, Hamilton et al. (2009) finds a decrease in unmarried women giving birth relative to married women following Hurricane Katrina. In early 20*th* century Jamaica, however, matrifocal households tended to be economically independent, so that this may not have been such an important factor in coping with the effects of hurricanes (Ortmayr, 1997). Information from the Jamaican birth records allows the partial examination of this implicitly by classifying births by whether a father was declared on the birth certificate or not, as well as distinguishing between likely conjugal and marital unions through the registered parents' surnames.

2. Background

2.1. Jamaican family structure

It has been widely argued that the family structure in Jamaica cannot be understood without considering how slavery determined family organization before emancipation in 1834 (Altink, 2011; Cohen, 1956; Henriques, 1949; Moore & Johnson, 2004; Roberts, 1955). More specifically, the sugar plantation economy in the West Indies relied heavily on masculine slave labor and implemented a number of practices relevant for family formation to maximize production (Cohen, 1956). Firstly, male slaves were often sold from plantation to plantation without consideration of their existing family ties (Cohen, 1956). In addition, slaves were generally not allowed to marry (Roberts, 1955). Henriques (1949) also points out that slave owners often encouraged female slaves to mate with several slave men under the belief that this would increase fecundity. Finally, slavery was inherited along female lines in that children of slaves were also slaves regardless of the status of the father. All these practices resulted in a general lack of permanency in the association between the sexes (Cohen, 1956), as well as children being considered the responsibility of the mother in a slave family (Cohen, 1956).[4] The abolition of slavery thus in principle created not only the means for legalizing unions but also implied that unions could be formed and dissolved solely on account of the attitude and actions of the couple (Roberts, 1955).

Despite considerable attempts by both the church and government over the hundred years following emancipation to encourage legal unions and the formation of a family structure along the lines of the English Victorian household, where people married early to procreate, this did not materialize in Jamaica (Moore & Johnson, 2004). Rather, three sorts of unions became prominent, those founded on the civil, Christian, or Jewish rites and functional unions referred to as faithful concubinage, and extra-residential conjugal relations (Besson, 1993).[5] Moreover, a large number of female single headed households with children born out of wedlock became common (Roberts, 1955). While no systematic official data were collected to allow insights into the relative prevalence of these different household types until the 1943 Population Census, statistics from this year are arguably instructive. In this regard, Roberts (1955) calculated that over 50% and 56%, respectively, of males and females above the age of 15 did not reside with a partner. Of those that were part of a union around 39% of males and 34% of females had never been married. Importantly, and unlike the common situation for Western households in much of Europe at the time, the ever having been married category was particularly stark in the higher age groups. Roberts (1955) postulates that many of these marriages were likely the cementing of unions long in existence, an argument that has also been echoed by Moore and Johnson (2004).

A number of reasons have been put forward in an attempt to explain the aforementioned features of Jamaican family structure post emancipation becoming prevalent despite marriage in principle providing greater financial security at least for women (Altink, 2011) and avoiding the social stigma associated with non-marital unions and illegitimacy often bestowed upon by the church, government, or the upper classes (Altink, 2011; De Barros, 2014; Moore & Johnson, 2004).[6] On the one hand, it has been argued that women feared that the possible undue dominance of the husband in marital and non-marital residential unions might restrict the freedom they gained through the abolition of slavery (Henriques, 1949; Moore & Johnson, 2004).[7] Related may also have been men's general attitude to marriage in that mothers continued to play a primarily role in their lives even after they reached adulthood (Cohen, 1956) and that men saw their responsibilities as a father as peripheral (Cohen, 1956). In contrast, it has also been postulated that while marriage was often desired, it could only be achieved once considerable funds had been accumulated since weddings were expected to be extravagant and thus expensive, and marriage licensing costs were non-trivial (Altink, 2011; Moore & Johnson, 2004). One should note that this would also suggest that marital unions were likely to have generally consisted of those couples that were financially better off (Cohen, 1956; Henriques, 1949).

As noted above, an important consequence of the Jamaican family structure post-emancipation was a high rate of illegitimate, i.e. born outside of wedlock, children (Cohen, 1956), and concerns over this phenomena were voiced continuously after emancipation both for moral reasons (Moore & Johnson, 2004) and because mortality rates among illegitimate children were believed to be substantially higher (Roberts, 1955). Moreover, over time the rate of illegitimacy of births appeared to have been increasing.[8] One should note, however, that illegitimacy did not necessarily mean that fathers were not obliged to support their children. Rather, the Bastardy Law No. 2 of 1881 compelled a father to contribute towards the support of his illegitimate children, as long as the mother could provide sufficient proof of fatherhood.[9] Nevertheless, it should be noted that the level of child support (5 shilling per week) established by the legislation was arguably only enough to support the child and not additionally the mother herself (Altink, 2011).[10] Moreover, De Barros (2014) has argued that the bastardy acts may have aggravated the situation for already impoverished non-married mothers since they were not able to obtain financial support from fathers if they were themselves recipients of poor relief (while before the act a single mother could at least in principle receive money from the father).

2.2. Hurricanes

Located in the Atlantic Ocean Basin, Jamaica is potentially subject to tropical cyclones throughout the Atlantic hurricane season, typically from June to November, with a probability that one hurricane will seriously affect the island every 10 years (Brown, 2017).[11] Importantly, one should note that during the time period under study here (1901–1929) there was essentially no hurricane warning in place. More precisely, the use of reconnaissance aircraft to anticipate hurricanes started in the 1930s, so that storm warnings were limited to ship sightings. While the United States did briefly establish a hurricane warnings office in Jamaica during Spanish-American War, it was shifted to Havana after the war ended in 1899 (Sheets, 1990). Moreover, the purpose of the office was to provide warnings for the United States, essentially relying on reported incidences of storms that had already affected the region (Dunn, 1971).

There was also arguably no explicit post-disaster management in place in Jamaica during the time. Rather, the British colonial approach to disaster relief was to prioritize colonial control and fiscal prudence, so that much financial relief relied on charity instead of explicit imperial government intervention (Webber, 2018). The local government also did not provide any explicit aid after natural disasters.[12] Rather, some relief could be obtained through the local poor relief program for those who became destitute after a hurricane (Bryan, 2000). More precisely, poor relief, first introduced in 1868, was extended in 1886 from persons who are destitute and unable to work because of physical or mental circumstances to also include those destitute that may be able to work but suffered ' ... under exceptional circumstances of destitution, arising from drought, epidemic disease or such like causes ... ' (The Law for the Relief of the Poor 1886). In this regard, there were two kinds of relief offered to those that qualified (Bryan, 2000). On the one hand, there was indoor relief through residing in specifically established poor houses.[13] On the other hand, financial aid could also be distributed as outdoor relief, although this was temporally limited and evidence suggests that the amounts provided were meager (Bryan, 2000; Roper, 2018).

3. Data

3.1. Geographical unit of analysis

The unit of empirical analysis is Jamaican sub-national administrative regions, called parishes, of which there are 14. However, the parishes of Kingston and Saint Andrew are combined into one region since the Kingston Parish is relatively small in terms of area and the city itself extends into Saint Andrew. Thus, Jamaica's 10,991 km^2 is broken down into 13 geographical units which range in size from 478 km^2 (Saint Andrew plus Kingston) to 1,213 km^2 (Saint Ann). These are shown in Figure 1.

3.2. Birth & death data

Concerns about a falling population during the latter half of the 19$^t h$ century led to a drive to take statistical account of local demographics (Roberts, 1955). Hence, it became compulsory to register births in Jamaica after April 1st 1878 following the implementation of Law 19 in 1877, 'A Law for the Registration of Births and Deaths in Jamaica', which was replaced in March 1881 by Law 13 'the Registration (Births and Deaths) Act' (Registration Act, 2019). The latter states that for: ' … every child born alive after the coming into operation of this Act', it shall be the duty of the father and mother of the child, … , to give to the Registrar, within forty-two days next after such birth, information of the particulars required to be registered concerning such birth, …'. In other words, from March 1881 onwards it became compulsory to register births within 42 days, or otherwise have to pay a penalty.[14]

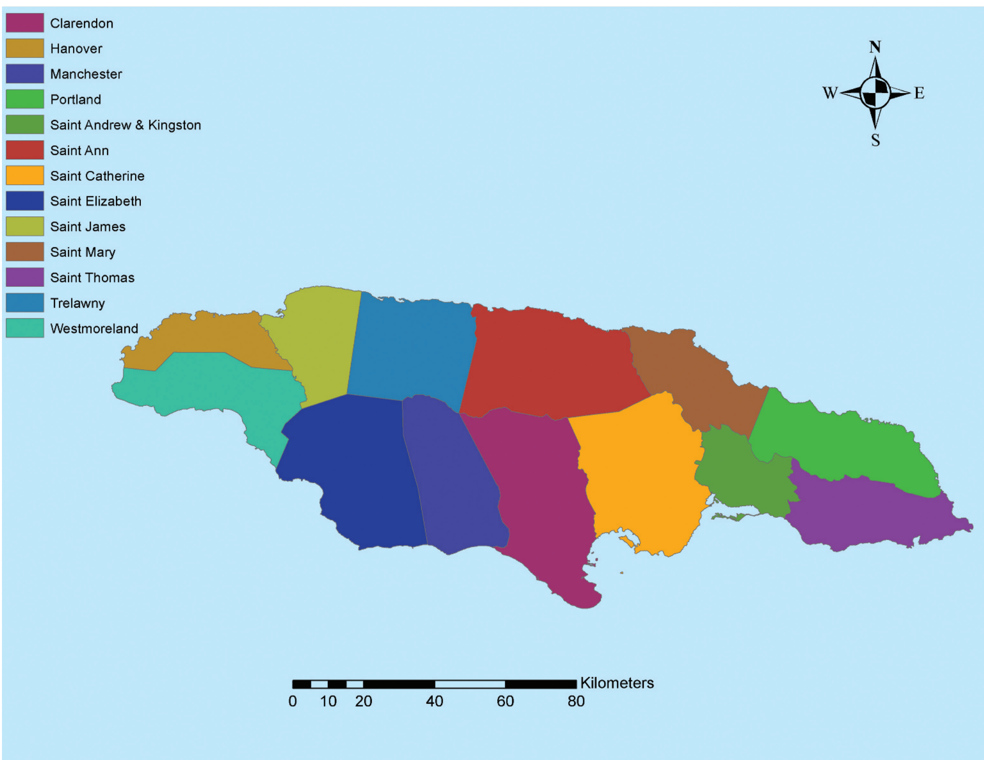


Figure 1. Thirteen regions of Jamaica. *Notes*: This figure shows the regional background used in the analysis, consisting of the original twelve parishes and two parishes (Saint Andrew and Kingston) combined as one region.

