# Gone with the Wind?

# Hurricane Risk, Fertility, and Education

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**Abstract**

Despite a large literature on fertility and education there is little research on how these joint decisions are affected by risks and shocks. This paper uses data on hurricanes in Guatemala combined with a household survey to analyze how households' decisions on fertility and investments in education respond to *both* risk and shocks. The data on hurricanes cover the period 1880 to 1997 and allow for the calculation of hurricane risk by municipality. An increase in risk leads to higher fertility for households with land, while households without land reduce fertility. For both types of households higher risk is associated with higher education but the effect is largest for households without land. Negative shocks lead to decreases in both fertility and education. There is a compensatory effect later in life for fertility, but not for education, indicating that births "lost" to shocks can be made up but lost schooling cannot. The most convincing explanation for these patterns is parents' need for insurance.

JEL codes: J1, 01, I2, J2, D8

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# 1 Introduction

People in developing countries are faced with many different types of risks against which little formal insurance is available. An important subset of these risks consists of natural hazards, such as hurricanes, floods and droughts, that occur relatively frequently and are potentially highly destructive. Their frequency and magnitude, together with the lack of insurance, means that people and societies have had to develop coping strategies or face severe consequences. Hence, most decisions made by households in developing countries are likely to be affected by these risks. This paper examines how two important decisions, education and fertility, respond to risk and shocks generated by hurricanes in Guatemala.

A hurricane is one of the most powerful weather systems and can have a devastating impact, especially in agricultural areas where they frequently lead to the destruction of crops and infrastructure.[1] Hurricane Stan in October 2005 is a good example. Guatemala was the hardest hit country with an official death toll of 652 and an estimated 130,000 people directly affected. Crops, businesses and homes were destroyed, water sources compromised and many areas were cut off by the floodwaters and mudslides. Guatemala faces a high annual hurricane risk; in fact, the very word hurricane comes originally from the Spanish "huracán", which is itself derived from Caribbean and Latin American indigenous words such as "Huraken", the god of thunder and lighting for the Quiche of southern Guatemala (Pielke and Pielke 2003).

Over the last couple of decades the study of risk coping strategies has been an active research area in economics and other social sciences, such as anthropology. In traditional anthropology natural hazards are considered part of the environment to which people establish relatively effective adaptations (Oliver-Smith 1996). Hence, people are considered to be able to assess and adapt to the risks posed by natural hazards. This idea has been applied to hazards such as floods in Bangladesh and China.[2] Furthermore, there is an anthropological literature on adjustments to

[1]The terms "hurricane" and "typhoon" are regionally specific names for a strong "tropical cyclone", which has sustained winds in excess of 64 knots (33 m/s). A tropical cyclone is the generic term for a non-frontal synoptic scale low-pressure system over tropical or sub-tropical waters with organized convection (i.e. thunderstorm activity) and definite cyclonic surface wind circulation (Holland 1993).

[2]See, for example, Haque and Zaman (1989) and Zaman (1993, 1994) on Bangladesh and Wong and Zhao (2001)

other hazards such as droughts and volcanoes.[3] Despite these examples, a substantial part of the anthropological and sociological literature have focused on analyzing the direct effects of shocks or disasters. Hence, in recent years there has been a call for greater attention to be paid to the strategies employed by people at risk (Wisner, Blaikie, Cannon, and Davis 2004).

The economic literature has identified a number of risk coping strategies. These include diversification of economic activities, either through the choice of farm input and crop choice or migration, the accumulation of assets for sale if an adverse income shock occurs and the pooling of risk with other households.[4] Furthermore, a household can adjust the labour supply of adults and children to deal with a shock.[5] A recurring problem in the economic literature on risk coping is, however, that while data on shocks are often available, it is significantly harder to measure risk. There have been a number of different approaches to this problem. First, a substantial part of the literature deals with how households respond to shocks rather than how they respond to risk. Second, those studies that do deal with responses to risk have focused on decisions which are repeated often, such as crop choice. Finally, studies have used indirect approaches to assess how households respond to risk as in the literature on pooling of risk.

The lack of direct information on risk is important for two reasons. First, it may lead to biased estimates of the effects of shocks. As discussed by Morduch (1995), there may be substantial costs associated with responses to risk which are not apparent if only information on shocks and their associated responses are available.[6] Second, and arguably more important, without information

on China.

[3]See Torry (1978, 1979) for a review of the older anthropological literature and Oliver-Smith (1996) for a more recent survey.

[4]Examples on diversification are Bliss and Stern (1982), Rosenzweig and Binswanger (1993), Dercon (1996) and Fafchamps (1993). On migration, Stark (1995) discusses transfers between family members and Lucas and Stark (1985), Rosenzweig and Stark (1989), Paulson (2000) and Yang and Choi (2005) are examples of empirical studies. With respect to assets accumulation Cain (1981), Deaton (1992), Paxson (1992) and Rosenzweig and Wolpin (1993) are examples. Furthermore, Clarke and Wallsten (2003) and Yang (2006) both examine the effect of hurricane shocks on capital flows. The former on household level flows and the latter on international capital flows. Townsend (1994) and Udry (1994) are the seminal papers in the literature on risk pooling.

[5]Kochar (1999) examines adult labour supply, while Jacoby and Skoufias (1997), Guarcello, Mealli, and Rosati (2002) and Beegle, Dehejia, and Gatti (2006) focuses on child labour and schooling.

[6]Farmers may, for example, choose crops that have lower variability in income but where this lower variability comes at the cost of a substantially lower average income. If this strategy is effective a shock will have little effect on observed income leading the researcher to claim that shocks and by implication risk are not important, thereby underestimating the true cost.

on risk it is difficult to analyse the response of "long-term" outcomes, i.e. decisions for which the outcome is only revealed with some delay or where the process is cumulative over time.

This paper focuses on two such outcomes: Education and fertility. Both are important determinants of individual welfare and society's growth prospects and are likely to be significantly affected by the risk environment. The lack of reliable direct data on risk means that there has so far been little research on the effects of risks on these outcomes and one of the contributions of this paper is that it is the first to analyse the effect of a direct measure of *risk* on education and fertility.[7] Furthermore, the paper shows how both of those decisions respond to shocks controlling for risk.[8] This is possible because of a highly unusual data set that contains information about all hurricanes that have hit Guatemala over almost 120 years and the areas affected by each. This allows risk and shocks measures to be created by municipality.

While the paper focuses on Guatemala, other countries in Central America and the Caribbean together with countries such as India, Bangladesh, China, the Philippines, Fiji and Mozambique also face high hurricane risk, and the results are likely to be relevant there as well.[9] Furthermore, the results in this paper may also carry over to other types of hazard that occur frequently and are potentially destructive such as floods.

The following section presents a model of parents' education and fertility decisions under uncertainty and outlines the possible pathways through which risk and shocks can affect these decisions. The empirical analysis of fertility shows that households with land respond to higher risks by having more children, while households without land have fewer children. It also shows that the increase in mortality associated with hurricanes explains only part of this higher fertility. The

[7]For a review of the literature see Schultz (1997) on fertility and and Strauss and Thomas (1995) on education. Lindstrom and Berhanu (1999) analyse the effects of war and famine on fertility in Ethiopia, Bengtsson and Dribe (2006) show that households in Sweden during the period 1766 to 1865 responded to economic shocks and the expectation of them by postponing births, but to the best of my knowledge nobody has looked at the effect of risk on total fertility.

[8]Previous research, such as Jacoby and Skoufias (1997), Beegle, Dehejia, and Gatti (2006) and Duryea, Lam, and Levison (2007), analyse how income shocks and access to credit affect child labour and schooling decisions without information on risk and without accounting for the potential effect of risk and shocks on fertility.

[9]There are about 84 tropical cyclones each year of which on average 45 reach hurricane strength. Of those 16 in the eastern Pacific and approximately 10 in the Atlantic (Pielke and Pielke 2003). See also the discussion of coastal storms in Wisner, Blaikie, Cannon, and Davis (2004, Chapter 7).

effect of risk on education is examined next and the main results are that both households with and without land respond to higher risk by investing more in education, although the effect is substantially larger for those without land. Finally, I argue that the hypothesis that best fits these results is that a need for insurance, through larger families and migration, is the driving force behind how fertility and education decisions respond to risk.

## 2 Theoretical Framework

This section examines potential pathways from risk and shocks to parents' decisions on fertility and schooling under uncertainty. It first presents a simple model, the details of which are presented in Appendix A, which forms the basis for the analyses of three questions. First, what happens when parental income is uncertain but there is no uncertainty with respect to the number of surviving children or their human capital? Secondly, what is the effect of mortality risk on human capital and fertility decisions? Finally, how will risk affect the return to human capital and what is the impact on the household's decisions? This section also examines the role of migration and shocks and discusses the implications of the model for the empirical analysis.

Consider a household that faces a two-period decision problem with uncertainty about outcomes in the second period.[10] The household derives utility from consumption, $c_t$, in each of the two periods, the number of children, $n_2$, and the education of those children, $H_2$,

$$U = u(c_1) + E[u(c_2) + v(H_2, n_2)]. \tag{1}$$

In period one, parents decide how to allocate a fixed and certain income, $Y_1$, between first period consumption, $c_1$, the number of children to have, $n_1$, the amount of schooling to invest in the children, $H_1$, and savings, $S$. For each child the parents incur a cost, $k$, which reflects both direct costs of the child and the time cost of the mother. Each unit of schooling costs $p$ and all

[10]For simplicity discounting and interest rates are ignored here.

children receive the same amount of education.[11] The first period budget constraint is

$$Y_1 = c_1 + kn_1 + n_1 pH_1 + S. \quad (2)$$

Children can potentially provide a substantial contribution either through working on the family farm or through transfers if they reside outside the home. The income from children, $F(n_2, H_2)$, depends on the number of children and their human capital, where the first order derivatives for both $n$ and $H$ are both positive. Furthermore, parents have a second period income, $Y_2$, and their savings. Hence, the total expected disposable income in the second period is

$$E[Y_2 + F(n_2, H_2) + S]. \quad (3)$$

The exact specification of $F(n_2, H_2)$ determines how much income the parents receive for a given number of children and amount of human capital. It is, for example, likely that the relative return of human capital to the number of children will differ depending on whether the household owns land or not. The amount received may also depend on how much "control" parents can exert over their children. If children are still at home parents can probably extract a substantially larger fraction than if the children have migrated to another area.

Having children at home can be especially important since hurricanes destroy crops, buildings and land and delays in replanting and rebuilding farm buildings can ultimately mean a failed harvest followed by food shortage or at least a significant reduction in profit. In principle a farmer could rely on hired labour for help with replanting and rebuilding. It is, however, often difficult or impossible to enforce labour contracts during crisis situations, such as when a hurricane hits. In contrast, family members have two incentives to help: First, altruism toward the other family member; secondly, if they live at home they will be directly affected by the negative effects of the shock. This lack of enforceable labour contracts is not only a problem in developing countries as

[11] This assumption obviously ignores the important aspect of intra-household allocation of schooling. See Ejrnæs and Pörtner (2004) for a discussion of this.

the example of the 2005 Hurricane Katrina in the US shows. Rivlin (2005) describes how, even with large hiring bonuses and substantially increased wages, it was next to impossible to attract workers in New Orleans. Another example is the following quote describing the situation during Hurricanes Charley and Frances in 2004: "You don't want to stay here with your family if it's not safe,... but if you don't stay here and keep those pumps running, nobody's going to" (Cridlin 2004). Hence, the possibility of hiring laborers is assumed away.

## 2.1 Uncertainty in Income

How uncertainty in income affects education and fertility decisions are analysed under two different assumption: Incomplete capital markets or perfect capital markets. Under the extreme version of incomplete capital markets it is not possible to borrow or save, while under perfect capital markets parents can borrow and save as much as they like. While the model leads to ambiguous results unless one imposes strong assumptions it provides a good framework for discussing the directions of the different effects.

Focus here is the effects of increasing income risk on the number of children and the investment in them. Following Sandmo (1970) an increase in second period income risk is modelled as a combination of multiplicative and additive shifts, such that the second period income can be written as $\gamma Y_2 + \theta$, which has an expected value of $E[\gamma Y_2 + \theta]$. For a mean-perserving spread $dE[\gamma Y_2 + \theta] = E[Y_2 d\gamma + d\theta] = 0$, which leads to $\frac{d\theta}{d\gamma} = -E[Y_2] = -\xi$. The effects of increasing risk is then given by $\frac{dn}{d\gamma}$ and $\frac{dH}{d\gamma}$ derived under the condition: $\frac{\partial\theta}{\partial\gamma} = -\xi$. As indicated the directions of these effects are not directly identifiable. Hence, emphasis is on how a *change in an exogenous variable* affects how households respond to a *change in income risk*. The interpretation of these effects is comparable to the interpretation of interaction variables, which figure prominently in the empirical sections below.

With $S \equiv 0$ and substituting in $\gamma Y_2 + \theta$ for second period income expected utility to be maximised is

$$
\begin{aligned}
E[U] &= u(c_1) + v(H,n) + E[u(c_2)] \\
&= u(Y_1 - kn - npH) + v(H,n) + E[u(\gamma Y_2 + \theta + F(n,H))]. \qquad (4)
\end{aligned}
$$

The two first order conditions, with respect to $n$ and $H$, are

$$\Psi_n : -u'(c_1)(k + pH) + v'_n(H,n) + E[u'(c_2)F_n(n,H)] = 0 \qquad (5)$$

$$\Psi_H : -u'(c_1)np + v'_H(H,n) + E[u'(c_2)F_H(n,H)] = 0. \qquad (6)$$

As in the standard quantity-quality model of fertility the shadow marginal cost of children, $k + pH$, is increasing in education and the shadow marginal cost of education, $np$, is increasing in the number of children. Total differentiating with respect to $n$, $H$ and $\gamma$ (given $\frac{\partial\theta}{\partial\gamma} = -\xi$) leads to a system of equations[12]

$$\begin{bmatrix} \Psi_{nn} & \Psi_{nH} \\ \Psi_{Hn} & \Psi_{HH} \end{bmatrix} \begin{bmatrix} dn \\ dH \end{bmatrix} = \begin{bmatrix} -\Psi_{n\gamma} \\ -\Psi_{H\gamma} \end{bmatrix} d\gamma. \qquad (7)$$

One can then find $\frac{dn}{d\gamma}$ and $\frac{dH}{d\gamma}$ given $\frac{\partial\theta}{\partial\gamma} = -\xi$. Let $|H|$ be the Hessian determinant, then using Cramer's rule leads to

$$\frac{dn}{d\gamma} = \frac{-\Psi_{n\gamma}\Psi_{HH} + \Psi_{H\gamma}\Psi_{nH}}{|H|} \qquad (8)$$

and

$$\frac{dH}{d\gamma} = \frac{-\Psi_{nn}\Psi_{H\gamma} + \Psi_{Hn}\Psi_{n\gamma}}{|H|}. \qquad (9)$$

The second-order sufficient conditions for a maximum are $|H| > 0$, $\Psi_{nn} < 0$ and $\Psi_{HH} < 0$. Furthermore, under decreasing temporal risk aversion Sandmo (1970) showed that $\Psi_{n\gamma} > 0$ and $\Psi_{H\gamma} > 0$. Given $|H| > 0$, the signs of $\frac{dn}{d\gamma}$ and $\frac{dH}{d\gamma}$ are determined by the numerator, making it possible to examine how the effect of risk changes with changes in the parameters.