In terms of the information on the child's parents contained in the data, one should note that the data is generally composed of records where either both the father's and mother's name are recorded or only the mother's name. In this regard, the Registration Act (2019) states that ' . . . , the word "father" means a person who is married to the mother of the child at the time of conception or at any time thereafter and prior to the child's birth.' It should be noted that a father can only be registered if both the mother and the father acknowledge the paternity or in other circumstances, such as the supposed father not denying paternity following a notice from the mother or a court ruling.

The Jamaican birth records have been digitized and compiled in Civil Registration (2019) for the period 1881 to 1929. Because the availability of weather data used in the analysis, only starts in 1901, the period under examination for this paper is limited to 1901–1921 and covers approximately one million birth registrations. From each individual entry the birth date, the parish of birth, the gender, the mother's name (when stated) and the father's name (when stated) were extracted. We categorize births in terms of those where only the mother's name was listed and those for which both a mother's and a father's name were listed. For the latter we also identify those for which the surname of the listed mother and father were the same and those for which they were not the same.[15]

The data in the deaths register contained similar information as for births, i.e. the date of death, and the age, as well as the names of the parents (when known). However, the completeness and time period differs from that of the birth records in that only deaths for five parishes (Portland, Saint Ann, Saint Andrew & Kingston, Saint Catherine and Saint Thomas) have been completely digitized and only for the period 1882 to 1920. The empirical analysis using deaths data is thus restricted to these five parishes over the more limited common time period of 1901 to 1920. We extracted information on the deaths of females that were potentially fertile, assumed to be those between 15 and 44 years old. We similarly extracted the information of registered deaths of males of the same age group.

One may of course question the ability of the official register to capture the complete extent of births and deaths in Jamaica during our sample period. In this regard, Roberts (1955) undertook a number of tests to determine the accuracy of the register to capture births. More precisely, Roberts (1950) compared the registered number with births derived from a life-table using the population censuses in 1921 and 1943 and found these to be similar. In contrast, the same author, under the assumption that the census figures of children under 10 years of age were accurate and that mortality records were reliable, compared populations estimated from registered births and deaths and determined the results to be inconclusive. Roberts (1955) extended the latter test to examine the difference between the census populations for 1881, 1911, 1921, and 1943 of 2- to 4-year-old children to the implied population of these from the registered births and deaths and discovered an under-registration of between 2.3% and 3.9%.

Finally, one should note that there are no consistent parish-level population data available at a sufficiently high temporal frequency. The only known parish population estimates are available from the population censuses undertaken in 1881, 1911 and 1921. It is for this reason that the analysis undertaken here is in terms of (excess) birth and death numbers rather than rates.

3.3. Hurricane destruction index

As noted by Grabich et al. (2015) an important challenge in measuring the local effect of hurricanes is the miss-classification of storm exposure. Existing studies have tended to use simple incidence indicator variables or some other fairly crude measure of damages. However, in reality, the damage due to hurricanes can differ widely across storms and space (Strobl, 2011), and this heterogeneity should ideally be captured in any analysis on the impact on fertility. For this study, a parish level measure of exposure to damaging hurricane winds is constructed using historical tropical storm tracks within a physical wind field model. In order to construct this index the approach of Emanuel (2011) is followed, which assumes that the fraction of property is lost or damaged in a cubic manner when wind speeds surpass a certain threshold.[16] Formally, the destruction index is given by:

$$H = \frac{v_n^3}{1 + v_n^3} \tag{1}$$

where H is the fraction of property lost or damaged and v_n is defined as:

$$v_n \equiv \frac{\max[V - V_{thresh}, 0]}{V_{half} - V_{thresh}}$$

where V is the wind speed, V_{thresh} is the wind threshold below which no damage occurs and V_{half} is the value at which half the property is destroyed. Following Emanuel (2011), it is assumed that $V_{thresh} = 92km/hr$ and $V_{half} = 203.7km/hr$.

In order to measure V for each storm in each parish, the approach by Strobl (2012) is employed, which uses a tropical storm wind field model developed by Boose et al. (2004). The base equation of this model stems from Holland (1980) and is given by:

$$V = GF\left[V_m - S(1 - sin(T))\frac{V_h}{2}\right]\left[\left(\frac{R_m}{R}\right)^B \exp\left(1 - \left[\frac{R_m}{R}\right]^B\right)\right]^{\frac{1}{2}} \tag{2}$$

where V is the wind speed at point P which in the case is the centroid of a parish, V_m is the maximum sustained wind velocity anywhere in the hurricane, T is the clockwise angle between the forward path of the hurricane and a radial line from the hurricane center to the point of interest (the centroid of a Parish), P, V_h is the forward velocity of the hurricane, R is the radial distance from the center of the hurricane to point P, Rm is the radius of maximum wind speed, and G is the gust wind factor (water = 1.2, land = 1.5). Of the remaining parameters F is a scaling parameter for surface friction (water = 1.0, land = 0.8), S is the asymmetry due to the forward motion of the hurricane (1.0) and B is the shape of the wind profile curve (1.2). These values have been verified in Boose et al. (2001) and Boose et al. (2004). The source for the hurricane track data to operationalize Equation 2 is the HURDAT database, which provides the location of the eye and the maximum wind speed of tropical storms in the North Atlantic Ocean Basin tracks every 6 h since 1851. One should note that the wind field model and input data as outlined above provide us with an estimate of hurricane damages for each storm for each parish.

3.4. Rainfall and temperature data

The data for rainfall (in mm) and temperature (in degrees Celsius) are taken from the Climatic Research Unit (CRU) TS4.00 gridded (0.5 degrees) time series data, available from 1901 onwards, and the value of the closest cell for each parish is used to measure these climatic factors.

4. Methods

4.1. Excess births & deaths

Births and deaths typically are characterized by strong seasonal and trend components (Bravo & Coelho, 2020; Lam et al., 1994). In order to take account of these trends a common approach, originally proposed by Serfling (1963), is to first model the seasonal component and trends, and then identify deviations from the outcome as 'excesses':

$$BIRTHS_{i,t} = \alpha + \sum_{i=1}^{13} \gamma_i sin\left(\frac{2\pi t}{12}\right)\mu_i + \sum_{i=1}^{13} \delta_i cos\left(\frac{2\pi t}{12}\right)\mu_i + \mu_i + \sum_{j=1}^{4}\sum_{i=1}^{13} \lambda_{ji} trend^j \mu_i + \epsilon_{it} \quad (3)$$

where *BIRTHS* are parish-level births, *trend* is time trend included up to the quadratic polynomial, μ is a parish level fixed effect, and ϵ is the error term. The subscripts *i* and *t* indicate regional and monthly time units, respectively. Note that the $sin(t)$ and $cosin(t)$ factors will capture the parish-specific seasonal component in births, the *trend* higher order terms will capture any parish-specific trends in births, for example due to population changes, and the parish level fixed effect μ will capture any time-invariant differences in births across parishes. Since the dependent variable in Equation (3) is a count variable, the model is estimated via Maximum Likelihood Conditional Fixed Effects Poisson estimator. Note that the parish level-fixed effects μ in a Poisson count model can be considered equivalent to linear rather than conditional-fixed effects (Wooldridge, 1999).

Excess births are calculated as:

$$EXCESS_{i,t} = BIRTHS_{it} - \widehat{BIRTHS}_{it} \quad (4)$$

where $\widehat{BIRTHS}_{it}$ are the predicted births from Equation (3). Excess deaths are calculated in an analogous manner using Equations 3 and 4.

4.2. Main regression specification

To estimate the impact of hurricane damages on excess births the following specification is employed:

$$\begin{aligned}\widehat{BIRTHS}_{it} = \alpha + \sum_{t=-9}^{24} \beta_t H_{it} + \sum_{t=-10}^{24} \eta RAIN_{it} + \sum_{t=-9}^{24} \zeta TEMP_{it} \\ + \sum_{t=-9}^{24} \tau EQ_{it}^{1907} + \mu_i + \sum_{m=1}^{12} \theta_m + \sum_{y=1900}^{1930} \kappa_y + \upsilon_{it}\end{aligned} \quad (5)$$

where *H* is the hurricane damage index, where subscripts *i* and *t* indicate regional and monthly time units, respectively. In order to control for other potential environmental shocks that might have taken place during our sample period we include rainfall, *RAIN*, temperature, *TEMP* and

EQ^{1907} as an indicator variable for the 1907 Kingston earthquake which takes a value of one for the parish Saint Andrew & Kingston in January of 1907 and zero otherwise.[17] The terms θ and κ are monthly and yearly indicator variables, and υ the error term. Equation (5) is estimated as a linear panel-fixed effects model (Wooldridge, 2010). In order to allow for both spatial and serial correlation standard errors are calculated as recommended by Driscoll and Kraay (1998). All estimations are performed using STATA Version 15.

Importantly one should note that in order to allow for lagged effects of hurricane damage on excess birth rates beyond the time of the storm at time $t = 0$ in Equation (5), lags of H for up to 24 months $t = 1, \ldots 24$ are included. The choice of limiting these to 24 months is based on the fact that the median time between damaging hurricanes, as determined by the wind field model, is 23.9 months. An integral part of the estimation strategy that enables one to identify the causal effect of hurricanes is allowing for time-invariant differences across parishes in the form of μ_i. More precisely, while the actual storm events are arguably exogenous and unanticipated, there may well be differences in the probability distributions of these events occurring across parishes, and this could be reflected in the size and composition of the local population distribution.[18]

Assuming that this local distribution of potential damages due to hurricanes, or at least the perception of it, is time invariant, then controlling for parish specific, time-invariant differences means that Equation (5) leaves us with a variation in H that arguably can be considered as random, unanticipated, realizations from it, particularly after controlling for other parish-specific climate factors (*RAIN* and *TEMP*) and other common time effects across all parishes (κ and θ). This allows a causal interpretation of the β_{t-j} coefficients on H. Including the leads of H from $t = -9, \ldots - 1$ also enables one to explicitly test the lack of anticipation assumption, at least in the short term.

5. Results

5.1. Summary statistics

5.1.1. Births, deaths, and their excesses

Table 1 presents parish-level summary statistics. The top panel of Table 1 shows that the average number of births per parish in a month was just over 221, and of these, there were more births registered to mothers only than to two parents. It is also noteworthy that the majority of two parent birth registrations are due to non-married couples. The male-female birth ratio is 102.3.[19] This is slightly lower than the expected ratio found by James (1987), which was in the range of 104–107. Reassuringly, Visaria (1967), using a database for Jamaica for the period 1878 to 1950, finds the sex ratio to be very close to the one found here. The average number of parish-level monthly deaths of fertile females is 14, but with considerable variation.

Figure 2 shows the total monthly births over the sample period. The annual variation ranges from approximately 2,500 births per month in the early period to over 3,000 per month in the later years. There is also clear seasonality and changing trends in births across the period.[20] These aspects are well captured by the model in Equation 3. From the bottom panel of Table 1, we see that the mean excess births vary between a minimum of −189 to and a maximum of 147 (where a negative number refers to months when there are fewer deaths compared to historical norms).

Table 1. Summary statistics.

	# Obs.	Mean	SD	Min.	Max.
Monthly Parish Level Births					
All:	4,524	221	85.6	49	557
Females:	4,524	109	43.2	25	299
Males:	4,524	112	43.9	19	301
Mother Only:	4,524	135	51.9	30	387
Not Mother Only:	4,524	87	40.8	7	295
Not Mother Only Same Name:	4,524	6	15	0	139
Not Mother Only Not Same Name:	4,524	81	36	2	258
Monthly Parish Level Deaths					
Females Aged 15–44:	1,454	14	13	1	275
Males Aged 15–44:	1,454	14	14	0	273
Monthly Parish Level Hurricane Damage					
$H > 0$:	166	0.40	0.38	0	0.95
$H \geq 0$:	4,524	0.015	0.10	0	0.95
Monthly Parish Level Climate Controls					
Rain (mm):	4,524	188	201.5	6	2,499.7
Temperature (C):	4,524	24.5	1.49	20.2	28.3
Monthly Parish Level Excess Births					
All:	4,524	−6.26e-07	32.7	−189	147
Females:	4,524	−3.65e-07	18.2	−100	96
Males:	4,524	2.25e-07	18.4	−93	82
Mother Only:	4,524	−1.11e-07	22.5	−119	123
Not Mother Only:	4,524	−3.55e-08	15.8	−79	94
Not Mother Only Same Name:	4,524	−4.64e-09	4.9	−41	53
Not Mother Only Not Same Name:	4,524	−7.74e-09	15.6	−74	73
Monthly Parish Level Excess Deaths					
Females Aged 15–44:	1,454	−5.75e-08	9.9	−21	228
Maless Aged 15–55:	1,454	−8.97e-08	10.4	−28	229

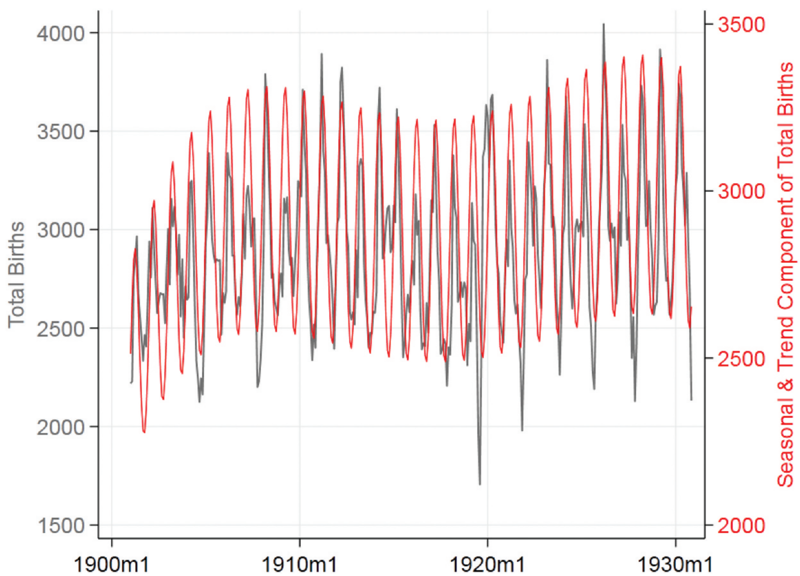


Figure 2. Births: observed and modelled seasonal & trend component. *Notes*: This figure shows the observed total monthly births (grey line) and the modelled seasonal and trend component (red line).

Categorizing births into the sub-groups, as shown in Figure 3, there is a similar seasonality, however, the trends in births reveal some differences across the different groups. More precisely, the trends for boys and girls are similar and follow the pattern of the overall sample. In contrast, while there was a continuous increase in births for those only registered by their mother, the number of children registered under two parents falls from around 1919 until around 1920, when this trend plateaus out and then begins to increase again. This pattern is also apparent when two registered parent births are split into those births that had different and those that had the same surname, although the

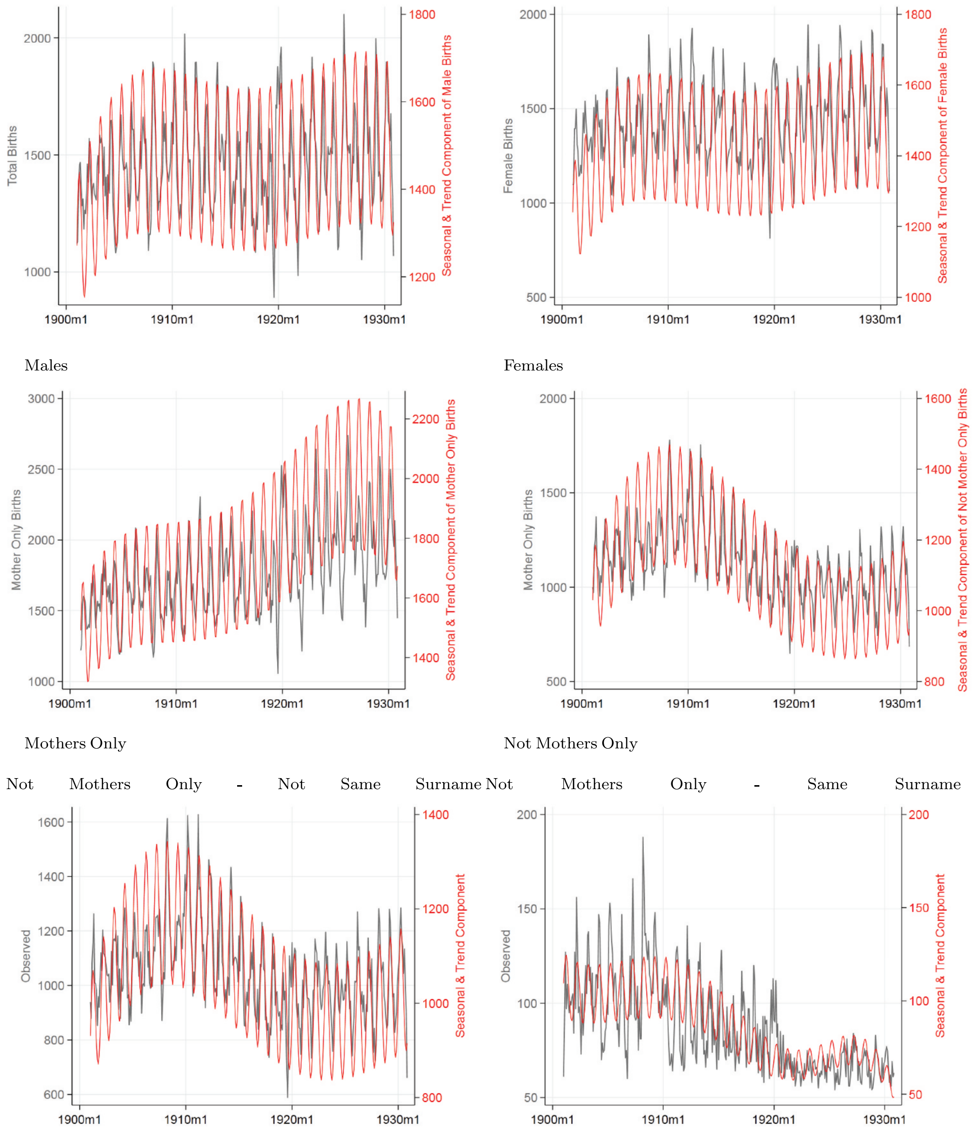


Figure 3. Births sub-groups: observed & modelled seasonal & trend component. *Notes*: This figure shows the observed monthly births (grey lines) by sub-group and the modelled seasonal and trend component (red line).

latter diverts from the pattern in the final few years of the sample. The seasonal and trend components capture the general pattern in births across all groups fairly well.

As a final descriptive piece of evidence, the Male and Female Aged 15–44 deaths for the five parishes are shown in Figure 4. In contrast to births, there is less of a obvious seasonal pattern over this period. Rather, there are large fluctuations and a suggestion of a slightly increasing trend. It is perhaps not surprising then that the modeling in Equation 3, also shown in Figure 4 appears to be better in capturing the trends rather than the fluctuations. As can be gathered from Table 1, average monthly fertile female deaths range from between 1 and 275, while for males the value is between 0 and 273.

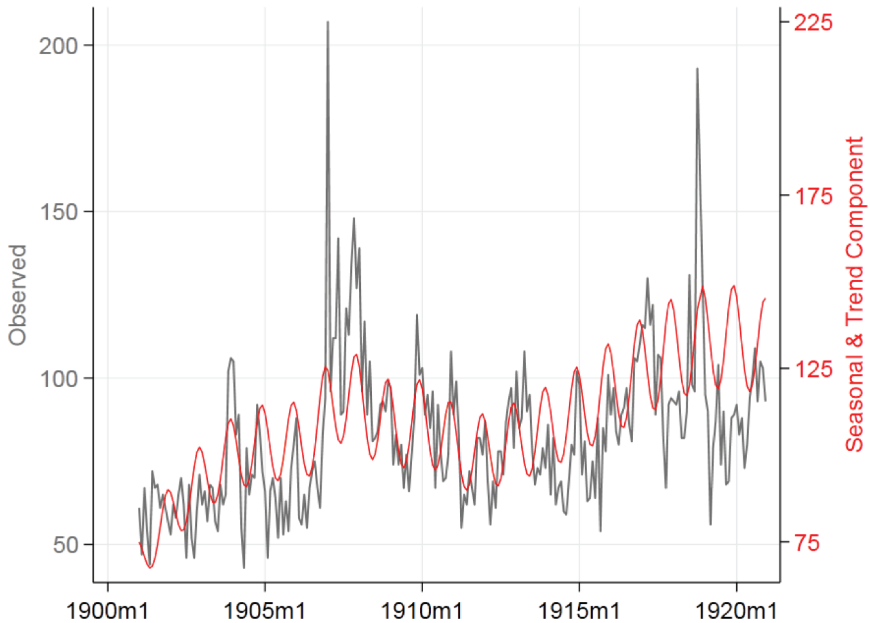
5.1.2. Hurricane damage, climatic factors, and birth and death excesses

In terms of the hurricane destruction index, the second panel of Table 1 shows that the average hurricane destroyed 40% of the parish-level property, while the most damaging hurricane to hit a parish destroyed 95% of property. These figures are based on 16 hurricanes that produced parish-level wind speeds over the 92.6 km/h threshold, with six hurricanes destroying more than 50% of the property in at least one parish. At the same time, six of the hurricanes caused less than ten percent damage. For the climatic control variables, as one would expect for a country in a temperate zone, the temperature is fairly stable with a difference of just eight degrees between the maximum and minimum temperatures within a given month. In contrast, the variation in rainfall is much higher, where the difference between the maximum and minimum is almost 250 mm of rain over the course of a month.