[12]The individual terms are provided in Appendix A

For the effect of risk on fertility, $\frac{dn}{d\gamma}$, the numerator of (8) becomes, after substituting,

$$
\begin{aligned}
&E\Big[u''(c_2)(Y_2-\xi)\Big]\times \\
&\qquad\Big[F_H(n,H)\times\Big\{u''(c_1)(k+pH)np-u'(c_1)p+v''_{nH}(H,n) \\
&\qquad\qquad +E[u''(c_2)F_H(n,H)F_n(n,H)+u'(c_2)F_{nH}(n,H)]\Big\} \\
&\qquad -F_n(n,H)\times\Big\{u''(c_1)np+v''_{HH}(H,n) \\
&\qquad\qquad +E[u''(c_2)(F_H(n,H))^2+u'(c_2)F_{HH}(n,H)]\Big\}\Big].
\end{aligned}
\tag{10}
$$

The term on the first line is positive and so are the two first order derivatives for the income function for children, $F_n$ and $F_H$.[13] Furthermore, the last term in curly brackets is $\Psi_{HH}$, which is negative under the second-order conditions for a maximum. Hence, whether the total effect of risk on fertility is positive or negative depends on the sign and size of the first term in curly brackets, which is $\Psi_{nH}$, relative to $\Psi_{HH}$, and the relative sizes of $F_n$ and $F_H$.

The effect of risk on education, $\frac{dH}{d\gamma}$, mirrors the effects on fertility. Substituting in the numerator for (9) leads to

$$
\begin{aligned}
&E\Big[u''(c_2)(Y_2-\xi)\Big]\times \\
&\qquad\Big[F_n(n,H)\times\Big\{u''(c_1)(k+pH)np-u'(c_1)p+v''_{Hn}(H,n) \\
&\qquad\qquad +E[u''(c_2)F_n(n,H)F_H(n,H)+u'(c_2)F_{Hn}(n,H)]\Big\} \\
&\qquad -F_H(n,H)\times\Big\{u''(c_1)(k+pH)+v''_{nn}(H,n) \\
&\qquad\qquad +E[u''(c_2)(F_n(n,H))^2+u'(c_2)F_{nn}(n,H)]\Big\}\Big].
\end{aligned}
\tag{11}
$$

As above, the term on the first line is positive and so are the two first order derivatives for the income function for children, $F_n$ and $F_H$. Furthermore, the last term in curly brackets is $\Psi_{nn}$, which is negative under the second-order conditions for a maximum. Whether the total effect is positive or negative depends again on the sign and size of the first term in curly brackets, which is

[13] That the first term is positive follows from $\Psi_{n\gamma} > 0$ since $F_n > 0$.

$\Psi_{Hn}$, relative to $\Psi_{nn}$, and the relative size of $F_n$ and $F_H$.

Clearly, the higher the shadow marginal cost of having an extra child the less likely it is that parents respond to an increase in risk by having more children. Whether it makes an increase in education as a response to higher risk more likely depends on the size of the marginal product from children times the shadow marginal cost of education relative to the marginal product of education. If the latter is larger than the former, higher risk is more likely to lead to more investment in education. The higher the marginal shadow cost of education is the less likely is an increase in education when risk increases. For fertility the effect of a higher shadow marginal cost of education depends on whether the shadow marginal cost of children times the marginal product of education is larger or smaller than the marginal product of children. If the latter is larger than the former, areas with higher cost of education are more likely to see increases in fertility in response to an increase in risk.

In order to draw inferences relevant for the empirical analysis it is worthwhile summarizing by whether a household owns land or not. In general the cost of children is lower for those with land than for those without. Furthermore, the marginal product of children relative to the marginal product of human capital is likely higher if a household own land since manpower is likely to be more important than human capital.[14] Combining these, the effect of risk on fertility is expected to be more positive among households with land, while the effect on human capital is likely to be higher if a household does not own land. An interesting possibility is that both fertility and education will increase with increasing risk. Since there is no other way of transferring resources from one period to the next in this model, it is entirely possible that parents will respond to an increase in risk by increasing both their fertility and the level of education provided to their children.

Assume now that capital markets are complete and hence that parents can borrow or save as much as they desire. It is likely that savings will increase with risk given that it is a relative cheap way of transferring resources from one period to the next. As discussed by Deaton (1992),

[14] An extreme version is that only the education of the most educated household members matters for agricultural productivity. This is what Jolliffe (2002) found for Ghana, although that study did not allow for returns to education because of risk. This section discusses the return to human capital and how it is influenced by risk in more detail below.

however, savings cannot completely satisfy the need for insurance over multiple periods since once the savings are exhausted there are few options available if another shock occurs. This, combined with the utility that parents derive from both children and their human capital means that it is possible that fertility and/or human capital investments increase when risk increase.[15]

## 2.2 Mortality, Risk and the Return to Human Capital

Besides their effect on income hurricanes might also change the mortality risk of both children and adults, which in turn, is likely to affect fertility and human capital decisions.[16] As shown in Sah (1991) and Pörtner (2001) an exogenous increase in mortality risk is likely to increase fertility. In Sah (1991) the model is based on parental utility of children where the only uncertainty is mortality, while in Pörtner (2001) children serve as incomplete substitutes for missing insurance markets when both future income and child survival are uncertain. In Pörtner (2001) parents who are sufficiently risk averse will respond to an increase in the risk of child mortality by increasing fertility. Hence, it is possible that higher hurricane risk can lead parents to increase their fertility to compensate for higher expected mortality. Furthermore, given that an increase in mortality leads to a reduction in the expected return to investments in human capital for a given number of children, the likely effect of increased mortality is a decrease in schooling.

The final question is how risk affects the return to investments in human capital. To the extent that hurricanes destroy infrastructure or generate interruptions one would expect the "quality" of schooling to be lower in more hurricane prone areas than in less hurricane prone areas. This leads to an increase in the cost of achieving a given level of human capital. Furthermore, if more hurricane prone areas also suffer from depressed economic development, since investors are presumable less likely to invest in more risky areas, the return to schooling would be lower than in similar areas with lower exposure to hurricanes.

[15] The model is derived in detail in Appendix A.

[16] As discussed above, hurricane Stan hit Guatemala in October 2005 leading to an official death toll of 652, although numbers as high as 2000 was mentioned. Areas that were cut off by floodwaters and mudslides furthermore faced the threat of hunger and disease.

There are, however, two pathways through which higher risk may lead to an increase in education. First, Schultz (1975) argued that education might improve the ability to deal with disequilibrium. Although the original argument was aimed at individuals in modernizing economies, a similar argument can be made for risky areas in developing countries:[17] When a shock hits, those who are better able to improvise and deal with the adverse situation are also likely to fare the best. Schooling could, for example, teach how to collect and process information, which helps in a situation where actions are time sensitive.

Secondly, an area with higher hurricane risk might see less investment in physical capital than a similar area with lower hurricane risk owing to the risk of losing the physical capital when a hurricane hits. Human capital is arguably less prone to destruction by hurricanes than physical capital. Hence, higher risk of hurricanes increases the return to human capital relative to physical capital, which would tend to increase education levels. In this case it could be possible to observe high levels of education and at the same time low returns to education when measured by wages during "normal" times. These effects are not captured by the model directly, but Sandmo (1970) found that without strong functional assumption the effects of uncertainty in the return to investments were ambiguous.

## 2.3 Migration, Shocks and Implications for Empirical Analysis

The remainder of this section looks at two aspect that are not captured directly by the model. The first is migration and the second is the effect of shocks. Finally, the implications of the preceding analysis for the empirical analysis are discussed.

Since migration to reduce exposure to risk or after a shock to smooth consumption has received a significant amount of attention in the literature (see, for example, Stark 1991), it is worth discussing how this affects fertility and education decisions. Imagine a household that can either send a household member to the closest city or to another agricultural area. Presumably the return to education is higher in the city, but if the city has a high covariance with the originating area, it

[17] Related arguments can be found in Rosenzweig (1995) and Foster and Rosenzweig (1996).

might be better for the household to send its migrant to the other agricultural area. In the latter case it is not clear that migration for risk diversification reasons should necessarily lead to higher investments in education. Furthermore, if parents are not convinced that all their children will remit after migrating they might have more children than they otherwise would.[18]

The previous discussion has dealt with the effect of risks. The realisation of an event will, for a given level of risk, of course also have an effect on the household's behavior. While there are a number of different possible prediction of how fertility and education respond to risks the effect of a hurricane shock is easier to predict. Since hurricanes lowers income during the current period both fertility and schooling should decreases after a hurricane. The mechanism is simple: As income decreases the marginal cost in first period utility of both having a child and sending children to school increases, which leads parents to substitute towards current consumption and away from children and education. Note, however, that a simple two-period model cannot capture the timing of education and fertility. In reality parents can, at least partly, make up for the temporary reduction by having children at older ages and by making their children work less in subsequent periods.

The advantage of this model is that it can guide the interpretation of the results and help disentangle the relative importance of the possible ways through which risk might affect fertility and education. Clearly, the expected impact of risk and shocks are very different and since they are obviously closely correlated there may be a substantial omitted variables bias if one is not included. Finally, one of the important differences between people in rural areas is whether they own land or not, and, as discussed above, there might be substantial differences in the response to risk depending on land ownership status. Specifically, the effect of risk on fertility is likely to be more positive for households with land, while the effect on human capital is likely to be bigger for households without land. The dependent and explanatory variables are discussed in detail below.

[18]For further discussion of why migrants remit, such as altruism and self-enforcing contracts, see Lucas and Stark (1985), Stark (1991, ch. 15), Cox and Stark (1994) and Lillard and Willis (1997).

# 3 Data

Two data sets are used here. The first is a household survey with information on fertility and education. The second has information on hurricanes which can be used to calculate risk measures for specific geographical areas. This section discusses both, starting with the latter.

The data used to calculate risk were collected for a report on natural disasters and vulnerability in Guatemala (UNICEF 2000). The raw data is a listing of natural disaster events, mostly drawn from written sources, such as newspapers, with information on the type of event, the date, the area hit, the source of the information and a short description of the event. For most of the disasters the information cover very long periods of time. A major advantage of the data is that information is available at municipality level which, together with the long time span, allows a relatively precise measure of the risks and shocks a household is exposed to.[19] While other types of events than hurricanes were originally considered for inclusion as risk they either suffer from having less data available, being less likely to be exogenous or from being harder to predict.[20]

The main variable of interest here is the measure of hurricane risk, which is calculated as the percent probability of an hurricane occurring in a year, based on events from 1880 to 1997.[21] Although there clearly may be issues with relying on data as far back as this, it is one of few ways to get a reasonable measure of the risks in an area. Hurricanes can hit essentially everywhere in Guatemala, but there is substantial variation in how likely a municipality is to be hit by a hurricane. Figure 1 shows the distribution of hurricane risk.

The household data are from ENCOVI 2000, which is a LSMS-style nationwide household survey from Guatemala collected in 2000. The survey covered 7,276 households, of which 3,852 were rural and 3,424 were urban. It was designed to be representative both at national and regional

[19] The household and the associated community surveys do contain questions on exposure to shocks, but these only cover the 12 month period prior to the survey date for the household questionnaire and the period 1995 and 2000 for the community questionnaire. These periods are clearly too short to be used for creating a believable measure of risk.

[20] Examples include forest fires and mudslides, which are likely to be affected by choices made by people in terms of where they locate and their farming patterns. Earthquakes were also considered since they occur frequently in Guatemala. The problem is that they are harder to predict and that the risk depends on previous shocks since a release of energy makes subsequent earthquakes less likely (as long as immediate aftershocks are not included).

[21] See below for a discussion of the definition of shocks since those depend on the dependent variable of interest.