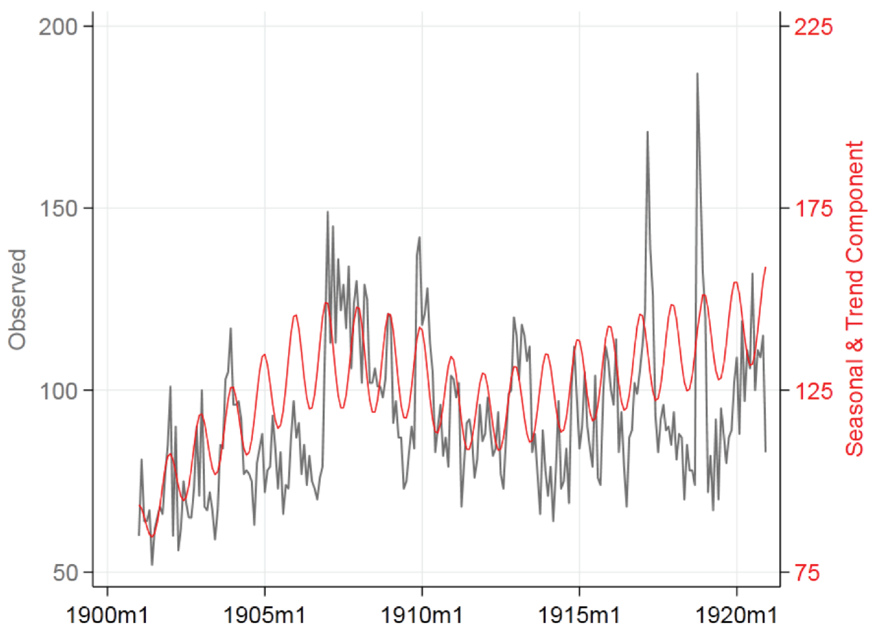
The average hurricane damage index and the total excess births are graphed in Figure 5. Accordingly, a few of the larger storms coincide with a slight fall in birth rates. This also appears to be the case for some storm incidences for some of the sub-groups of births, depicted in Figure 6. Finally, for deaths of fertile females such a pattern appears some what less clear, as shown in Figure 7.

5.2. Regression results

The estimated coefficients on H, i.e. $\hat{\beta}_{t-j}$, as well as their 99% confidence bands, from Equation 5 for all births are shown in Figure 8. As can be seen, reassuringly, there are no anticipatory effects of hurricane damages on births, i.e. all lead effects ($t = -9 \rightarrow t - 1$) are insignificant. Considering only the lags for which the hurricane strike occurred in utero, implies negative impacts for $t - 2, t - 5, t - 9$.[21] The sum of these significant coefficients (110) multiplied by the average damaging storm ($H = 0.4$) suggests that a damaging event reduces in utero parish-level births by 41, whereas the most damaging storm observed ($H = 0.95$) in any parish over the sample period indicates in utero parish losses of 105 births. After the 9 months, the cut-off for which one arguably captures births of mothers that were pregnant at the time of the storm, there is a continuous statistically significant negative effect until month $t = 22$.[22] The impact increases until month $t = 15$ and then reduces until it becomes small and insignificant. The sum of the significant coefficients indicates that an average storm reduces births conceived by women after a hurricane by 265 within a parish, and for the maximum level of damage by 630. Using the mean monthly level of total births,



Males



Females

Figure 4. Male & female Aged 15–44 deaths: observed and modelled seasonal & trend component. *Notes*: This figure shows the observed monthly deaths (grey lines) by gender aged 15–44 and the modelled seasonal and trend component (red line).

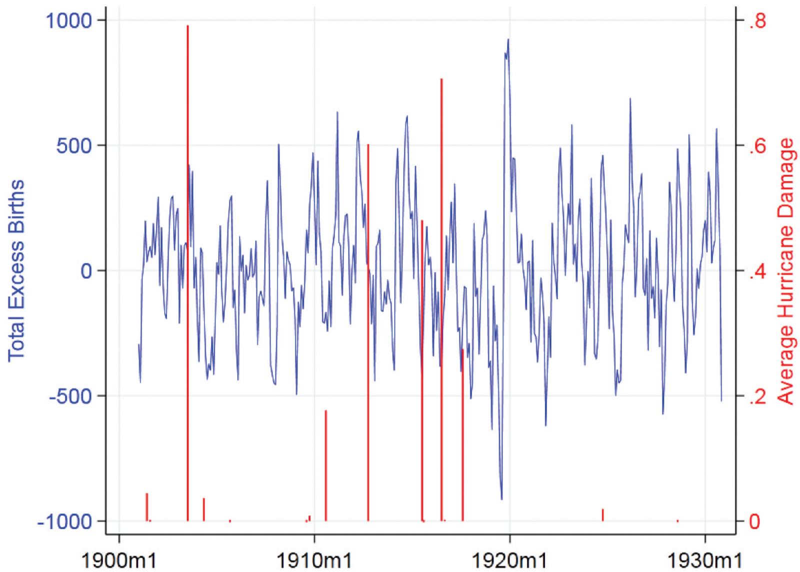


Figure 5. Excess births & hurricane damage. *Notes*: This figure shows the total monthly excess births (blue line) and average parish-level hurricane damage (red bars).

these calculations suggest that the average damaging hurricane reduces parish-level births within a two-year period by 13.9%.

Figure 9 depicts the estimated coefficients on H for the four sub-groups of births. Accordingly, the estimated coefficients for the male, female, mothers only, and not mothers only groups all follow a fairly similar pattern to the total sample, with some in utero effects of hurricanes on subsequent births, as well as impacts on births conceived after. However, decomposing two parent births into those with a different and those with the same surname, one finds that the general pattern of both small in utero and larger, longer lasting post-even conception effects only is driven by the former. In contrast, for those with the same surname the estimated coefficient is much smaller and almost always insignificant.

The relative cumulative parish-level effect inferred from the significant coefficients is 556 for males and 401 for females, i.e. 20% and 15% of their two-year average totals. For mother registered births one finds no significant in utero impact of hurricanes except at $t = 9$.[23], whereas several in utero coefficients can be statistically distinguished from zero for not mothers only births. For post storm conceived births for the former the lowest dip (at $t = 15$) is about 21% lower than that of the latter (at $t = 16$). [24] Using only the statistically significant coefficients from $t = 0 \rightarrow t = 24$ suggests losses in births of 391 and 292 for mother only births and not mother only births, respectively, with fairly similar percentages of their two-year parish level monthly totals (14 vs. 13%).

Examining the results for male and female aged 15–44 excess deaths in Figure 10 shows that there is no impact of hurricanes on their deaths.

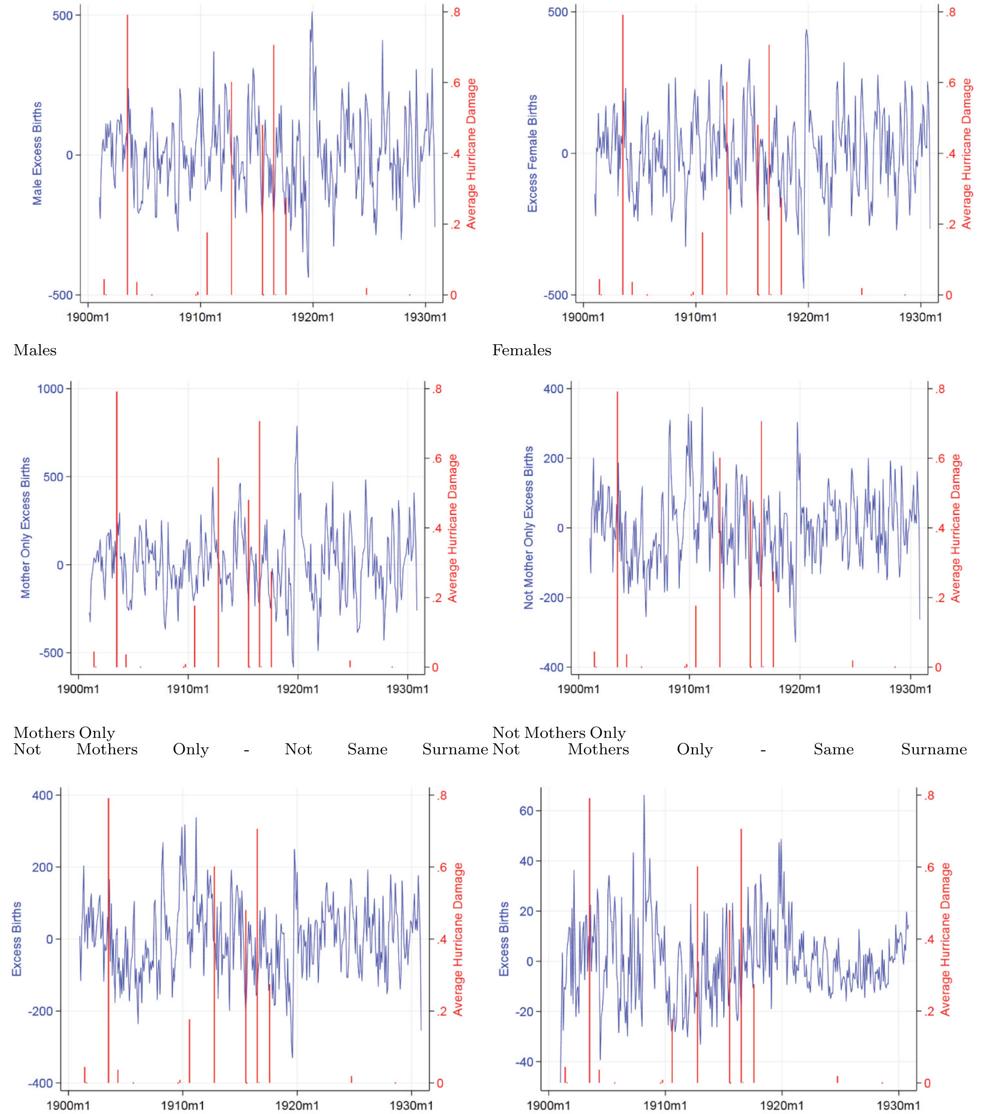
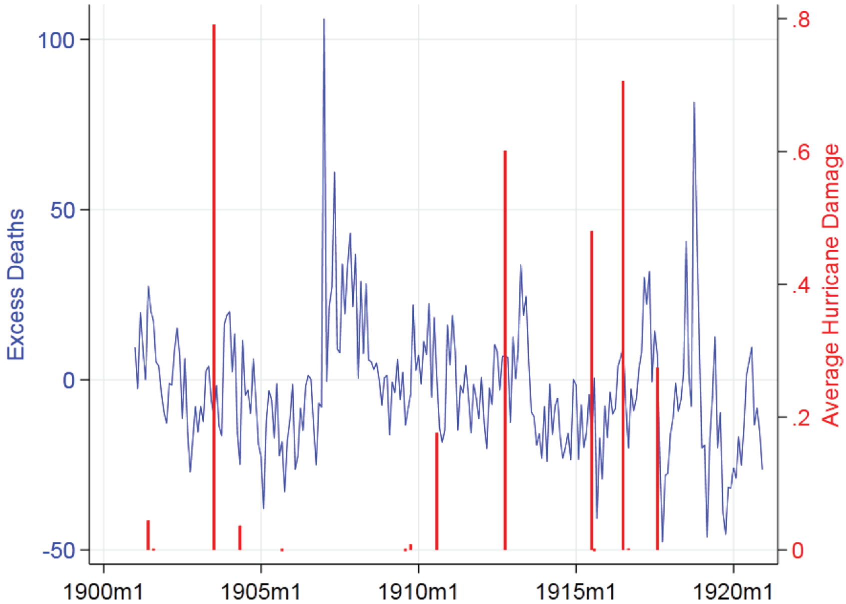


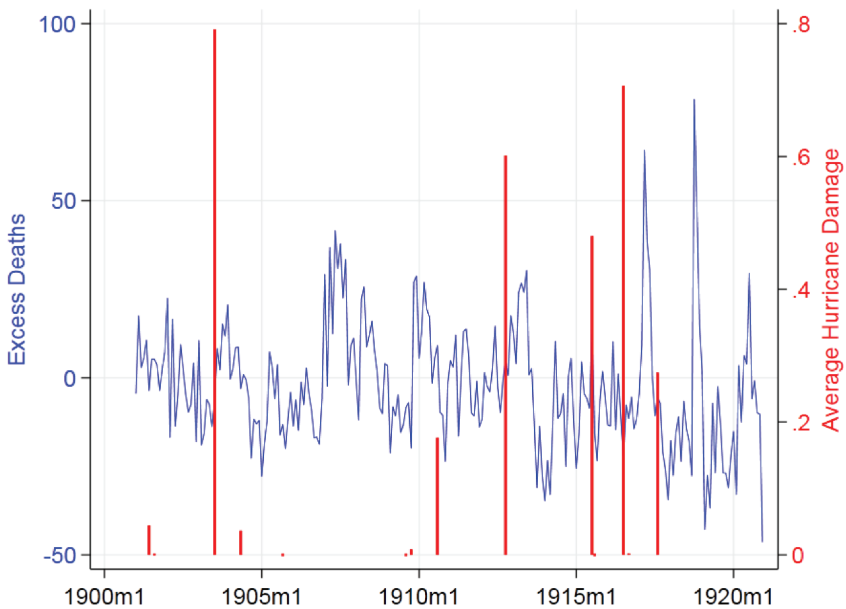
Figure 6. Excess births sub-groups & hurricane damage. *Notes*: This figure shows the monthly excess births by sub-group (blue lines) and average parish-level hurricane damage (red bars).

6. Discussion

Using a monthly cross-sectional time series of regional level excess births, this study has shown that hurricanes caused changes in birth patterns in early 20th century Jamaica. More precisely, the storms caused a fall in births of children conceived prior to and those conceived after the event. The latter aspect lasted up to 23 months after the storm and was larger in relative terms. Evidence from excess deaths for a smaller sub-sample suggests that these impacts were, in contrast to what has been found elsewhere (Nobles et al., 2015), neither driven by the death of fertile females nor by the deaths of



Males



Females

Figure 7. Male & female Aged 15–44 excess deaths & hurricane damage. *Notes*: This figure shows the monthly excess deaths by gender aged 15–44 (black lines) and average parish-level hurricane damage (red bars).

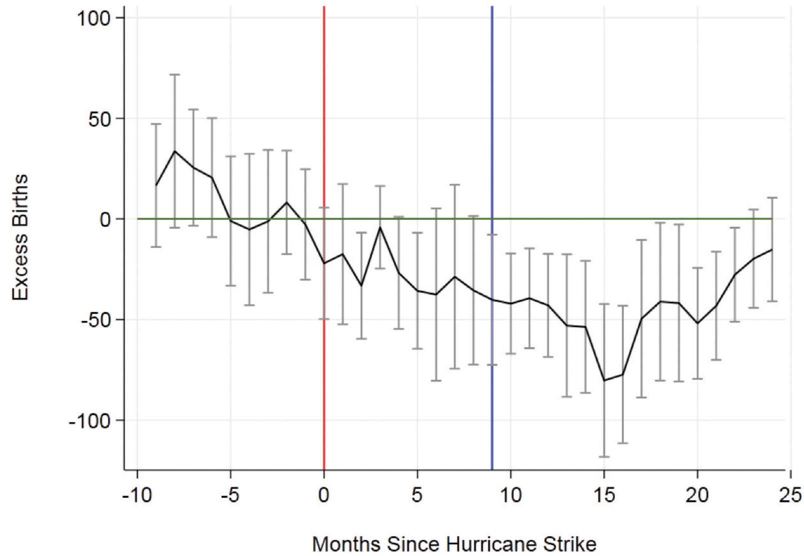
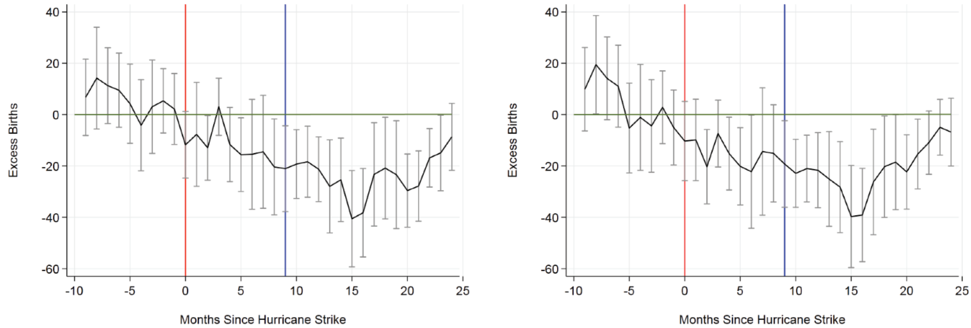


Figure 8. Impact of hurricane damage on all excess births. *Notes*: This figure shows the monthly coefficients (black line) β_{t-j} from Equation 5 on hurricane damage (red line) of the effect on total excess births from $t = -10$ to $t = 24$, along with 99% confidence intervals (grey bars). The red line indicates the month $t = 0$ when the hurricane strikes and the blue line 9 months after at $t = 9$.

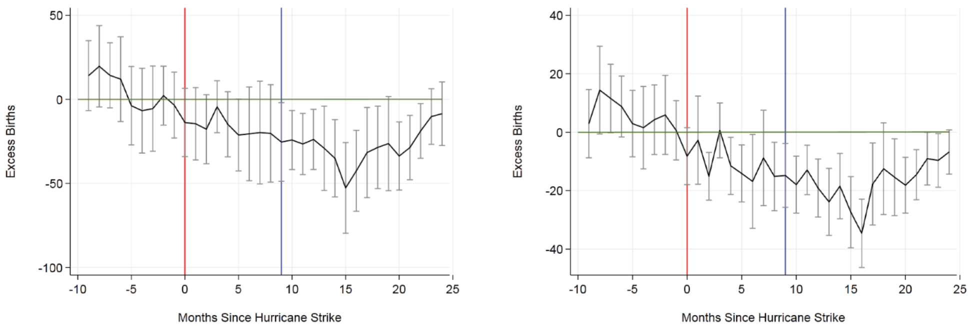
potential fathers. One should note that the net negative effect found in this study is different from the positive impact of tropical storms discovered in modern settings, such as by Cohan and Cole (2002) and Evans et al. (2010). This could be caused by the lack of government support and warning systems in the early 20th century Jamaican setting, leading to most of the rebuilding having to be done by those directly affected with their own resources.

Overall, the estimates in this study suggest a reduction of around 14% of births for an average storm, and thus arguably the impact had non-negligible local population implications. Interestingly, Jamaica during the time period analyzed here was just about to demographically transition from Stage 1 (total population is low but balanced due to high birth and high death rates) to Stage 2 (total population rises because death rates fall while birth rates remain high), arguably as a result of a decrease in infant mortality due to better maternal care (McCaw-Binns, 2005) and a number of public health campaigns (Riley, 2005).