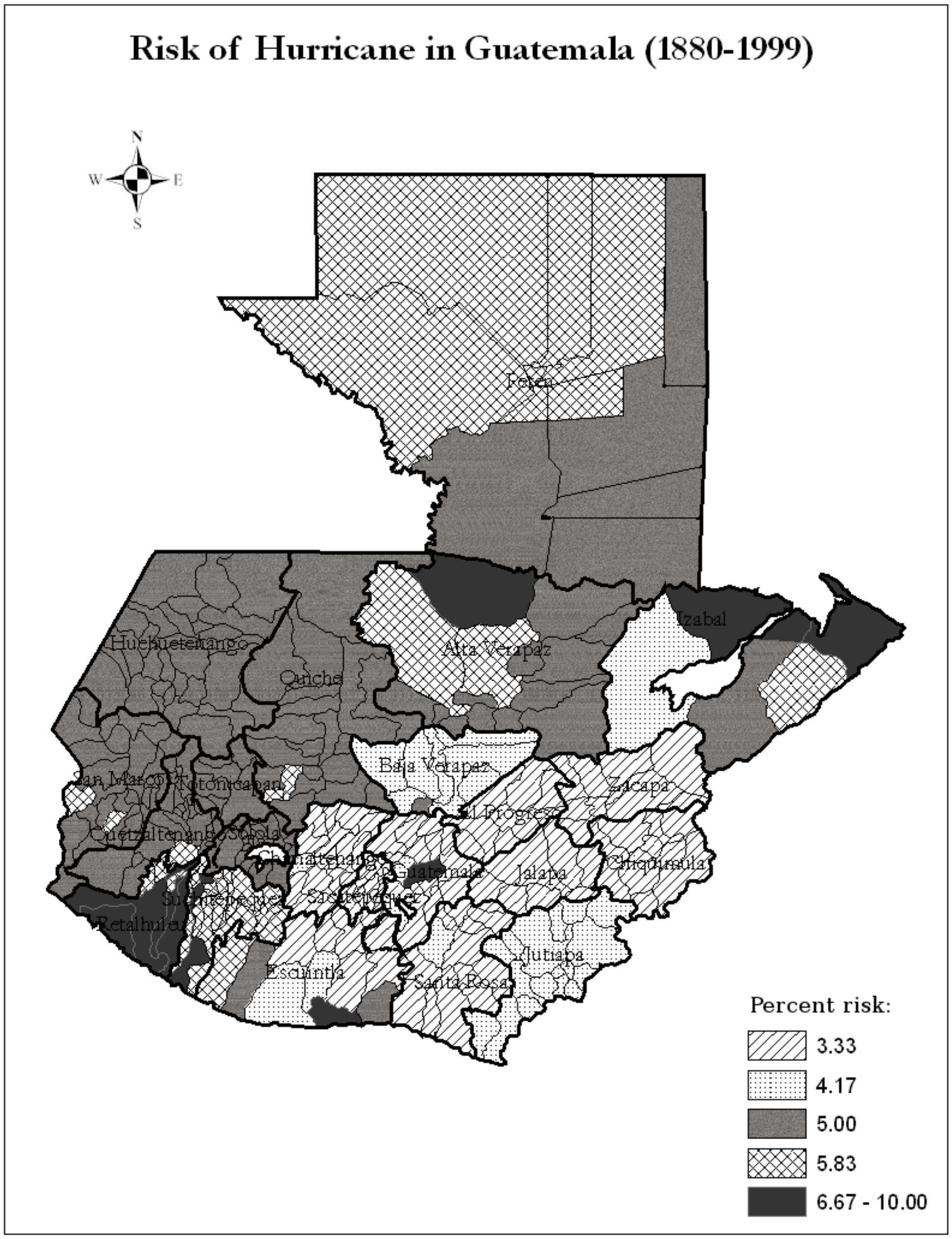



Figure 1: Hurricane Risk by Municipality

levels and for urban and rural areas.

The household survey provides information on education and fertility. Since these are joint decisions it would be preferable to use the same subjects for both analyses, but unfortunately there is no information for children who have either died or left the household. Instead the analysis of education examines the effect of risk and shocks on the adult population. This is possible because the ENCOVI 2000 is a representative survey of the population and contains information on municipality of birth, information on parents and how long an individual has lived in an area. Furthermore, given the long series of event data it is possible to identify how many shocks someone has been exposed to when growing up. The main advantages of using adults are that there is no sample selection bias from lack of information on children who have died or left home, that their education can be assumed to be completed and that the sample size is substantially larger.

## 4 The Effects of Risk and Shocks on Fertility

This section analyses how risk and shocks affect fertility. It first discusses the econometric model and selection of the sample. Second, it presents the variables and their likely impact on fertility. This is followed by the results. Finally, it examines whether mortality risk can explain the change in fertility from hurricane risk.

The estimated equation is

$$F_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \qquad (12)$$

where $F$ is the fertility outcome of interest, $X$ is a vector of individual and household variables, $R$ is a vector of risk, including interactions with individual and household variables and $S$ measures shocks. The estimation method is OLS with robust standard errors where the cluster level is the household.[22]

Since the number of births is very small between age 12 and 14, the sample contains only women aged 15 to 49. Furthermore, the focus is on rural areas since standard insurance is less likely to be available there. Guatemala has, however, a relatively low level of urbanisation and even areas that are officially urban often have a very strong rural component.[23] The sample therefore

[22]Two advantages of OLS over count models, such as the Poisson model, are the less restrictive nature of the assumptions needed and that the effects are easier to interpret. The results remain qualitatively the same if using a Poisson model instead. The results are available from the author on request.

[23]Urban is defined as officially recognized centers of departments and municipalities and the Municipality of Guatemala Department, which includes the capital and surrounding areas.

only excludes highly urbanized areas.[24] After dropping observations with missing information there are 6648 women in the sample.

## 4.1 Variables

Table 1 presents the descriptive statistics for the variables used in estimating equation (12). The explanatory variables fall into three groups: Individual and household variables, risk and risk interactions and finally shocks. This section first examines the dependent variables and then discusses the explanatory variables.

ENCOVI 2000 includes two measures of fertility for each women: The number of live births and the number of children alive at the time of the survey. The number of live births comes closest to the choice variable in the model, but the number of surviving children may be a better indicator of what the household cares about, especially if children are needed as "insurance" (either through their labour when a hurricane hits a farm or through their income as migrants). The majority of women were still in their fertile years, 15-44 years of age at the time of the survey, and hence, what is used is not completed fertility but the cumulative age-specific fertility. The average number of births in the sample is 2.8.[25] The number of surviving children reflects a death rate of around eight percent. Guatemala's infant and child mortality rates in 2003 were around 35 and 47 per 1000 children born, respectively. The higher number of deaths in this sample reflects both the rural nature of the sample and that it includes all deaths, even those after age five.

Risk is the percentage annual risk of a hurricane. The mean probability is around 4.6 percent per year, with the minimum being 3.3 and the maximum 7.6 and a standard deviation just shy of 1.[26] While these numbers may not appear very high, there are two things to consider. First, in the highest risk areas, a woman can expect to experience more than two hurricanes during her fertile ages and around four from age 15 to retirement age, while the corresponding numbers for

[24]There are 22 departments in Guatemala with a total of 331 municipalities, of which we use data from 205 of them. The results remain qualitatively the same if the sample is more strictly defined, but the standard errors are larger.

[25]Guatemala's total fertility rate is around 4.6 and the average number of births for women in the sample aged 45 and older is 5.5.

[26]The municipalities shown in Figure 1 with a risk higher than 7.6 are not covered by the household survey.

Table 1: Descriptive Statistics — Fertility

| Variable | Mean | Std. Dev. |
|---|---|---|
| Number of births | 2.84 | 3.02 |
| Number of children alive | 2.59 | 2.70 |
| Age | 28.02 | 9.88 |
| Age$^2$/100 | 8.83 | 6.05 |
| Indigenous | 0.45 | 0.50 |
| Owns land | 0.47 | 0.50 |
| Rural | 0.67 | 0.47 |
| Risk of hurricane (percent) | 4.63 | 0.96 |
| Risk of hurricane × owns land | 2.23 | 2.44 |
| Risk of hurricane × age | 129.58 | 53.67 |
| Risk of hurricane × age$^2$/100 | 40.78 | 29.77 |
| Risk of hurricane × age × owns land | 62.45 | 76.06 |
| Risk of hurricane × age$^2$/100 × owns land | 19.81 | 29.87 |
| Hurricane shocks (before age 30) | 0.80 | 0.67 |
| Hurricane shocks × age 35-49 | 0.30 | 0.70 |
| Hurricane shocks × owns land | 0.38 | 0.61 |
| Hurricane shocks × age 35-49 × owns land | 0.15 | 0.52 |
| Number of observations: | 6648 | |

the lowest risk areas are one and just below two. Second, a higher risk of hurricanes is correlated with a higher risk of other storms. Only those storms with strong enough winds are classified as hurricanes, but for every hurricane there is likely to be a substantial number of smaller storms which may be also destructive, albeit not on the same scale.

Once one control for risk, shocks should have a negative impact on fertility. The measure of shocks is the number of hurricanes between the year the woman enters her fertility period (taken to be 15 years) and her 29th year or the survey year, whichever is first. The reason for the 29 year cutoff is that the majority of women have their children before they turn 30. Furthermore, it is useful for examining whether there is a “catch up” effect later in life. The average number of shocks for the 15 year period during the early fertile period is 0.8, with a standard deviation of 0.7 and a minimum of zero and a maximum of 5. This is in line with the predicted number of shocks based on the risk measure, in that a woman exposed to the average risk would expect to see around 0.7 hurricanes during the 15 year period.

The individual and household characteristics are age, ethnicity and land ownership, area of residence, altitude and geographical region. Since the fertility measures are cumulative and not completed fertility, the woman's age and her age squared (divided by 100) are included.[27] There are three ways that higher risks can affect the age profile of fertility. First, women can begin having children earlier than they would otherwise have. Second, they can continue having children later in life. Finally, they can have children more closely spaced. The mother's age and age squared are interacted with the risk measure to capture these effects.

Another age related effect is the possibility of "catch-up" fertility. Women who have been exposed to a shock while young could compensate for the negative impacts on fertility when older.[28] To capture this a dummy for being between 35 and 49 years old at the time of the survey is interacted with the number of shocks experienced by the woman when she was between 15 and 29 years of age. If women are able to compensate for shocks by having children later in life the estimated effect of the interaction should be positive.

A dummy for belonging to an indigenous group captures ethnicity, with the excluded group being "ladino". The majority of the indigenous peoples are various groups of Mayan with a very small number who are Garifuna or Xinka. In the sample the indigenous group comprises slightly less than half of all women.

The main household characteristic is ownership of land. There are two variables in the survey that capture how much land a household has: The area owned and the (self-evaluated) value of this land. The value of land may change over time and the quality of land can vary widely even within small geographical areas and there is no direct information on quality. Instead a dummy variable for whether the household owns land is used. Just less than half of the sample live in households that own land.

Beside the direct effects of access to land on fertility, both risk and shocks are likely to have different effects depending on whether a household owns land or not. A child may, for example, be of more use as "insurance" if a household owns land, since children can play a special role during the immediate aftermath of a hurricane. To capture this and other possible differences the risk and shocks measures are interacted with the land dummy variables. In addition age and age squared are

[27] An alternative is to use age dummies, but this would not easily allow for interactions with the risk measure.

[28] Recall that the number of shocks between age 15 and 29 is the measure of shocks.

interacted with the interaction between land ownership and risk to capture the possibility that the age profile of fertility might be different between landed and non-landed households for different levels of risk. Finally, to examine whether there is a difference in the compensation in fertility after a shock between the two groups, shocks are interacted with the interaction between owning land and the dummy for being 35 to 49 years of age.

A potentially important issue is whether the risk measure captures only the risks or whether it also pick up unobservable area characteristics which might influence the fertility decisions of the households. To overcome this, the explanatory variables include dummies for the 22 departments, with the Guatemala Department, where Guatemala City is located, as the excluded category.[29] These dummies, however, clearly only account for some of the geographical variation and the explanatory variables therefore also include a fourth-order polynomial in altitude. The main reason for this is that altitude is an important factor in what type of crops can be grown in an area, something which might affect the fertility decision directly.[30] Finally, a dummy for an area being purely rural is included.[31]

Before moving on to the results is it worth discussing some of the explanatory variables which are not included and why. In the individual and household characteristics some would consider whether a woman is married to be a relevant variable. Marital status is, however, not an appropriate explanatory variable since it is closely connected with the decision to have children and it therefore determined by the same factors. Including an endogenous variable may lead to bias in both the affected parameter *and* the other estimated parameters. Having rented land is also likely to be endogenous to the decision on how many children to have and the same is the case for the

[29] Using department dummies can also partly capture the effect of the civil war, which began in 1960 and lasted 36 years and resulted in more than 200,000 dead. The disruption and turmoil resulting from the civil war may have a substantial impact on both fertility and education, but finding a suitable way of capturing these effects is difficult. The five departments with the highest number of massacres were Chimaltenango, Huehuetenango, Quiche, Baja Verapaz and Alta Verapaz.

[30] Since there is little directly relevant information in the estimated parameters for department and altitude they are not presented in the descriptive statistics or in the results below. The full tables are available on request.

[31] The reason that the rural dummy is not interacted with the other variables, especially the risk and shocks variables, is that these interactions add very little to the overall results, except by increasing the standard errors of the estimated parameters. This is to be expected given that the so-called urban areas in the sample have a substantial amount of agricultural activity in them. Results with the interactions are available from the author on request.

types of crops grown. A similar argument holds for most other individual and household variables not included. The most controversial is probably the exclusion of the mother's education as an explanatory variable. Since the parents of the mothers surveyed were likely faced with the same risk environment and this influenced their decisions on fertility and education, the mothers' education is endogenous and therefore excluded. Furthermore, the following section presents the determinants of adult education using the same risk measure and it would therefore be inconsistent to assume that the mother's education is exogenous here.[32]

There are also no controls for infant and child mortality in the area. The main issue is that infant and child mortality is, to some extent, a joint outcome with fertility, since having more children and possibly space them closer together can increase the mortality risk. In other words, parents trade off the increased mortality risk against the benefits of having more children. The effects of hurricanes and hurricane risk on mortality are estimated below to examine if higher mortality can explain the effect of the risk of hurricanes on fertility.

Finally, most of the often included community variables, such as access to health services, schools or markets, have also been left out since the risk environment is likely to have a significant effect on how a community develops and hence whether these services are available. A community with a high hurricanes risk may, for example, be less likely to have a well developed infrastructure. Hence, if the explanatory variables include infrastructure the full effect of risks and shocks on mothers' behavior would not be captured.

As mentioned above a potentially important issue is whether the risk measure is picking up unobservable area characteristics that influence fertility and education decisions. Given this possibility and the exclusion of variables just discussed Appendix B presents municipality fixed effect estimations corresponding to all of the main regressions. The advantage of using municipality fixed effects are that all municipality characteristics are removed and therefore cannot bias the results. This means that variables such as access to schools, infrastructure, municipality level land quality, whether one municipality is richer or poorer than another or any unobservable character-

[32]The results for the determinants of fertility with the mother's educational attainment and its square show qualitative similar results and are available upon request.

istics influencing fertility and education decisions, no longer have an impact. While it is clearly not possible to identify the *level* effects of hurricane risk, since it is measured at the municipality level, one can still identify the *relative* effects between groups and hence the fixed effects results can serve as consistency checks on the OLS estimations. If the relative effects from the fixed effect estimations are similar to the relative effects from the OLS estimations this is an indication that the excluded variables discussed above and unobservable municipality characteristics do not have important effects on how households respond to hurricane risk and that the estimated effect of hurricane risk is not capturing other characteristics of the municipality. Finally, note that it is possible to identify the level effects of hurricane shocks since they vary within a municipality depending on age.