The fall in births of already pregnant women living in parishes affected by hurricanes may have been due to the subsequent psychological stress, leading to still births, as has been shown to be a factor in many modern contexts; see, for example, Hobel et al. (2008); Eick et al. (2020). The negative impact on excess births that were conceived after the storm is arguably in line with the reasoning by Hum et al. (1977), who point to the socio-economic structure of Jamaica during the latter part of the 19th and the early part of the 20th century and argue that it is after periods of hard work that people have relatively more time to procreate. More specifically, the authors hypothesize that the agricultural seasonal demands of a high workload during some periods and a low workload during the off-season might have led to Jamaicans to explicitly timing when to have children. A similar



Males Females



Mothers Only Not Mothers Only
Not Mothers Only - Not Same Surname Not Mothers Only - Same Surname

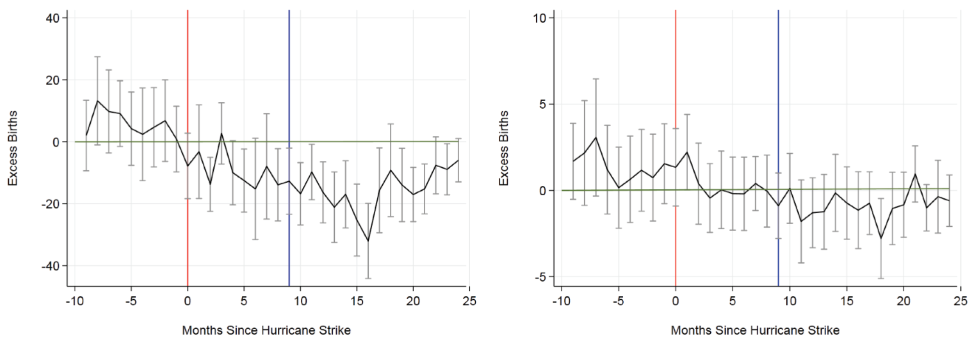
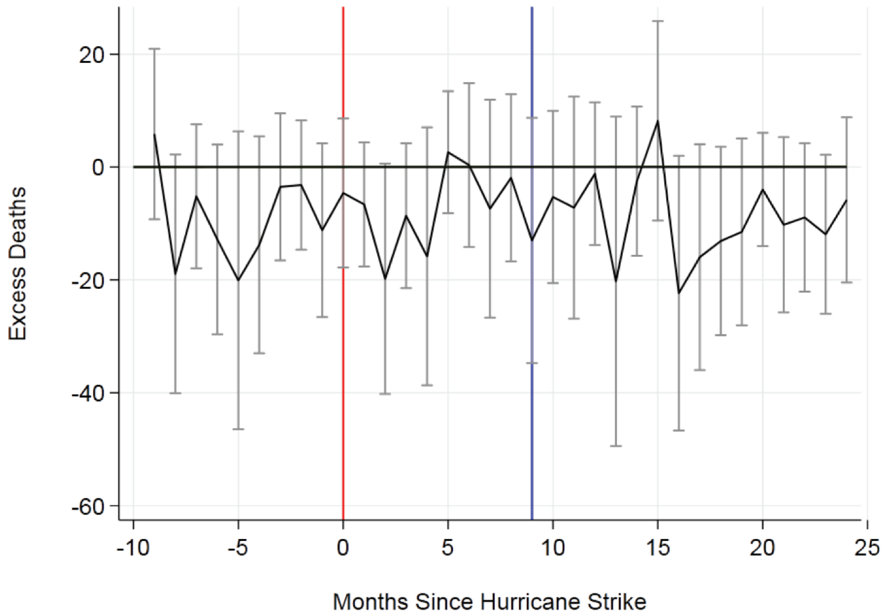
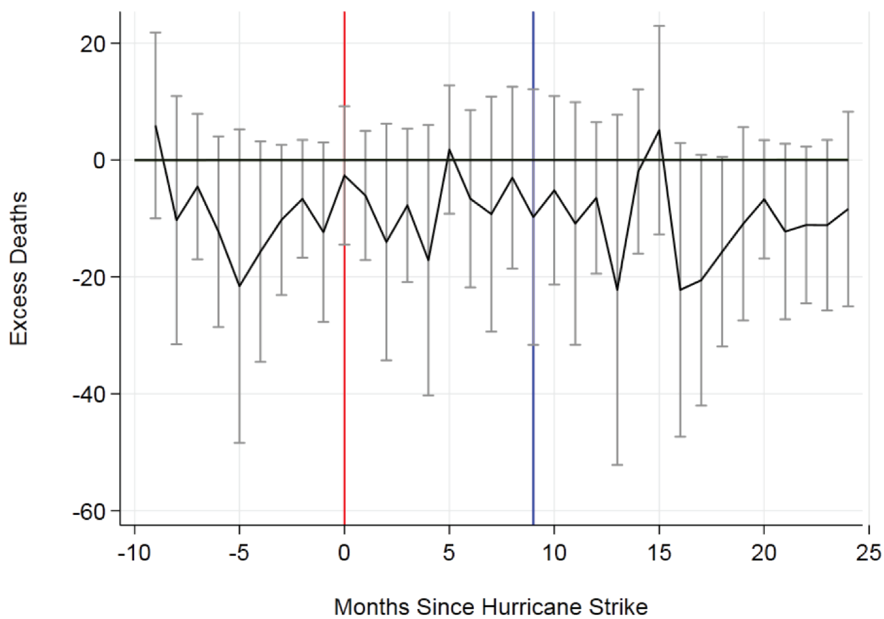


Figure 9. Impact of hurricane damage on excess births by sub-group. *Notes*: This figure shows the monthly coefficients (black line) β_{t-j} from Equation 5 on hurricane damage (red line) of the effect on excess births by sub-group from $t = -10$ to $t = 24$, along with 99% confidence intervals (grey bars). The red line indicates the month $t = 0$ when the hurricane strikes and the blue line 9 months after at $t = 9$.

phenomena might have taken place after hurricane strikes, which required reconstruction and recovery activities and thus increased the workload of those affected. A hurricane could also lead to a temporary lack of financial resources or even housing, making it more difficult to procreate (Cowan & Douds, 2022). Related to this, the initial stress due to hurricanes and their damages might have led to



Males



Females

Figure 10. Impact of hurricane damage on male & female Aged 15–44 excess deaths. *Notes*: This figure shows the monthly coefficients (black line) β_{t-j} from Equation 5 on hurricane damage (red line) of the effect on male and female aged 15–44 excess deaths from $t = -10$ to $t = 24$, along with 99% confidence intervals (grey bars). The red line indicates the month $t = 0$ when the hurricane strikes and the blue line 9 months after at $t = 9$.

temporary trouble conceiving, which would be in line with findings by, for example, Herrenkohl (1979) and Agarwal et al. (2005).

The analysis also finds a relatively larger effect on males compared to females which means we find no support for the Trivers-Willard hypothesis, according to which negative shocks such as hurricanes might affect female more than male births (also shown by Grech (2015)). Note that the difference between males and females in our analysis is mostly due to some coefficients being only significant for the male sample and not because of notable differences in the size of the estimated effects. Thus, it is more likely that the overall effect is similar across gender, but with differences in statistical precision.

The effects of births registered only by the mother compared to that registered by both a mother and a father were of similar magnitude. This may at first sight seem surprising considering that even in modern contexts, where public relief is much more extensive compared to Jamaica at the time, single mothers have been found to be affected more financially and psychologically by tropical storms (Hamilton et al., 2009; Seltzer & Nobles, 2017; Tobin-Gurley et al., 2010; Zahran et al., 2011) and for single mothers (Hamilton et al., 2009). One should note, however, that while a father's name on the birth certificate did imply that he agreed to this and thus was liable for child support, this does not mean that if the name was absent that he would have not been required to support the child since the Bastardy Law No. 2 of 1881 gave the mother the right to his financial support as long as she could prove paternity. Additionally, as noted by Ortmayr (1997), at the time matrifocal families were widespread in Jamaica, particularly among the lower classes, and thud did not necessarily imply greater hardship compared to co-residential-based conjugal unions. Rather, lower class women typically had access to employment outside of the home and small plots of land, assuring them an economic basis that allowed them to independently lead households.

In contrast, once one separates those births that registered a father and mother into those where both have the same surname, i.e. likely marital unions, and those that do not, one finds that there is no discernible effect on births is found for the former. In this regard, middle and upper class households tended to be patrifocal and marital because of the greater extent of church control and because of behavioural codes that did not permit married women to work outside of the home (Ortmayr, 1997). Also, as noted earlier, marital unions were likely, even for lower class households, to signal greater financial security, so that the lack of an impact of negative shocks on fertility may not be surprising.

A major limitation of the analysis is the lack of high-frequency population data, which could undermine the interpretation of the findings as working solely through in utero effects and post-event fertility decisions. First, while the calculation of excess births takes account, and thus abstracts from directly controlling for other storm-induced population dynamics both in the short and long term, hurricanes might have altered these directly. For example, in a modern context Spencer and Urquhart (2018) show that hurricanes caused considerable external migration in the Caribbean. While one cannot test if this was also the case for early 20*th* century Jamaica, other secondary sources provide some insight into whether external migration might have played a role.

More specifically, it is known that it was not uncommon for Jamaicans to emigrate, with many leaving for Panama and Cuba as well as other countries in the Americas (Graham, 2013). For instance, Roberts (2013) found that the population growth between 1911 and 1921 was very slow despite a high birth-to-death ratio and attributes this in part to emigration to Cuba. Also, Graham (2013) suggests that a potential factor driving people to emigrate was that several hurricanes struck during the 1910s. In terms of seeking more explicit evidence for this, Graham (2013) uses Cuban data to show that during the period 1912 to 1920 the number of Jamaican male and female immigrants were 69,828 and 12,367, respectively, but that the net gain was only 32,689, i.e. less than half of the total inflow. After 1920, the year of the sugar crash, many of the immigrants were forced to leave due to a lack of work and pressure from the Cuban government. Thus, while migration did play an important role in the population dynamics in Jamaica during the time period, the Cuban data suggests that males heavily outnumbered females in terms of outward migration, meaning that the effect on births is likely not as pronounced as the migration numbers suggest, at least not directly through a loss of potentially fertile females relative to males.

There may have also been internal migration in response to hurricane damages, although a lack of data for early 20th century Jamaica did not allow this possibility to be explored empirically. Feasibly the negative effect on births might simply be due to migration to non- or less hurricane affected parishes, although the results here did not suggest that such was reflected in lower fertile female deaths. However, if one wanted to speculate regarding the likelihood of this playing a role in the results on account of evidence for other countries during a similar time period, the evidence is to the contrary. More specifically, Boustan et al. (2012) find that damaged counties in the US in the period 1920 to 1940 attracted more migrants and argue this may have been because of increased labor demand for reconstruction. Nevertheless, Eisner (1961) provides evidence that the population in Jamaica during the period was fairly responsive to employment opportunities by migrating across parishes.

Finally, it was not possible to verify how many births may not have been registered despite the legal obligation to do so. A significant amount of noise in this regard could lead to considerable imprecision in the estimates, where some have attested to the quality of the data (Riley, 2005) and others suggest that births may be underestimated by between 2% and 4% (Roberts, 1955). In this regard, it could be that the probability a birth is not reported may be higher after a hurricane. Alternatively, migration in response to the negative shock might cause births to be registered in other parishes, although, as noted above, secondary evidence does not suggest that internal migration of women was a typical response. Moreover, people may have delayed reporting deaths in the aftermath of a hurricane. However, in order for this to affect the results it would have meant that they subsequently used the date of reporting rather than the date of birth in the register, for which there is no a priori reason, except if they were trying to avoid a penalty for the delay.