## 4.2 Results

Table 2 presents the results for the number of children born and the results for the number of children alive are in Table 3.[33] Each table shows seven different specifications. The first is the baseline regression with just the background variables. The second and third add risk and risk interacted with land ownership, while Model IV also includes the age and risk interactions, both on their on own and interacted with land. Specifications V and VI are the same as Model I, but with shocks added. Model V has just the shocks and shocks interacted with being 35 to 49 years of age, while VI also include these two shocks variables interacted with land ownership. Finally, Model VII is the complete specification with both risk and shocks and all of the interactions.

Overall the results for the two outcomes are very similar. In the basic model (II) there is no significant effects of risk on fertility. This, however, changes if one adds an interaction between risk and land ownership (Model III). An increase in the risk of a hurricane leads to a statistically significant increase in fertility for households that own land, while there is a negative but not statistically significant effect on those without land. The sizes of the effects are, however, relatively

[33]F-tests of combined parameters are presented in Table C-1 and the municipality fixed effects results are in Tables B-1 and B-2.

Table 2: Effects of Risks and Shocks on Number of Children Born

| | Model I | Model II | Model III | Model IV | Model V | Model VI | Model VII |
|---|---|---|---|---|---|---|---|
| Age | 0.390*** | 0.390*** | 0.390*** | 0.216** | 0.451*** | 0.457*** | 0.248*** |
| | (0.019) | (0.019) | (0.019) | (0.087) | (0.045) | (0.046) | (0.091) |
| Age squared | −0.276*** | −0.276*** | −0.276*** | −0.078 | −0.388*** | −0.402*** | −0.143 |
| | (0.033) | (0.033) | (0.033) | (0.153) | (0.088) | (0.088) | (0.160) |
| Indigenous | 0.464*** | 0.463*** | 0.461*** | 0.461*** | 0.460*** | 0.463*** | 0.456*** |
| | (0.069) | (0.069) | (0.069) | (0.069) | (0.068) | (0.068) | (0.068) |
| Owns land | 0.031 | 0.032 | −0.504* | −0.537* | 0.030 | 0.158* | −0.316 |
| | (0.062) | (0.062) | (0.296) | (0.294) | (0.062) | (0.091) | (0.308) |
| Hurricane risk (%) | | −0.016 | −0.052 | −0.615** | | | −0.648** |
| | | (0.069) | (0.070) | (0.251) | | | (0.269) |
| Risk × owns land | | | 0.116* | −0.100 | | | −0.162 |
| | | | (0.062) | (0.115) | | | (0.233) |
| Risk × age | | | | 0.034* | | | 0.036* |
| | | | | (0.019) | | | (0.021) |
| Risk × age$^2$ | | | | −0.045 | | | −0.047 |
| | | | | (0.034) | | | (0.038) |
| Risk × age × owns land | | | | 0.007 | | | 0.011 |
| | | | | (0.008) | | | (0.019) |
| Risk × age$^2$ owns land | | | | 0.003 | | | −0.002 |
| | | | | (0.014) | | | (0.037) |
| Hurricane shocks (age 15 - 29) | | | | | −0.437*** | −0.250*** | −0.291*** |
| | | | | | (0.082) | (0.095) | (0.113) |
| Shocks × age 35 - 49 | | | | | 0.401** | 0.094 | 0.268 |
| | | | | | (0.200) | (0.210) | (0.276) |
| Shocks × owns land | | | | | | −0.427*** | −0.332** |
| | | | | | | (0.097) | (0.162) |
| Shocks × age 35 - 49 × owns land | | | | | | 0.707*** | 0.174 |
| | | | | | | (0.123) | (0.399) |
| Constant | −6.501*** | −6.436*** | −6.286*** | −3.154*** | −7.013*** | −7.124*** | −3.345*** |
| | (0.320) | (0.439) | (0.442) | (1.149) | (0.543) | (0.546) | (1.176) |
| Observations | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 |
| R-squared | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.58 |
| Adj. R-squared | 0.56 | 0.56 | 0.56 | 0.57 | 0.57 | 0.57 | 0.57 |

**Note.** Robust standard errors in parentheses, clustered at the household level; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variables (not shown) are department and rural dummies and a fourth-order polynomial in altitude.

small. To provide an idea of the magnitude consider a one percentage point increase in hurricane risk. This would lead to an increase in the number of children of only about 0.05 for land-owning households. Recall, however, that this is based on the entire sample of women aged 15 to 49 and that the most likely way to increase fertility is by continuing to have children later in life. One way to capture this possibility is to introduce the interactions between the two age variables and the risk and risk interacted with land. This is done in Models IV and VII. The main drawback is that since the effect is no longer linear it is more difficult to directly interpret the effects of an increase

Table 3: Effects of Risks and Shocks on Number of Children Alive

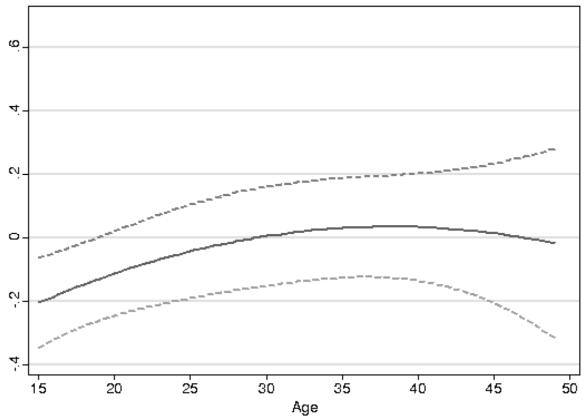
| | Model I | Model II | Model III | Model IV | Model V | Model VI | Model VII |
|---|---|---|---|---|---|---|---|
| Age | 0.406$^{***}$ | 0.406$^{***}$ | 0.406$^{***}$ | 0.214$^{***}$ | 0.461$^{***}$ | 0.465$^{***}$ | 0.248$^{***}$ |
| | (0.017) | (0.017) | (0.017) | (0.078) | (0.041) | (0.041) | (0.082) |
| Age squared | −0.346$^{***}$ | −0.346$^{***}$ | −0.346$^{***}$ | −0.099 | −0.447$^{***}$ | −0.456$^{***}$ | −0.169 |
| | (0.030) | (0.030) | (0.030) | (0.137) | (0.079) | (0.080) | (0.145) |
| Indigenous | 0.317$^{***}$ | 0.315$^{***}$ | 0.313$^{***}$ | 0.314$^{***}$ | 0.313$^{***}$ | 0.315$^{***}$ | 0.308$^{***}$ |
| | (0.062) | (0.063) | (0.063) | (0.062) | (0.062) | (0.062) | (0.062) |
| Owns land | 0.037 | 0.039 | −0.482$^{*}$ | −0.519$^{**}$ | 0.037 | 0.167$^{**}$ | −0.326 |
| | (0.056) | (0.056) | (0.266) | (0.264) | (0.055) | (0.083) | (0.276) |
| Hurricane risk (%) | | −0.030 | −0.066 | −0.667$^{***}$ | | | −0.744$^{***}$ |
| | | (0.062) | (0.063) | (0.225) | | | (0.241) |
| Risk × owns land | | | 0.113$^{**}$ | −0.054 | | | −0.012 |
| | | | (0.056) | (0.103) | | | (0.205) |
| Risk × age | | | | 0.039$^{**}$ | | | 0.045$^{**}$ |
| | | | | (0.017) | | | (0.019) |
| Risk × age$^2$ | | | | −0.055$^{*}$ | | | −0.065$^{*}$ |
| | | | | (0.031) | | | (0.034) |
| Risk × age × | | | | 0.005 | | | −0.000 |
| owns land | | | | (0.007) | | | (0.017) |
| Risk × age$^2$ | | | | 0.003 | | | 0.016 |
| owns land | | | | (0.013) | | | (0.033) |
| Hurricane shocks | | | | | −0.435$^{***}$ | −0.268$^{***}$ | −0.339$^{***}$ |
| (age 15 - 29) | | | | | (0.074) | (0.085) | (0.101) |
| Shocks × age 34 - 49 | | | | | 0.375$^{**}$ | 0.126 | 0.376 |
| | | | | | (0.182) | (0.191) | (0.251) |
| Shocks × owns land | | | | | | −0.376$^{***}$ | −0.233 |
| | | | | | | (0.090) | (0.144) |
| Shocks × age 35 - 49 × | | | | | | 0.567$^{***}$ | −0.059 |
| owns land | | | | | | (0.111) | (0.355) |
| Constant | −6.500$^{***}$ | −6.376$^{***}$ | −6.230$^{***}$ | −3.037$^{***}$ | −6.952$^{***}$ | −7.046$^{***}$ | −3.235$^{***}$ |
| | (0.290) | (0.393) | (0.397) | (1.035) | (0.492) | (0.496) | (1.064) |
| Observations | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 |
| R-squared | 0.55 | 0.55 | 0.55 | 0.56 | 0.56 | 0.56 | 0.56 |
| Adj. R-squared | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.56 | 0.56 |

**Note.** Robust standard errors in parentheses, clustered at the household level; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variables (not shown) are department and rural dummies and a fourth-order polynomial in altitude.

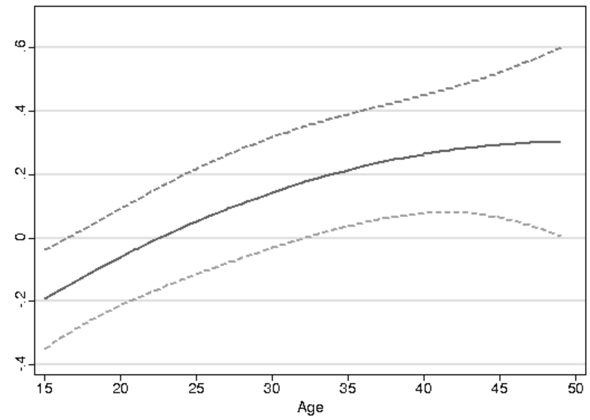
in hurricane risk. Figures 2 and 3 therefore graph the estimated marginal effects of an increase in hurricane risk on the number of children born and children alive by the age of the mother together with the upper and lower bounds of the 95 percent confidence interval.[34] In both figures, panels (a) and (b) are from Model IV, which is the specification without shocks, and panels (c) and (d) are from Model VII, which includes the shock variables.

The main result is how the risk of hurricanes affects the number of children born and the

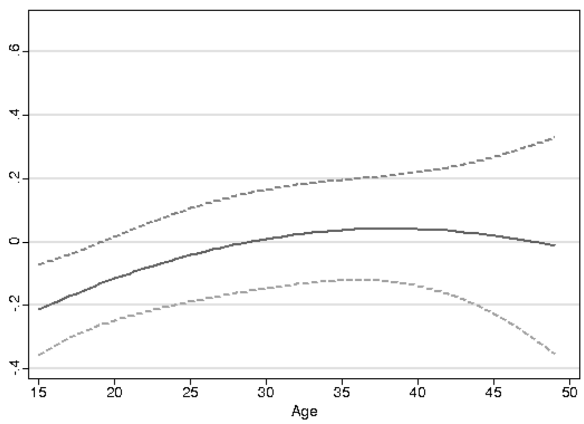
[34]The confidence interval is calculated using the delta method.