7. Conclusions

This study investigated the impact of hurricanes on excess births for early 20th century Jamaica. For identification, a spatially and temporally varying hurricane wind exposure measure across parishes was constructed using historical storm tracks and a physical tropical cyclone wind field model and combined with exhaustive monthly regional birth data from the Jamaican register. The lack of an effective early warning system and little by way of an ex-post disaster management planning meant that this provided a relatively clean setting with which to causally identify the impact of a natural disaster on fertility. Our findings show that hurricanes affected births conceived both before and after the storm and suggest that this was not due to deaths of fertile males or females. There was no discernible difference in the impact between births registered only by the mother and those registered by both the mother and the father, but with different names. In contrast, births registered by parents with the same name, possibly indicative of marital union, were not affected.

More generally, while our findings do not allow us to unequivocally disentangle differences across the three conjugal union types (extra-residential non-marital, residential non-marital, and marital) prevalent at the time in Jamaica, they do provide some preliminary insight into the potential role of family structure in how fertility responded to hurricanes. More specifically, the fact that births due to likely married persons were not affected is in line with that these tended to be higher income households and patriarchal in nature. In contrast, the similarity in response to births registered by mothers only and those registered by mothers and fathers of different surnames indicates that this distinction is not likely to capture any difference in the availability of financial resources across these two registration types. This may be because the lack of a registered father does not necessarily mean that these did not support their children. Alternatively, extra-residential conjugal unions may have not been necessarily less financially secure than their residential counterparts.

Notes

1. In an extensive review of the reproductive health literature, Zotti et al. (2012) concludes that an effect of both non-natural and natural disasters on birth outcomes has not yet been consistently demonstrated; see also Jeffers and Glass (2020).
2. There is also a related literature on the impact of other large shocks on births, and the evidence is similarly mixed. For example, for the case of terrorist attacks (Rodgers et al., 2005) and blackouts (Burlando, 2014; Udry, 1970) births have been shown to increase, while for earthquakes Lin (2010) and Tan et al. (2009) find a decrease in marital fertility.
3. Evans et al. (2010) investigate the effect of hurricane advisory announcements on fertility. They define the shock not as the hurricane striking, but as the warning of a storm or hurricane approaching, that may or may not eventually strike at a level that is higher or lower than the warning level given in the initial advisories. Using county level data on hurricane advisories and births for the period 1995 to 2001 they show that fertility decreases monotonically from positive to negative as the severity of the warning increases, with the largest negative effect being for hurricane warnings.
4. Nevertheless, Higman (1995) points out that nuclear families were not necessarily uncommon for slaves in Jamaica.
5. As a matter of fact, Cohen (1956) notes that in the mid–20*th* century in Jamaica only about 50% of all family groups were considered to be in the marriage or faithful concubinage categories.
6. The majority of churches at the time would have been Christian, although there was also some Jewish religious communities present in Jamaica (Moore & Johnson, 2004).
7. Note that although divorce became legally possible after 1879, in practise it was difficult to obtain (Moore & Johnson, 2004).
8. For example, Moore and Johnson (2004) note that illegitimate births increased from 59.3 to 72.14% over the 1878 to 1920 period.
9. The first bastardy law was passed in 1869 (Law 31) but was ineffective because it did not provide guidelines for establishing paternity (Roberts, 1955).

10. The 5 shillings per week child support level can be compared to the average daily predial age of 2 shillings (Blue book of Jamaica, 1888).
11. According to the National Library of Jamaica (2016) there were 16 hurricanes (7 of them considered major hurricanes) that struck Jamaica between 1901 and 1929 with the number of deaths estimated to be at least 250 and many more left homeless. For example, for the November 1912 the Jamaica weather report (number 411, pages 1–3) describes a cyclone with heavy rains that struck the north-eastern part of the island (St. Thomas, Portland, St. Andrew, and St. Mary). A total of 100 people died and severe damaged was caused by a tidal wave in Savanna-la-Mar. In 1916 a hurricane struck the South coast, killing 17 and destroying the entire banana crop across the island.
12. Two exceptions were the loan programs offered by the government after destructive hurricanes in 1903 and 1912. However, the 1903 Hurricane Loan Law only offered loans to planters whose could demonstrate that they had suffered damage, while The Hurricane Loan Law of 1912 provided loans to members of agricultural loan society members.
13. However, not all parishes offered both indoor and outdoor relief to claimants (Bryan, 2000).
14. At the time of the passing of the law, the penalty was 40 shilling, which was equivalent to about 3 weeks of the average predial wage rate at the time (Blue book of Jamaica, 1888).
15. In a small number of cases the birth certificates record only the name of the father. These were dropped from the analysis.
16. Damages are related to wind speed in a cubic manner due to the nature of energy dissipation of the hurricane. While hurricanes typically also cause damages through storm surge and rainfall, these features tend to be strongly correlated with wind speed (Zhai & Jiang, 2014).
17. On the 14th January, 1907, an earthquake of magnitude 6.2 hit the capital of Kingston killing about 1,000 and causing considerable structural (Fuller, 1907).
18. For example, Hum et al. (1977) explore the socio-economic differences between parishes and their effects on parish level seasonality. The authors find that the socio-economic structures seem to be largely time invariant, albeit with a shift in what the main export staple is, from bananas at the beginning of 1912 and sugar products thereafter.
19. Calculated by dividing average parish level monthly births of boys over the same measure for girls.
20. Hum et al. (1977) note that one reason for the seasonality may be the varying workload distribution in the agricultural sector during the year.
21. The corresponding point estimates (p-values) were −33.74 (0.014), −36.07 (0.015), and −41.06 (0.014), respectively.
22. The corresponding point estimates (p-values) were −41.24 (0.002), −39.82 (0.002), −43.52 (0.001), −52.44 (0.004), −52.43 (0.004), −78.40 (0.000), −76.43 (0.000), −48.38 (0.017), −40.58 (0.038), −41.93 (0.035), −52.46 (0.000), −43.52 (0.002), and −27.78 (0.020) for *t*-10 to *t*-22, respectively.
23. The point estimate (p-value) was −25.7 (0.032).
24. The corresponding point estimates (p-values) were −23.97 (0.009), −29.91 (0.004), −24.30 (0.009), −28.89 (0.025), −34.60 (0.003), −51.97 (0.000), −42.23 (0.001), −31.25 (0.023), −28.35 (0.022), −26.13 (0.066), −33.66 (0.001), −28.57 (0.003), and −18.86 (0.023) for *t*-10 to *t*-22, respectively.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Robert J R Elliott http://orcid.org/0000-0002-3966-2082

References

Agarwal, A., Gupta, S., & Sharma, R. K. (2005). Role of oxidative stress in female reproduction. *Reproductive Biology and Endocrinology*, *3*(1), 28. https://doi.org/10.1186/1477-7827-3-28

Altink, H. (2011). *Destined for a life of service: Defining African Jamaican womanhood, 1865-1938*. Manchester University Press.

Besson, J. (1993). Reputation and respectability reconsidered: A new perspective on the Afro-Caribbean Change in the Caribbean. In J. Momsen (Ed.), *A Pan-Caribbean perspective*. Indiana University Press.

Blue book of Jamaica. (1888) . *Blue books of statistics, etc. Of Jamaica*. Colony of Jamaica.

Bongaarts, J., & Feeney, G. (1998). On the quantum and tempo of fertility. *Population & Development Review*, *24*(2), 271–291. https://doi.org/10.2307/2807974

Boose, E. R., Chamberlin, K. E., & Foster, D. R. (2001). Landscape and regional impacts of hurricanes in New England. *Ecological Monographs*, *71*(1), 27–48. https://doi.org/10.1890/0012-9615(2001)0710027:LARIOH2.0.CO;2

Boose, E. R., Serrano, M. I., & Foster, D. R. (2004). Landscape and regional impacts of hurricanes in Puerto Rico. *Ecological Monographs*, *74*(2), 335–352. https://doi.org/10.1890/02-4057

Boustan, L. P., Kahn, M. E., & Rhode, P. W. (2012). Moving to higher ground: Migration response to natural disasters in the early twentieth century. *American Economic Review*, *102*(3), 238–244. https://doi.org/10.1257/aer.102.3.238

Bravo, J. M., & Coelho, E. (2020). Modelling monthly births and deaths using seasonal forecasting Methods as an input for population estimates. In *Demography of population health, aging and health expenditures* (pp. 203–222). Springer International Publishing. https://doi.org/10.1007/978-3-030-44695-6_14

Brown, A. A. (2017). The state of the Jamaican Climate 2015: Information for resilience building (summary for policy makers). *Produced for the Planning Institute of Jamaica*.

Bryan, P. E. (2000). *The Jamaican people, 1880-1902: Race, class, and social control*. University of West Indies Press.

Burlando, A. (2014). Power outages, power externalities, and Baby Booms. *Demography*, *51*(4), 1477–1500. https://doi.org/10.1007/s13524-014-0316-7

Civil Registration. (2019). Jamaica, Civil Registration, 1880-1999. index and images. FamilySearch. Citing Registrar General's Department, Spanish Town. Retrieved July 31st, 2019, from. http://FamilySearch.org.

Cohan, C. L., & Cole, S. W. (2002). Life course transitions and natural disaster: Marriage, birth, and divorce following hurricane hugo. *Journal of Family Psychology*, *16*(1), 14–25. https://doi.org/10.1037/0893-3200.16.1.14

Cohen, Y. A. (1956). Structure and function: Family organization and socialization in a Jamaican community 1. *American Anthropologist*, *58*(4), 664–686. https://doi.org/10.1525/aa.1956.58.4.02a00070

Costa, E. C., Moreira, L., Castanheira, E., Correira, P., Ribeiro, D., & Pereira, M. G. (2019). Demographic, psychological and relationship factors are associated with resource loss among pregnant women. *Journal of Reproductive and Infant Psychology*, *37*(4), 429–443. https://doi.org/10.1080/02646838.2019.1577957

Cowan, S. K., & Douds, K. W. (2022). Examining the effects of a universal cash transfer on fertility. *Social Forces*, *101*(2), 1003–1030. https://doi.org/10.1093/sf/soac013

Davis, J. (2017). Fertility after natural disaster: Hurricane mitch in Nicaragua. *Population and Environment*, *38*(4), 448–464. https://doi.org/10.1007/s11111-017-0271-5

De Barros, J. (2014). *Reproducing the British Caribbean: Sex, gender, and population politics after slavery*. UNC Press Books. https://doi.org/10.5149/northcarolina/9781469616056.001.0001

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics*, *80*(4), 549–560. https://doi.org/10.1162/003465398557825

Dunn, G. E. (1971). A brief history of the United States hurricane warning service. *Muse News*, *3*, 140–143.