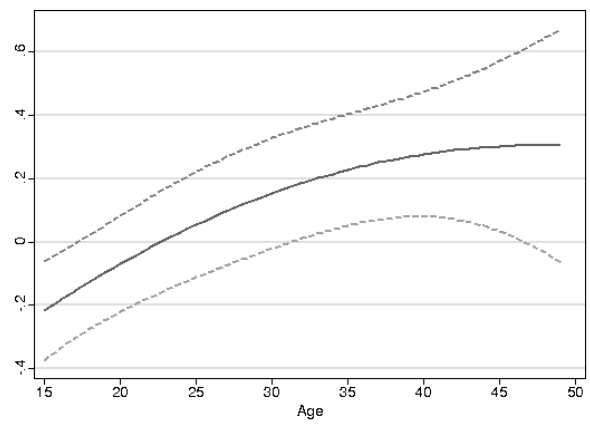

(a) Model IV for Landless




(b) Model IV for Land Owners




(c) Model VII for Landless



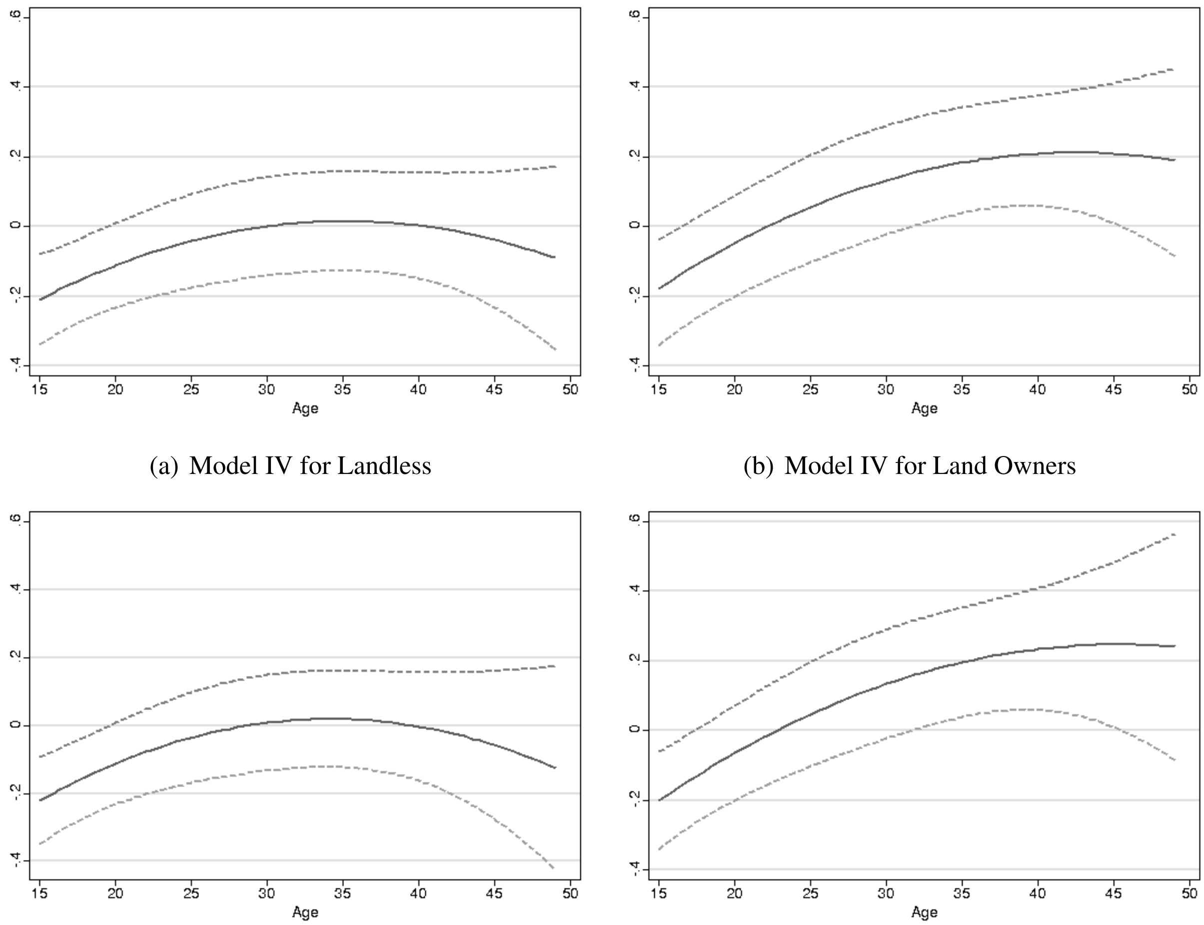

(d) Model VII for Land Owners

Figure 2: Marginal Effect of Hurricane Risk on Number of Children Born

number of children alive for households that own land.[35] The predicted marginal effect of hurricane risk on fertility is positive from around age 23, and becomes statistically significant at age 32 and remains so until slightly after age 45.[36] Hence, higher hurricane risk leads to higher fertility for households with land. Furthermore, the estimated effect of hurricane risk on fertility is now substantial. For women aged 45 the effect of a one percentage point, about one standard deviation, increase in hurricane risk is now about 0.3 children. With a more than four percentage points difference between the highest and the lowest risk areas this corresponds to an difference of more

[35] Since the results are essentially the same for the four different versions focus here is on Figure 2(d), which is the preferred specification.

[36] The most likely explanation for the widening of the confidence interval is that, consistent with the young age distribution in Guatemala, there are relatively fewer older women compared to younger women. Women age 45 to 49 comprise less than ten percent of the sample.




(a) Model IV for Landless (b) Model IV for Land Owners

(c) Model VII for Landless (d) Model VII for Land Owners

Figure 3: Marginal Effect of Hurricane Risk on Number of Children Alive

than one child. For comparison the average number of births for women aged 45 and older is 5.5. As expected the effect on the number of children alive is somewhat lower but still substantial, providing a first indication that mortality is not the main reason for the higher number of children in more risk prone areas.[37]

There is no statistically significant effect of hurricane risk on either fertility or children alive for households without land. The one caveat to this result is that there does appear to be a tendency for very young women to have fewer children in areas with higher risk of hurricanes and this holds for both household with and without land and the effect is statistically significant until around age 18. One possible interpretation is that women in more risk prone areas postpone their childbearing

[37]The relation between hurricanes and child mortality will be discussed in more detail below.

compared with women with similar characteristics in less risk prone areas, for example because of pursuing education.

Models V and VI show the results when including shocks, which is measured as the number of hurricanes during the mother's main childbearing years (15 to 29 years of age). The number of hurricanes has a large and statistically significant negative effect in both models. In Model V each hurricane reduces the number of children born by just over 0.4. Interacting the number of hurricanes with land ownership in Model VI shows that the reduction is especially pronounced for households that own land. The effect for households without land is now about 0.25, which is still statistically significant, while the reduction in the number of children for women in households with land is around 0.65 per hurricane, which is strongly statistically significant.

The reduction in fertility following a hurricane is, however, only part of the story. The interaction between the number of hurricanes experienced between 15 and 29 years of age and being between 35 and 49 years old at the time of the survey shows that the mother is able to, at least partly, compensate for the reduction in fertility following a shock by having the children later. For women without land the combined effect is about -0.15, while for women with land the effect on fertility is 0.12. It is impossible to reject that any of these combined effects of the number of hurricanes and the interaction with being older are different from zero. Note, however, that it clearly becomes less likely that the mother will be able to fully compensate for the reduction in fertility for shocks that take place later in life.[38]

It is worthwhile briefly examining how the estimated effects of shocks change when hurricane risk and the interactions with risk described above are included. For households without land the direct effect of shocks on fertility and children alive becomes larger (from -0.25 to -0.29 for fertility and from -0.27 to -0.34 for children alive), but when the interaction with being 35 to 49 years of age is included the combined effect is essentially zero. The results for households with land show a smaller direct effect, but a much smaller catch-up effect than when risk measures are not included. The combined effects of shocks and being older is -0.18 for fertility and -0.26 for children alive.

[38]Including the number of hurricanes a women has experienced between age 35 and 49 does not yield any statistically effect, mainly due to the relatively low number of women in this age group.

Hence, women from households with land are on average not completely able to make up the number of births lost to hurricane shocks, although note that neither of those combined effects are statistically significant.

Finally, comparison of the OLS results above with the municipality fixed effects estimations shown in Tables B-1 and B-2 reveals only very minor differences in the estimated parameter values. This holds for both fertility and number of children alive. Hence, it appears that the risk measure is not simply capturing unobservable area characteristics but have a strong, direct and independent effect on fertility.

## 4.3 The Relation between Hurricanes and Mortality

As Section 2 discusses, one possible explanation why higher risk can lead to higher fertility is an increase in mortality. That the results above are nearly identical for fertility and the number of children alive indicates that this is unlikely to be the complete story. It is, however, worthwhile examining the possibility in more detail. The remainder of this section does that by estimating how mortality is affected by hurricane risk and the number of hurricanes experienced.

Given the lack of information on children who have died and those who have moved out of the household the data is not ideal for analyzing mortality, but it nonetheless possible since there is information on both the number of children born and children alive. This means that the unit of analysis is the mother and not the child, which would be more appropriate. Furthermore, since the women are between 15 and 49 years old, their children can be anywhere between zero and 35 years old at the time of the survey. Out of the 6,648 women in the sample 4,507 have given birth to at least one child and they form the basis for the analysis of mortality. Among the women with at least one child, 73 percent in households with land and 82 percent of those without land did not suffer the death of a child, while 15 and 10 percent had one death, and 6 and 4 percent experienced two deaths.

The two mortality outcomes of interest here are whether the woman has ever lost a child and

Table 4: Descriptive Statistics — Mortality

| Variable | Mean | Std. Dev. |
|---|---|---|
| Number of deaths | 0.37 | 0.88 |
| Mortality dummy | 0.22 | 0.41 |
| Age | 31.95 | 8.94 |
| Age$^2$/100 | 11.01 | 5.89 |
| Indigenous | 0.45 | 0.50 |
| Owns land | 0.45 | 0.50 |
| Rural | 0.69 | 0.46 |
| Risk of hurricane (percent) | 4.65 | 0.97 |
| Risk of hurricane × owns land | 2.17 | 2.44 |
| Risk of hurricane × age | 148.16 | 52.10 |
| Risk of hurricane × age$^2$ | 50.99 | 29.77 |
| Risk of hurricane × age × owns land | 70.39 | 84.61 |
| Risk of hurricane × age$^2$ × owns land | 24.66 | 34.01 |
| Hurricane shocks | 1.38 | 0.81 |
| Hurricane shocks × owns land | 0.65 | 0.91 |
| Number of observations: 4507 | | |

the number of children who have died. The estimated equation is

$$M_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \tag{13}$$

where $M$ is the mortality outcome of interest, $X$ is a vector of individual and household variables, $R$ is a vector of risk, including interactions with individual and household variables and $S$ measures shocks. The main difference from above is how the number of hurricanes is measured. Since a hurricane can increase mortality both directly and through its negative impact on income, it presumably affects all ages and not just the very young. The number of hurricanes is therefore the total number a woman has experienced from age 15 until age 49 or the survey date. The average number of hurricanes is 1.4 with a standard deviation of 0.8. Furthermore, the maximum number of hurricane shocks is 6, although less than two percent of the women have experienced more than 3 hurricanes. Alternative specifications of the number of hurricanes lead to qualitatively identical results, but often results in low precision.[39] Table 4 provides the descriptive statistics.

Table 5 presents the results of OLS estimation of (13) with robust standard errors where the

[39] One possibility is to measure shocks as the number of hurricanes which have occurred during a certain age periods of the mother, such as 15-19, 20-24, etc.

Table 5: Effects of Risks and Shocks on Mortality

| | Probability of Mortality | | | Number of Deaths | | |
|---|---|---|---|---|---|---|
| | Model I | Model II | Model III | Model IV | Model V | Model VI |
| Age | −0.001 | 0.009* | −0.004 | 0.003 | −0.009 | 0.003 |
| | (0.024) | (0.005) | (0.024) | (0.048) | (0.013) | (0.048) |
| Age squared / 100 | 0.016 | 0.007 | 0.021 | 0.022 | 0.059** | 0.021 |
| | (0.038) | (0.009) | (0.038) | (0.078) | (0.024) | (0.079) |
| Indigenous | 0.106*** | 0.104*** | 0.106*** | 0.208*** | 0.207*** | 0.210*** |
| | (0.016) | (0.016) | (0.016) | (0.034) | (0.034) | (0.034) |
| Owns land | 0.052 | −0.024 | −0.031 | 0.035 | −0.161*** | −0.140 |
| | (0.070) | (0.025) | (0.078) | (0.135) | (0.055) | (0.157) |
| Hurricane risk (%) | 0.010 | | 0.025 | 0.074 | | 0.104 |
| | (0.078) | | (0.078) | (0.148) | | (0.148) |
| Risk × owns land | −0.091*** | | −0.118*** | −0.111 | | −0.166** |
| | (0.032) | | (0.033) | (0.072) | | (0.080) |
| Risk × age | 0.000 | | −0.001 | −0.006 | | −0.008 |
| | (0.005) | | (0.005) | (0.011) | | (0.011) |
| Risk × age squared | 0.000 | | 0.003 | 0.012 | | 0.017 |
| | (0.008) | | (0.008) | (0.018) | | (0.018) |
| Risk × age × | 0.005** | | 0.008*** | 0.005 | | 0.010* |
| owns land | (0.002) | | (0.002) | (0.005) | | (0.006) |
| Risk × age squared | −0.006** | | −0.012*** | −0.004 | | −0.016 |
| owns land | (0.003) | | (0.004) | (0.008) | | (0.011) |
| Hurricane shocks | | −0.026 | −0.047** | | −0.031 | −0.058 |
| | | (0.017) | (0.021) | | (0.041) | (0.045) |
| Shocks × owns land | | 0.033** | 0.067** | | 0.112** | 0.138* |
| | | (0.016) | (0.031) | | (0.043) | (0.079) |
| Constant | −0.076 | −0.176* | 0.010 | −0.149 | −0.049 | −0.093 |
| | (0.369) | (0.096) | (0.376) | (0.693) | (0.221) | (0.702) |
| Observations | 4507 | 4507 | 4507 | 4507 | 4507 | 4507 |
| R-squared | 0.12 | 0.12 | 0.13 | 0.14 | 0.14 | 0.14 |
| Adj. R-squared | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 | 0.13 |

**Note.** Robust standard errors in parentheses, clustered at the household level; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variables (not shown) are department and rural dummies and a fourth-order polynomial in altitude.

cluster level is the household.[40] Models I and IV include the annual hurricane risk in percent, the risk interacted with owning land, age and age squared and the age interactions interacted with owning land. Models II and V include the number of hurricanes and its interaction with owning land. Finally, Models III and VI combine the risk and shock variables and are the preferred specifications.

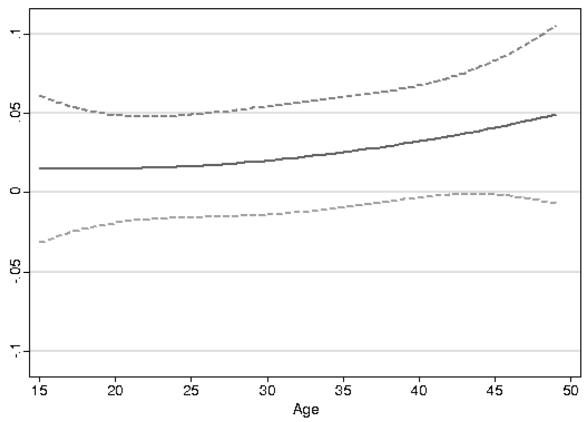
The main variables of interests are the two shock variables. For all models the interaction

[40]The results using probit for the binary variable and tobit for the number of children are available on request. The results are qualitatively the same. F-tests for combined parameters are in Table C-2 and the municipality fixed effect results are in Table B-3.

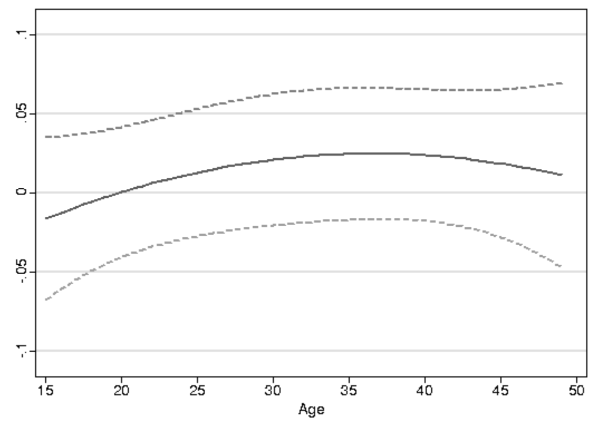
between number of hurricanes and land ownership is positive and statistically significant, although the net effects are relatively small. One extra hurricane leads an only two percentage point increase in the probability of having a child die. For the number of children who have died an additional hurricane increases the number by less than 0.1 children.

For women without land the effect of hurricanes on mortality is negative and is statistically significant in Model III. Since the results above show that there is a negative effect of hurricanes on the number of children born, it may be that a women hit by a higher number of hurricane both delay childbearing and end up with a lower number of children. Both of these should lead to lower mortality risk. This explanation points, however, to an issue with analyzing mortality using this data set. Since it is not possible to follow individual children, a woman's children may not even have been born when the hurricane hit. In essence the fertility and the mortality effects of hurricanes are confounded, which may explain the relatively low effects on mortality. Given, however, that the effect of hurricane risk on the number of children alive is statistically significant and large, it is unlikely that a mortality effect can explain more than a small part of the increase in fertility from increasing hurricane risk. For the sake of argument assume that a women in a high risk area can expect three hurricanes over a period of time, which would be equal to a reduction in the number of surviving children of less than 0.3 for a household with land. Even if this is significantly biased downward there is still a substantial gap to the 1.2 births increase in completed fertility that results from going from the lowest to the highest hurricane risk.

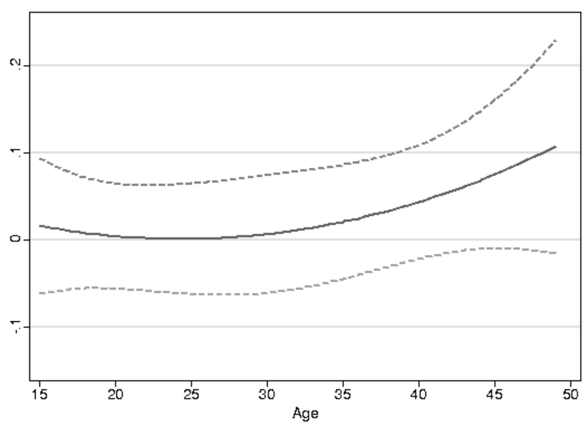
Before turning to how risk affects investment in education, it is worth briefly looking at the effect of hurricane risk on mortality. Since higher risk leads to higher fertility one might also expect a higher mortality if less resources are devoted to each child as a result. This "second-order" effect has attracted some attention in the literature on child mortality in developing countries, although it generally has been hard to identify (Wolpin 1997). Figure 4 shows the marginal effect of risk by age for Models III and VI for households without land and households with land together with the upper and lower bounds of the 95 percent confidence interval. Interestingly, there appear to be little difference in how risk affect mortality between household with and households without land although the effect is generally positive for both. Somewhat contrary to expectations the households without land is closer to showing a statistically significant marginal effect of hurricane risk on mortality. For both the probability of mortality in Figure 4(a) and the number of deaths in Figure 4(c) the effect is statistically significant at the ten percent level for age 40 and above.



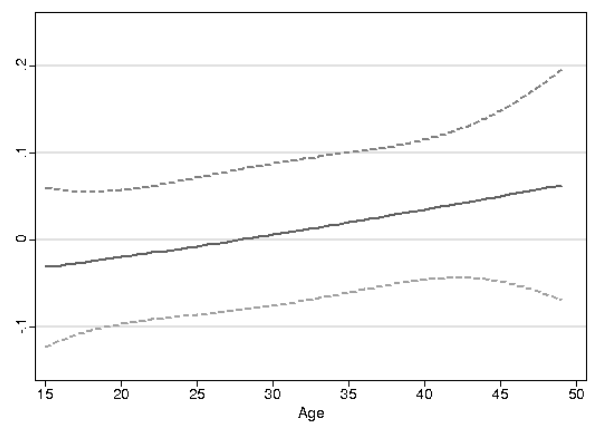

(a) Model III for Landless




(b) Model III for Land Owners




(c) Model VI for Landless




(d) Model VI for Land Owners

Figure 4: Marginal Effect of Hurricane Risk on Probability of Mortality and Number of Deaths

As for the fertility estimations above, there is very little difference between the mortality OLS estimates and the municipality fixed effects estimates shown in Table B-3. This holds for both the probability of mortality and for the number of deaths. Hence, it is unlikely that the hurricane risks and shocks measures are capturing some underlying unobservable area characteristics that drive the results for fertility and mortality.

# 5 Education, Risk and Shocks

This section examines the effects of hurricane risk and shocks on educational attainment. It first discusses the econometric model and the selection of the sample. Then is introduces the variables and their expected effects. Third, it presents and discusses the results. Finally, it looks at the return to education and how it interacts with the risk of hurricanes.

There are a number of different ways to specify educational attainment. The measures here is number of years of education, based on the highest grade reached. Hence, repeating a year does not count as additional education.[41] The estimated equation is

$$E_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \tag{14}$$

where $E$ is the years of schooling achieved, $X$ is a vector of individual and household variables, $R$ is a vector of risk, including interactions with individual and household variables and $S$ measures shocks. Again the estimation method is OLS with robust standard errors where the cluster level is the household.

The sample consists of all adults aged 20 to 69 years of age, who were not born in a city or in the Municipality of Guatemala (the capital and surrounding areas). Hence, selection is strictly by place of birth, not where somebody currently resides. This is the sample that corresponds best to the sample used in the fertility estimations above. If migration, of either an individual or a complete household, is an important response to hurricane risk and shocks then only looking at the population currently in the rural areas would bias the estimations. Since the survey is nationally representative this sample should furthermore closely resemble a representative sample of educational attainment for the areas of interest.

Migration is also one of the main reason why the schooling information on the children born to the women in the sample is not useable. Since the survey does not collect information on children who have either left the household or died this is not the complete sample of children born. With

[41] Alternative measures are be binary variables such as “any schooling”, “finished primary” etc., depending on the level of interest. Those results are available on request and lead to qualitatively identical results.

substantial migration it is likely that the education level of the sample will be different from that of the the true population. Furthermore, it is not clear *a priori* what the direction of the bias will be. On one hand, it is possible that those who are most exposed to risks and shocks end school sooner and therefore leave the household. This would lead to an underestimation of the effects of risks and shocks, since what will be left is the part of the population that for one reason or another were better able to withstand a shock. This could, for example, be children who have higher abilities and therefore are more likely to be kept in school by their parents.[42] On the other hand, it is also possible that children from households that can better withstand shocks are more likely to leave the household to go to a (better or higher level) school somewhere else. In that case the sample consists of children who are more likely to be affected by risks and shocks which results in an overestimate of the effect, especially if the remaining children stay in the household but do not go to school.

## 5.1 Variables

Table 6 presents the descriptive statistics for the variables.[43] As above the explanatory variables fall into three groups: Individual and household variables, risks and risk interactions and finally shocks, although the definitions for shocks are different from above. This section discusses these after examining the dependent variable. The average education is relatively low at about 3.4 years and about 40 percent of the sample has no education at all. Just over 15 percent has more than a primary education (equal to six years of education), and less than 3 percent have more than a secondary education.

The main variables of interest are those that reflect the hurricane risk of an an area. Risk is again measured as the percent annual risk of experiencing a hurricane. Since people can move between areas an important question is which municipality to base the risk measure on. For those who are born in the same area that they are currently living in there is no problem. For those

[42]See, however, Beegle, Dehejia, and Gatti (2004) for an example where it appears that the opposite is the case. Those with lower abilities are more likely to go to school.

[43]Table C-3 shows the F-test for combined parameters and Table B-4 presents the municipality fixed effects results.

Table 6: Descriptive Statistics — Education

| Variable | Mean | Std. Dev. |
|---|---|---|
| Education in years | 3.38 | 4.10 |
| Female | 0.53 | 0.50 |
| Age 30-39 | 0.24 | 0.43 |
| Age 40-49 | 0.19 | 0.39 |
| Age 50-59 | 0.14 | 0.34 |
| Age 60-69 | 0.09 | 0.28 |
| Indigenous | 0.45 | 0.50 |
| Parent's owned land | 0.27 | 0.44 |
| Female × owned land | 0.23 | 0.42 |
| Risk of hurricane (percent) | 4.60 | 1.01 |
| Risk of hurricane × owned land | 1.24 | 2.11 |
| Risk of hurricane × female | 2.43 | 2.41 |
| Risk of hurricane × owned land × female | 0.62 | 1.61 |
| Hurricane shocks (age 0-6) | 0.54 | 0.71 |
| Hurricane shocks (age 0-6) × owned land | 0.15 | 0.44 |
| Hurricane shocks (age 0-6) × female | 0.28 | 0.59 |
| Hurricane shocks (age 0-6) × owned land × female | 0.07 | 0.32 |
| Hurricane shocks (age 7-12) | 0.40 | 0.65 |
| Hurricane shocks (age 7-12) × owned land | 0.10 | 0.36 |
| Hurricane shocks (age 7-12) × female | 0.22 | 0.52 |
| Hurricane shocks (age 7-12) × owned land × female | 0.05 | 0.27 |
| Number of observations: 12331 | | |

who moved into their current municipality after turning 13 years old or older, the risk from the municipality they were born in is used. Finally, if a person moved into their current municipality before turning 13 years old the risk measure from the current municipality is used. The cutoff age of 13 is based on the approximate age when finishing primary education. Other cutoff ages leads to practically identical results. The average annual risk of being hit by a hurricane is around 4.5, with a minimum of 3.4 and a maximum of 7.6. In addition to the interaction between risk and ownership of land there are now also two interactions with being female. First is the risk interacted with female and second is the interaction of being female with the interaction between risk and land ownership. These capture possible different responses to risk by land ownership status and sex.

Deciding on a measure of shocks is more complicated. Here, two different measures of shocks are used. The first is the number of shocks that have occurred between the person's birth year and the year they turn six. The second is the number of shocks that have occurred between the year the child is supposed to begin school (at age seven) and their 13th year, which is when most students finish their primary education. These two measures capture shocks that have an effect on the likelihood of entering school and shocks that affect whether you remain in school, respectively. One complication is that the second shock measure is most likely to have an effect on individuals who were enrolled at the time of the shocks. For those who have never enrolled or have already left school before finishing primary the only effect of these shocks would be to decrease the chance of (re)entering school. Hence, one might expect less clear results from the analysis of the effects of shocks on education than on fertility. For the zero to six shock measure the average number of hurricanes is 0.5, while it is 0.4 for the seven to thirteen shock measure. In both cases the maximum number of hurricanes is four, although in both cases less than one percent were hit by more than two hurricanes. The two shock variables are interacted with a dummy for female and a dummy for land ownership and the complete interaction between all three.

Finally, the individual and households variable are mainly as above. The main differences are that five age dummies, with 20 to 29 years old as the excluded variable, is used and that there now is a dummy for being female. Furthermore, the interaction between female and land ownership is also included.

## 5.2 Results

Table 7 presents the results for the determinants of educational attainment.[44] There are six different specifications. Model I is the baseline model which does not include risk or shocks, while Model II adds the hurricane risk and the hurricane risk interacted with land. To allow for differences between boys and girls Model III interacts the risk variables with a dummy for being female. Model IV extends Model I with the two measures of hurricane shocks and the interaction with land ownership, while Model V also allows the effects of the shocks to vary by sex. Finally, Model VI is the complete specification.

There is a statistically significant and substantial positive effect of hurricane risk on educational

[44]The results using a Tobit model are qualitatively identical and are available on request.

Table 7: Effects of Risks and Shocks on Education — OLS

| | Model I | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|---|
| Female | −0.868*** | −0.874*** | −0.335 | −0.869*** | −0.660*** | −0.221 |
| | (0.075) | (0.074) | (0.297) | (0.075) | (0.105) | (0.301) |
| Age 30-39 | −0.934*** | −0.940*** | −0.942*** | −0.708*** | −0.700*** | −0.604*** |
| | (0.105) | (0.105) | (0.105) | (0.157) | (0.157) | (0.157) |
| Age 40-49 | −1.594*** | −1.604*** | −1.607*** | −1.502*** | −1.499*** | −1.472*** |
| | (0.108) | (0.108) | (0.108) | (0.118) | (0.118) | (0.118) |
| Age 50-59 | −2.614*** | −2.623*** | −2.625*** | −2.575*** | −2.567*** | −2.558*** |
| | (0.103) | (0.103) | (0.103) | (0.110) | (0.110) | (0.110) |
| Age 60-69 | −3.160*** | −3.172*** | −3.178*** | −3.200*** | −3.190*** | −3.224*** |
| | (0.114) | (0.114) | (0.114) | (0.117) | (0.117) | (0.117) |
| Indigenous | −2.313*** | −2.290*** | −2.289*** | −2.314*** | −2.310*** | −2.287*** |
| | (0.120) | (0.120) | (0.120) | (0.120) | (0.120) | (0.120) |
| Parents owned land | −0.070 | 0.942** | 0.966** | 0.007 | 0.024 | 1.006** |
| | (0.086) | (0.413) | (0.413) | (0.119) | (0.119) | (0.413) |
| Female × owned land | −0.960*** | −0.960*** | −0.982*** | −0.959*** | −0.997*** | −0.988*** |
| | (0.095) | (0.095) | (0.097) | (0.095) | (0.096) | (0.097) |
| Risk of hurricane (percent) | | 0.313*** | 0.385*** | | | 0.407*** |
| | | (0.095) | (0.102) | | | (0.103) |
| Risk of hurricane × owned land | | −0.220** | −0.249*** | | | −0.219** |
| | | (0.086) | (0.088) | | | (0.090) |
| Risk of hurricane × female | | | −0.128** | | | −0.099 |
| | | | (0.064) | | | (0.065) |
| Risk of hurricane × owned land × female | | | 0.047 | | | −0.005 |
| | | | (0.029) | | | (0.043) |
| Hurricane shocks (age 0-6) | | | | −0.083 | 0.082 | 0.015 |
| | | | | (0.083) | (0.105) | (0.108) |
| Hurricane shocks (age 0-6) × owned land | | | | −0.169 | −0.364** | −0.338** |
| | | | | (0.108) | (0.143) | (0.161) |
| Hurricane shocks (age 0-6) × female | | | | | −0.303*** | −0.298** |
| | | | | | (0.109) | (0.116) |
| Hurricane shocks (age 0-6) × owned land × female | | | | | 0.360** | 0.383* |
| | | | | | (0.166) | (0.206) |
| Hurricane shocks (age 7-12) | | | | −0.153 | −0.034 | −0.120 |
| | | | | (0.096) | (0.124) | (0.126) |
| Hurricane shocks (age 7-12) × owned land | | | | 0.030 | −0.016 | 0.006 |
| | | | | (0.127) | (0.186) | (0.199) |
| Hurricane shocks (age 7-12) × female | | | | | −0.219* | −0.208* |
| | | | | | (0.118) | (0.125) |
| Hurricane shocks (age 7-12) × owned land × female | | | | | 0.065 | 0.078 |
| | | | | | (0.208) | (0.244) |
| Constant | 6.469*** | 5.133*** | 4.836*** | 6.505*** | 6.392*** | 4.686*** |
| | (0.353) | (0.544) | (0.572) | (0.354) | (0.357) | (0.574) |
| Observations | 12331 | 12331 | 12331 | 12331 | 12331 | 12331 |
| R-squared | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| Adj. R-squared | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variables (not shown) are department dummies and a fourth-order polynomial in altitude.

attainment for those without land in all models. This fits nicely with the negative effect of hurricane risk on fertility for this group. Presumably these households trade off the number of children against investments in human capital for their children. Furthermore, while the effect of risk on education is lower for women than for men it is still statistically significant. Increasing hurricane risk by one percentage point increases schooling by 0.4 years for men and 0.3 for women.