Eick, S. M., Goin, D. E., Izano, M. A., Cushing, L., DeMicco, E., Padula, A. M., Woodruff Tracey, J., Morello-Frosch, R., & Hashimoto, K. (2020). Relationships between psychosocial stressors among pregnant women in San Francisco: A path analysis. *PLoS One*, *15*(6), e0234579. https://doi.org/10.1371/journal.pone.0234579

Eisner, G. (1961). *Jamaica, 1830-1930: A study in economic growth*. Manchester University Press.

Emanuel, K. (2011). Global warming effects on U.S. Hurricane damage. *Weather, Climate, and Society*, *3*(4), 261–268. https://doi.org/10.1175/WCAS-D-11-00007.1

Evans, R. W., Hu, Y., & Zhao, Z. (2010). The fertility effect of catastrophe: U.S. hurricane births. *Journal of Population Economics*, *23*(1), 1–36. https://doi.org/10.1007/s00148-008-0219-2

Fuller, M. L. (1907). Notes on the Jamaica earthquake. *The Journal of Geology*, *15*(7), 696–721. https://doi.org/10.1086/621461

Grabich, S. C., Robinson, W. R., Engel, S. M., Konrad, C. E., Richardson, D. B., & Horney, J. A. (2015). County-level hurricane exposure and birth rates: Application of difference-in-differences analysis for confounding control. *Emerging Themes in Epidemiology*, *12*(1). https://doi.org/10.1186/s12982-015-0042-7

Graham, T. E. (2013). *Jamaican migration to Cuba, 1912–1940*. The University of Chicago.

Grech, V. (2015). Terrorist attacks and the male-to-female ratio at birth: The troubles in Northern Ireland, the Rodney King riots, and the Breivik and Sandy Hook shootings. *Early Human Development*, *91*(12), 837–840. https://doi.org/10.1016/j.earlhumdev.2015.10.011

Grech, V., & Scherb, H. (2015). Hurricane Katrina: Influence on the male-to-female birth ratio. *Medical Principles and Practice*, *24*(5), 477–485. https://doi.org/10.1159/000431363

Hamilton, B. E., Sutton, P. D., Mathews, T. J., Martin, J. A., & Ventura, S. J. (2009). The effect of hurricane Katrina: Births in the US Gulf Coast region, before and after the storm. *National Vital Statistics Reports: From the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System*, *58*(2), 1–28.

Henriques, F. (1949). West Indian family organization. *American Journal of Sociology*, *55*(1), 30–37. https://doi.org/10.1086/220449

Herrenkohl, L. R. (1979). Prenatal stress reduces fertility and fecundity in female offspring. *Science*, *206*(4422), 1097–1099. https://doi.org/10.1126/science.573923

Higman, B. W. (1995). *Slave population and economy in Jamaica, 1807-1834*. University of West Indies Press.

Hobel, C. J., Goldstein, A. M. Y., & Barrett, E. S. (2008). Psychosocial stress and pregnancy outcome. *Clinical Obstetrics and Gynecology*, *51*(2), 333–348. https://doi.org/10.1097/GRF.0b013e31816f2709

Holland, G. J. (1980). An analytic model of the wind and pressure profiles in hurricanes. *Monthly Weather Review*, *108*(8), 1212–1218. https://doi.org/10.1175/1520-0493(1980)108<1212:AAMOTW>2.0.CO;2

Hum, D., Lobdell, R., & Spencer, B. (1977). Plantations, staple exports and the seasonality of births in Jamaica: 1880-1938. *Social and Economic Studies*, 63–85.

Hung, L.-S., Wang, C., & Yarnal, B. (2016). Vulnerability of families and households to natural hazards: A case study of storm surge flooding in Sarasota County, Florida. *Applied Geography*, *76*, 184–197. https://doi.org/10.1016/j.apgeog.2016.09.021

James, W. H. (1987). The Human sex ratio. Part 1: A Review of the literature. *Human Biology*, *59*(5), 721–752.

Jeffers, N. K., & Glass, N. (2020). Integrative review of pregnancy and birth outcomes after exposure to a hurricane. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, *49*(4), 348–360. https://doi.org/10.1016/j.jogn.2020.04.006

Jones, M. (2013). *Public health in Jamaica, 1850-1940: Neglect, philanthropy and development*. The University of the West Indies Press.

Lam, D. A., Miron, J. A., & Riley, A. (1994). Modeling seasonality in fecundability, conceptions, and births. *Demography*, *31*(2), 321–346. https://doi.org/10.2307/2061888

Lin, C.-Y. C. (2010). Instability, investment, disasters, and demography: Natural disasters and fertility in Italy (1820 - 1962) and Japan (1671 - 1965). *Population and Environment*, *31*(4), 255–281. https://doi.org/10.1007/s11111-010-0103-3

McCaw-Binns, A. (2005). Safe motherhood in Jamaica: From slavery to self-determination. *Paediatric and Perinatal Epidemiology*, *19*(4), 254–261. https://doi.org/10.1111/j.1365-3016.2005.00650.x

Moore, B. L., & Johnson, M. A. (2004). *Neither led nor driven: Contesting British cultural imperialism in Jamaica, 1865-1920*. University of the West Indies Press.

National Library of Jamaica. (2016). *History of Hurricanes and Floods in Jamaica*.

Nobles, J., Frankenberg, E., & Thomas, D. (2015). The effects of mortality on fertility: Population dynamics after a natural disaster. *Demography*, *52*(1), 15–38. https://doi.org/10.1007/s13524-014-0362-1

Ortmayr, N. (1997). Church, marriage, and legitimacy in the British West Indies (nineteenth and twentieth centuries). *The History of the Family*, *2*(2), 141–170. https://doi.org/10.1016/S1081-602X(97)90003-8

Registration Act. (2019). *the Registration (Births and Deaths) Act*.

Riley, J. C. (2005). *Poverty and life expectancy: The Jamaica paradox*. Cambridge University Press.

Roberts, G. W. (1950). A note on mortality in Jamaica. *Population Studies*, *4*(1), 64–85. https://doi.org/10.1080/00324728.1950.10415505

Roberts, G. W. (1955). Some aspects of mating and fertility in the West Indies. *Population Studies*, *8*(3), 199–227. https://doi.org/10.1080/00324728.1955.10415568

Roberts, G. W. (2013). *The population of Jamaica*. Cambridge University Press.

Rodgers, J. L., John, C. A. S., & Coleman, R. (2005). Did fertility go up after the Oklahoma city bombing? An analysis of births in metropolitan counties in Oklahoma, 1990-1999. *Demography*, *42*(4), 675–692. https://doi.org/10.1353/dem.2005.0034

Roper, S. (2018). Centering women in Jamaica's poor relief administration: The 1930s. *Caribbean Studies*, 161–181. https://doi.org/10.1353/crb.2018.0027

Schwartz, S. B. (2005). Hurricanes and the shaping of Circum-Caribbean societies. *The Florida Historical Quarterly*, *83*(4), 381–409.

Seltzer, N., & Nobles, J. (2017). Post-disaster fertility: Hurricane Katrina and the changing racial composition of New Orleans. *Population and Environment*, *38*(4), 465–490. https://doi.org/10.1007/s11111-017-0273-3

Serfling, R. E. (1963). Methods for current statistical analysis of excess pneumonia influenza deaths. *Public Health Reports*, *78*(6), 494. https://doi.org/10.2307/4591848

Sheets, R. C. (1990). The National hurricane center—past, present, and future. *Weather and Forecasting*, *5*(2), 185–232. https://doi.org/10.1175/1520-0434(1990)005<0185:TNHCPA>2.0.CO;2

Spencer, N., & Urquhart, M.-A. (2018). Hurricane strikes and migration: Evidence from storms in Central America and the Caribbean. *Weather, Climate, and Society*, *10*(3), 569–577. https://doi.org/10.1175/WCAS-D-17-0057.1

Strobl, E. (2011). The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions. *Journal of Development Economics*, *97*(1), 130–141. https://doi.org/10.1016/j.jdeveco.2010.12.002

Strobl, E. (2012). The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions. *Journal of Development Economics*, *97*(1), 130–141. https://doi.org/10.1016/j.jdeveco.2010.12.002

Tan, C. E., Li, H. J., Zhang, X. G., Zhang, H., Han, P. Y., An, Q., Ding, W. J., & Wang, M. Q. (2009). The impact of the wenchuan earthquake on birth outcomes. *PLOS ONE*, *4*(12), 1–5. https://doi.org/10.1371/journal.pone.0008200

Tobin-Gurley, J., Peek, L., & Loomis, J. (2010). Displaced single mothers in the aftermath of hurricane Katrina: Resource needs and resource acquisition. *International Journal of Mass Emergencies and Disasters*, *28*(2), 170–206. https://doi.org/10.1177/028072701002800202

Trivers, R. L., & Willard, D. E. (1973). Natural selection of parental ability to vary the sex ratio of offspring. *Science*, *179*(4068), 90–92. https://doi.org/10.1126/science.179.4068.90

Udry, J. R. (1970). The effect of the great blackout of 1965 on births in New York City. *Demography*, *7*(3), 325–327. https://doi.org/10.2307/2060151

Visaria, P. M. (1967). Sex ratio at birth in territories with a relatively complete registration. *Eugenics Quarterly*, *14*(2), 132–142. https://doi.org/10.1080/19485565.1967.9987713

Webber, O. 2018. *'Practical Sympathy': Disaster Response in the British Caribbean 1812-1907* [Ph.D. thesis]. University of Leeds.

Wooldridge, J. M. (1999). Distribution-free estimation of some nonlinear panel data models. *Journal of Econometrics*, *90*(1), 77–97. https://doi.org/10.1016/S0304-4076(98)00033-5
Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.
Zahran, S., Peek, L., Snodgrass, J. G., Weiler, S., & Hempel, L. (2011). Economics of disaster risk, social vulnerability, and mental health resilience. *Risk Analysis*, *31*(7), 1107–1119. https://doi.org/10.1111/j.1539-6924.2010.01580.x
Zhai, A. R., & Jiang, J. H. (2014). Dependence of US hurricane economic loss on maximum wind speed and storm size. *Environmental Research Letters*, *9*(6), 064019. https://doi.org/10.1088/1748-9326/9/6/064019
Zotti, M. E., Williams, A. M., Robertson, M., Horney, J., & Hsia, J. (2012). Post-disaster reproductive health outcomes. *Maternal and Child Health Journal*, *17*(5), 783–796. https://doi.org/10.1007/s10995-012-1068-x