The main result of interest is how hurricane risks affect the schooling of individuals from households with land. The estimated parameter for men is negative and statistically significant, but more importantly the total effect is an increase of 0.19 which is statistically significant. Hence, not only do households with land who live in more risk prone areas have more children, they also appear to educate their boys more than households in less risky areas. Furthermore, it should be kept in mind that the average educational attainment for men from households with land is just over 3 years. The difference between the highest and the lowest risk levels is about four percentage points, which would correspond to a difference in education of 0.8 years. For girls in households with land the effect of increasing risk is not statistically significant and less than half the size of the effect for boys. Note that most of the negative effect comes from the interaction between sex and risk, rather than from the triple interaction between sex, land and risk.

That households with and without land show higher levels of education is an important result. Given that households without land show lower fertility from higher hurricane risk it may not be surprising that education levels for their children are higher. Since, however, *both* fertility and education are increasing in hurricane risk for households with land it is worthwhile examining in more detail why education is positively correlated with hurricane risks. There are at least three possible explanations. First, returns to education could be higher in areas that are more risk prone. Second, if migration is an important insurance mechanism it may be beneficial to families in higher risk areas to invest more in their children's education. Finally, it is possible that education can increase the ability to deal with disequilibrium as was discussed in Section 2 (Schultz 1975) and that this might lead households to invest more in education.

While it is not possible to distinguish between the migration and the ability to deal with dis-

Table 8: Returns to Education and Hurricane Risks

| | Model I | Model II | Model III (Males) | Model IV (Females) |
|---|---|---|---|---|
| Female | 0.270 | 0.282 | | |
| | (0.210) | (0.210) | | |
| Age | 0.361*** | 0.360*** | 0.360*** | 0.375*** |
| | (0.068) | (0.068) | (0.081) | (0.122) |
| Age squared /100 | −0.368*** | −0.366*** | −0.356*** | −0.406*** |
| | (0.083) | (0.083) | (0.100) | (0.150) |
| Indigenous | −0.380* | −0.412** | −0.393* | −0.322 |
| | (0.194) | (0.195) | (0.234) | (0.355) |
| Rural | −0.610*** | −0.621*** | −0.588*** | −0.589** |
| | (0.166) | (0.166) | (0.204) | (0.289) |
| Education (years) | 0.803*** | 0.918*** | 0.999*** | 0.657*** |
| | (0.021) | (0.068) | (0.086) | (0.106) |
| Education × Female | −0.154*** | −0.156*** | | |
| | (0.031) | (0.031) | | |
| Hurricane Risk (%) | | −0.027 | 0.180 | −0.408 |
| | | (0.178) | (0.215) | (0.325) |
| Risk × education | | −0.025* | −0.042** | −0.001 |
| | | (0.014) | (0.018) | (0.022) |
| Constant | −3.616** | −3.559** | −4.490** | −1.572 |
| | (1.454) | (1.671) | (2.000) | (3.076) |
| Observations | 6561 | 6561 | 4321 | 2240 |
| R-squared | 0.31 | 0.31 | 0.34 | 0.27 |
| Adj. R-squared | 0.31 | 0.31 | 0.34 | 0.26 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variables (not shown) are department dummies and a fourth-order polynomial in altitude.

equilibrium explanations with the current data set, one can examine how the return to education varies by hurricane risk by estimating a wage equation with years of education and risk of hurricanes and their interaction plus a standard set of other explanatory variables.[45] The sample consists of adults between 24 and 65 who live outside of the Municipality of Guatemala. The results are in Table 8. Model I shows the results without hurricane risk, while Model II includes hurricane risk and the interaction with years of education. Models III and IV are identically to Model II but are split by sex with males in III and females in IV.

Clearly, it is unlikely that the higher education investment in males for both household with and without land is due to higher returns to education in those areas. In fact, the contrary seems to

[45]Note, that these results are mainly exploratory. There is no attempt to deal with questions of selection into wage labour or other issues, such as the return to education on own land.

be the case. As Model III shows there is a statistically significant negative effect of the interaction between hurricane risk and education. This is in line with both the story about human capital being less prone to destruction than physical capital leading to relatively more investment in human capital *and* the possibility that more education makes individuals better at dealing with shocks. Hence, the most likely explanation for why higher hurricane risk leads households with land to have more children and invest more in them is that they may need both more people to help with post-hurricane reconstruction and better educated people to deal with the lack of resources after a hurricane.

As expected shocks that occur before an individual begins school appear to have more of an impact than those that occur while the person is of school-going ages. While there is no statistically significant effect of hurricane shocks that occur between age 0 and 6 for men in household without land the effect is statistically significant and negative for women in the same households. For both men and women from households with land the effect is large, negative and statistically significant. One hurricane shock has an estimated negative effect on years of schooling of 0.32 for men and 0.24 for women. For the hurricanes that occur between age seven and twelve there is little effect on men's schooling, no matter whether they are from a household with land or without land. Women are, however, significantly negatively impacted with the largest negative impact for women from households without land. Since there is no information on the timing of schooling and all individuals in the sample have completed their schooling it is only possible to estimate the total effect of hurricane shocks. Hence, it is possible that the relatively small effect on boys' education of hurricane shocks between ages seven and twelve masks an immediate response of taking them out of school to help at home combined with having them stay in school to an older age to achieve almost the same level of education as in the absence of a hurricane shock.

In Table 7 there is more evidence of the potential biases that may result from looking exclusively at shocks or risk rather than both simultaneously, than in the estimations for fertility and mortality. At first blush there might not appear to be any substantial differences in the effects of hurricane risk on men's schooling between Model III and Model VI, but while the direct effect for men who grew up in households without land is only slightly larger (0.39 to 0.41) the effect does become more strongly significant. More importantly, the effect of hurricane risk on men in households with land becomes larger and statistically significant. In Model III the effect is 0.14, while it is 0.19 in Model VI which includes shocks. For women the pattern of changes is the same and the size of the changes are close to those of men. Women in households without land have a stronger positive and more statistically significant effect of risk on education when shocks are included, while for those in households with land the effect is larger but still far from statistically significant.

While the changes in the estimated parameters when including shocks are interesting in themselves the changes from Model V to VI are arguably more important since most of the previous literature have only included shocks. Hence, these changes can provide us with an idea of to what extent the bias from not having information on risk is important when analyzing the effects of shocks. The most obvious impact of including the risk variables is that the effect of shocks between age zero and six for men in households without land becomes substantially smaller and essentially zero, instead of the counterintuitive increase of close to 0.1 per hurricane shock. For men in landed households the negative effect of hurricanes becomes even more apparent going from -0.28 to -0.32 and an increase in statistical significance. The same happens for women with the effect for women in households without land going from -0.22 to -0.28 and -0.23 to -0.24 for women from landed households. As for shocks between age zero and six the effect of shocks between age seven and twelve also becomes more negative for all men. The important change is, however, what happens to the shocks parameters for women. For women without land the negative effect of a hurricane goes from -0.25 to -0.33 and becomes highly statistically significant. Even more interesting is the change for women with land for whom the effect changes from -0.20 to -0.24, the latter of which is statistically significant.

There are, however, also important changes in the background variables. What is particularly interesting is that the dummy for being female in the complete specification is one-third of what it is for the model that has only shocks and no risks. Furthermore, the effect is now far from being statistically significant. Hence, it appears that much of the variation which would be attributed to being female in Model V can be explained by including the risk variables and especially the interactions with being female. The reverse is the case for the land ownership dummy for parents with the estimated effect being about forty times bigger, and statistically significant, when the risk variables are added to the model.

Finally, while the correspondence between the OLS estimates and the municipality fixed effects in Table B-4 is not quite as close as for the fertility and mortality the parameter estimates are still very similar. This holds especially for the main variables of interest, the risk measures. For the shock variables the fixed effect estimates are generally slightly larger and more statistically significant than the corresponding OLS estimates.[46] Even despite the slightly larger differences here it is still unlikely that the positive effects of hurricane risk on, especially, men's education is due to unobservable community characteristics.

# 6 Conclusion

With risk a significant fact of life in developing countries it is important to analyse its effects on households' decisions. Two areas of special importance are education and fertility since they have a substantial impact on both individuals' welfare and countries' growth prospects. A recurring problem in the literature on risk coping is, however, that while data on shocks are often available it is significantly harder to capture risks.

This paper uses data on hurricanes in Guatemala over the last 120 years to create measures of risk and shocks. These data are combined with a household survey to analyse how decisions on fertility and education respond to risk and shocks. For households with land, an increase in the *risk* of hurricanes leads to *both* higher fertility and higher education, while households without land also have higher education but fewer children. That education is increasing in risk is fascinating, especially since fertility also increases for the households with land. As expected, hurricane

[46] By far the biggest difference is for the effect of shocks between age seven and twelve for women in households with land where the fixed effect estimate is -0.35 versus -0.24 with OLS.

*shocks* lead to decreases in both fertility and education. It does appear, however, that if the hurricane shocks occur relatively early in women's reproductive years they are able to compensate almost completely for the reduction by having children later. While it it only possible to assess the completed effect of hurricane shocks on education it is clearly the case that any compensatory effects are not sufficient to make up for the reduction that occurs for children in households with land from hurricane shocks before school age and for girls from hurricane shocks between ages seven and twelve.

What explains these results? One possibility is that the increase in fertility under higher hurricane risk is the result of an associated increase in expected mortality. This explanation is, however, not consistent with two of the results. First, there is relatively low mortality following hurricane shocks and there is only small differences between the effect of risk and shocks on fertility and on the number of children alive. Second, increasing mortality should lead to a lower return to investing in children's education, but areas with higher hurricane risk show higher education levels than less risky areas.

Another possible explanation is that differences in risk may lead to differences in the return to education. This can, for example, happen through lower quality schools or depressed economic development in more risk prone areas. There is some evidence that the return to education is lower in higher risk areas and in that case the standard quantity-quality model predicts that a fall in the return to education leads to a corresponding increase in fertility. The problem with this explanation is the same as for the mortality explanation: Higher risk is indeed associated with higher fertility, at least for the households with land, but rather than lower, educational attainment is higher for households both with and without land.

It is also possible that the risk measure captures something else about an area beside the risk of hurricanes. Given that both education and the number of children are normal goods one could, for example, argue that the areas with higher risk may be richer. There are two problems with this explanation. First, if the areas are indeed richer then it is not clear why fertility falls for households without land, while it increases for households with land. Second, the return to education appears to be lower in higher risk areas leading to lower household income, at least for those who depend on wage labour. Furthermore, the municipality fixed effect models consistently lead to the same results as the OLS models for both the risk and shocks parameters. The estimated effects are so close that it is very difficult to argue that some unobservable community characteristics drive the results.

This leaves insurance as the most likely explanation for the results. A combination of direct insurance through having more children and insurance through migration are consistent with both the higher number of children for households with land and the higher levels of education for both groups. First, households with land can benefit from having more children to help on the land after a hurricane hits, while there is less benefit to having more children for those without land. Second, the increase in education can be attributed to both the increased ability to deal with disequilibrium and the increased opportunities if a person migrates both of which are related to insurance. That households with land show higher levels of education with higher hurricane risk is possible if they are more likely to need insurance from hurricanes. This explanation also fits the observed lower return to education in higher risk areas since education in this case is mainly for dealing with adverse situations and in years where there are no shocks, such as the survey year, this may results in a "over-supply" of education. Finally, as shown by Clarke and Wallsten (2003) and Yang and Choi (2005) remittances do act as insurance against shocks.

This paper covers one specific risk, namely hurricanes. This is important given that children, or more generally families, might play a special role in the aftermath of hurricanes that cannot readily be fulfilled by the labour market. However, while Guatemala does experience a high number of hurricanes many other countries, both in Central America and outside, are also faced with a high risk from storms and hence the results here may carry over to these countries. Furthermore, other risks such as floods also occur relatively frequently and a potentially as destructive. Establishing to what extent the responses to these risks in other countries are the same is an important area for future research. This is especially so if other data sets are available that have more detailed information on schooling and grade progression. Finally, it is possible to use the current hurricane data to look at other decisions, such as crop choice or the decision to migrate, which can provide a more rounded picture of how households respond to risks.

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# A Model Details

This appendix examines the implications of uncertainty parental income in more detail. First, the case of imperfect capital markets is examined. Second, perfect capital markets are assumed.

## A.1 Uncertain Parental Income

Assume that the only uncertainty in the model arises from second period parental income, $Y_2$. Hence, the subscripts on $n$ and $H$ are dropped. This section examines the case of incomplete capital markets, while the following section assumes perfect capital markets. Under the extreme version of incomplete capital markets it is not possible to borrow or save. Hence, $S \equiv 0$ and the only way of transferring resources from period one to period two is through children or their human capital. Expected utility is then

$$\begin{aligned} E[U] &= u(c_1) + v(H, n) + E[u(c_2)] \\ &= u(Y_1 - kn - npH) + v(H, n) + E[u(Y_2 + F(n, H))]. \end{aligned} \tag{A-1}$$

As in Sandmo (1970), define an increase in the degree of risk in second period income as a combination of multiplicative and additive shifts. Second period income can then be written as $\gamma Y_2 + \theta$, which has an expected value of $E[\gamma Y_2 + \theta]$. For a mean-perserving spread $dE[\gamma Y_2 + \theta] = E[Y_2 d\gamma + d\theta] = 0$, which leads to

$$\frac{d\theta}{d\gamma} = -E[Y_2] = -\xi. \tag{A-2}$$

The two first order conditions, with respect to $n$ and $H$, are

$$\Psi_n : -u'(c_1)(k + pH) + v'_n(H, n) + E[u'(c_2)F_n(n, H)] = 0 \tag{A-3}$$

$$\Psi_H : -u'(c_1)np + v'_H(H, n) + E[u'(c_2)F_H(n, H)] = 0. \tag{A-4}$$

In (A-3) the shadow marginal cost of increasing the number of children, $k + pH$, is increasing in the amount of education provided to each child, since all children are assumed to receive the same amount of education. Likewise, in (A-4) the shadow marginal cost of increasing education, $np$, is increasing in the number of children. For both fertility and education parents trade off the reduction in first-period consumption against the marginal increases in $v(H, n)$ and in expected second-period consumption from the terms $F_n$ and $F_H$, respectively.

Total differentiating the first order conditions with respect to $n$, $H$ and $\gamma$ (given $\frac{\partial\theta}{\partial\gamma} = -\xi$) leads to a system of equations

$$\begin{bmatrix} \Psi_{nn} & \Psi_{nH} \\ \Psi_{Hn} & \Psi_{HH} \end{bmatrix} \begin{bmatrix} dn \\ dH \end{bmatrix} = \begin{bmatrix} -\Psi_{n\gamma} \\ -\Psi_{H\gamma} \end{bmatrix} d\gamma. \tag{A-5}$$

Hence, one can find $\frac{dn}{d\gamma}$ and $\frac{dH}{d\gamma}$ given $\frac{\partial\theta}{\partial\gamma} = -\xi$. Let $|H|$ be the Hessian determinant, then using Cramer's rule leads to

$$\frac{dn}{d\gamma} = \frac{-\Psi_{n\gamma}\Psi_{HH} + \Psi_{H\gamma}\Psi_{nH}}{|H|} \tag{A-6}$$

and

$$\frac{dH}{d\gamma} = \frac{-\Psi_{nn}\Psi_{H\gamma} + \Psi_{Hn}\Psi_{n\gamma}}{|H|} \tag{A-7}$$

The individual terms for the model are

$$\begin{aligned}
\Psi_{nn} &: \; u''(c_1)(k + pH) + v''_{nn}(H, n) + E[u''(c_2)(F_n(n, H))^2 \\
&\quad + u'(c_2)F_{nn}(n, H)] \\
\Psi_{nH} &: \; u''(c_1)(k + pH)np - u'(c_1)p + v''_{nH}(H, n) \\
&\quad + E[u''(c_2)F_H(n, H)F_n(n, H) + u'(c_2)F_{nH}(n, H)] \\
\Psi_{n\gamma} &: \; E[u''(c_2)F_n(n, H)(Y_2 - \xi)] \\
\Psi_{Hn} &: \; u''(c_1)(k + pH)np - u'(c_1)p + v''_{Hn}(H, n) \\
&\quad + E[u''(c_2)F_n(n, H)F_H(n, H) + u'(c_2)F_{Hn}(n, H))] \\
\Psi_{HH} &: \; u''(c_1)np + v''_{HH}(H, n) + E[u''(c_2)(F_H(n, H))^2 \\
&\quad + u'(c_2)F_{HH}(n, H)]
\end{aligned}$$

$$\Psi_{H\gamma} \quad : \quad E[u''(c_2)F_H(n,H)(Y_2-\xi)]$$

The second-order sufficient conditions for a maximum are $|H| > 0$, $\Psi_{nn} < 0$ and $\Psi_{HH} < 0$. Furthermore, under decreasing temporal risk aversion Sandmo (1970) showed that $\Psi_{n\gamma} > 0$ and $\Psi_{H\gamma} > 0$. It is not *a priori* possible to sign (A-6) and (A-7), but given that $|H| > 0$ the signs of (A-6) and (A-7) are determined by the numerator. Hence, it is possible to examine how the effect of risk changes with changes in the parameters.

To examine the sign of $\frac{dn}{d\gamma}$ substitute the individual terms into the numerator for (A-6), which leads to

$$\begin{aligned} & E\Big[u''(c_2)(Y_2-\xi)\Big]\times \\ & \quad \Big[F_H(n,H)\times\Big\{u''(c_1)(k+pH)np-u'(c_1)p+v''_{nH}(H,n) \\ & \qquad\qquad +E\big[u''(c_2)F_H(n,H)F_n(n,H)+u'(c_2)F_{nH}(n,H)\big]\Big\} \\ & \quad -F_n(n,H)\times\Big\{u''(c_1)np+v''_{HH}(H,n) \\ & \qquad\qquad +E\big[u''(c_2)(F_H(n,H))^2+u'(c_2)F_{HH}(n,H)\big]\Big\}\Big]. \end{aligned} \tag{A-8}$$

As already discussed the term on the first line is positive and so are the two first order derivatives for the income function for children, $F_n$ and $F_H$. Furthermore, the last term in curly brackets is $\Psi_{HH}$, which is negative under the second-order conditions for a maximum. Hence, whether the total effect of risk on fertility is positive or negative depends on the sign and size of the first term in curly brackets, which is $\Psi_{nH}$, relative to $\Psi_{HH}$, and the relative size of $F_n$ and $F_H$.

The effect of risk on education, $\frac{dH}{d\gamma}$, mirrors the effects on fertility. Substituting in the numerator for (A-7) leads to

$$\begin{aligned} & E\Big[u''(c_2)(Y_2-\xi)\Big]\times \\ & \quad \Big[F_n(n,H)\times\Big\{u''(c_1)(k+pH)np-u'(c_1)p+v''_{Hn}(H,n) \\ & \qquad\qquad +E\big[u''(c_2)F_n(n,H)F_H(n,H)+u'(c_2)F_{Hn}(n,H)\big]\Big\} \end{aligned}$$

$$
\begin{aligned}
-F_H(n,H) \times \Big\{ & u''(c_1)(k+pH) + v''_{nn}(H,n) \\
& + E\big[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)\big]\Big\}\Big].
\end{aligned} \tag{A-9}
$$

As above, the term on the first line is positive and so are the two first order derivatives for the income function for children, $F_n$ and $F_H$. Furthermore, the last term in curly brackets is $\Psi_{nn}$, which is negative under the second-order conditions for a maximum. Whether the total effect is positive or negative depends again on the sign and size of the first term in curly brackets, which is $\Psi_{Hn}$, relative to $\Psi_{nn}$, and the relative size of $F_n$ and $F_H$.

Clearly, the higher the shadow marginal cost of having an extra child, $(k + pH)$, is, the less likely it is that parents respond to an increase in risk by having more children. Whether it makes an increase in education as a response to higher risk more likely depends on the size of the marginal product from children, $F_n$, multiplied with the shadow marginal cost of education, $np$, relative to the marginal product of human capital, $F_H$. It seems a reasonable assumption that the former is larger than the latter and hence that areas with higher marginal costs of children are likely to see a smaller increase in education as a result of an increase in risks.

The effect of a higher shadow marginal cost of education, $np$, on fertility depends on whether the shadow marginal cost of children, $k + pH$, times the marginal product of human capital, $F_H$ is larger or smaller than the marginal product of children, $F_n$. If the former is larger than the latter, areas with higher marginal cost of education are likely to see smaller increases in fertility in response to an increase in risk. Meanwhile the higher the marginal shadow cost of education, $np$, is, the less likely is an increase in education when risk increases.

Parents with lower first period income are less likely to increase fertility and education in response to an increase in risk. This effect comes from the higher cost, in terms of utility, from foregoing first period consumption. A lower expected second period income, however, increases the need for transferring resources to the second period and hence makes it more likely that an a more risky environment will lead to higher fertility and higher education.

The higher is the cost of an additional unit of education, $p$, the less inclined parents are to respond to an increase in risk by having more children or invest more in education. Furthermore, not surprisingly, the more parents care about the number of children they have and their education the more likely it is that an increase in risk leads to both higher fertility and higher education.

## A.2 Perfect Capital Markets

Assume now that capital markets are complete and hence that parents can borrow or save as much as they desire. Furthermore, for simplicity assume that there is no discounting and that the interest rate on savings is zero. Expected utility is then

$$\begin{aligned} E[U] &= u(c_1) + v(H,n) + E[u(c_2)] \\ &= u(Y_1 - kn - npH - S) + v(H,n) + E[u(Y_2 + F(n,H) + S)], \end{aligned} \tag{A-10}$$

which is maximised with respect to $S$, $n$ and $H$. There are three first order conditions:

$$\Psi_n : -u'(c_1)(k + pH) + v'_n(H,n) + E[u'(c_2)F_n(n,H)] = 0 \tag{A-11}$$

$$\Psi_H : -u'(c_1)np + v'_H(H,n) + E[u'(c_2)F_H(n,H)] = 0 \tag{A-12}$$

$$\Psi_S : -u'(c_1) + E[u'(c_2)] = 0 \tag{A-13}$$

Both (A-11) and (A-12) are essentially the same as the first order conditions for the absent market case above. The last condition (A-13) says simply that the marginal decrease in utility from lower first period consumption is equal to the expected marginal utility of consumption in the second period.

Inserting $\gamma Y_2 + \theta$ for $Y_2$ and total differentiating with respect to $S$, $n$, $H$ and $\gamma$ (given that

$\frac{\partial\theta}{\partial\gamma} = -\xi$) leads a system of equations

$$\begin{bmatrix} \Psi_{SS} & \Psi_{Sn} & \Psi_{SH} \\ \Psi_{nS} & \Psi_{nn} & \Psi_{nH} \\ \Psi_{HS} & \Psi_{Hn} & \Psi_{HH} \end{bmatrix} \begin{bmatrix} dS \\ dn \\ dH \end{bmatrix} = \begin{bmatrix} -\Psi_{S\gamma} \\ -\Psi_{n\gamma} \\ -\Psi_{H\gamma} \end{bmatrix} d\gamma \tag{A-14}$$

Let $|H|$ be the Hessian determinant, then using Cramer's rule and Laplace expansion leads to

$$\frac{dS}{d\gamma} = \frac{-\Psi_{S\gamma}\begin{vmatrix} \Psi_{nn} & \Psi_{nH} \\ \Psi_{Hn} & \Psi_{HH} \end{vmatrix} + \Psi_{n\gamma}\begin{vmatrix} \Psi_{Sn} & \Psi_{SH} \\ \Psi_{Hn} & \Psi_{HH} \end{vmatrix} - \Psi_{H\gamma}\begin{vmatrix} \Psi_{Sn} & \Psi_{SH} \\ \Psi_{nn} & \Psi_{nH} \end{vmatrix}}{|H|} \tag{A-15}$$

and

$$\frac{dn}{d\gamma} = \frac{\Psi_{S\gamma}\begin{vmatrix} \Psi_{nS} & \Psi_{nH} \\ \Psi_{HS} & \Psi_{HH} \end{vmatrix} - \Psi_{n\gamma}\begin{vmatrix} \Psi_{SS} & \Psi_{SH} \\ \Psi_{HS} & \Psi_{HH} \end{vmatrix} + \Psi_{H\gamma}\begin{vmatrix} \Psi_{SS} & \Psi_{SH} \\ \Psi_{nS} & \Psi_{nH} \end{vmatrix}}{|H|} \tag{A-16}$$

and

$$\frac{dH}{d\gamma} = \frac{-\Psi_{S\gamma}\begin{vmatrix} \Psi_{nS} & \Psi_{nn} \\ \Psi_{HS} & \Psi_{Hn} \end{vmatrix} + \Psi_{n\gamma}\begin{vmatrix} \Psi_{SS} & \Psi_{Sn} \\ \Psi_{HS} & \Psi_{Hn} \end{vmatrix} - \Psi_{H\gamma}\begin{vmatrix} \Psi_{SS} & \Psi_{Sn} \\ \Psi_{nS} & \Psi_{nn} \end{vmatrix}}{|H|} \tag{A-17}$$

The individual terms for the model, given that $\frac{\partial\theta}{\partial\gamma} = -\xi$, are

$$\begin{aligned}
\Psi_{SS} &: \quad u''(c_1) + E[u''(c_2)] \\
\Psi_{Sn} &: \quad u''(c_1)(k + pH) + E[u''(c_2)F_n(n, H)] \\
\Psi_{SH} &: \quad u''(c_1)np + E[u''(c_2)F_H(n, H)] \\
\Psi_{S\gamma} &: \quad E[u''(c_2)(Y_2 - \xi)] \\
\Psi_{nS} &: \quad u''(c_1)(k + pH) + E[u''(c_2)F_n(n, H)] \\
\Psi_{nn} &: \quad u''(c_1)(k + pH) + v''_{nn}(H, n) + E[u''(c_2)(F_n(n, H))^2 \\
&\quad\; + u'(c_2)F_{nn}(n, H)]
\end{aligned}$$

$$\Psi_{nH} \;:\; u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H)$$
$$+u'(c_2)F_{nH}(n,H)]$$
$$\Psi_{n\gamma} \;:\; E[u''(c_2)F_n(n,H)(Y_2-\xi)]$$
$$\Psi_{HS} \;:\; u''(c_1)np + E[u''(c_2)F_H(n,H)]$$
$$\Psi_{Hn} \;:\; u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H)$$
$$+u'(c_2)F_{Hn}(n,H))]$$
$$\Psi_{HH} \;:\; u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2$$
$$+u'(c_2)F_{HH}(n,H)]$$
$$\Psi_{H\gamma} \;:\; E[u''(c_2)F_H(n,H)(Y_2-\xi)]$$

The numerator for $\frac{dS}{d\gamma}$, after substituting in the terms above, is

$$-E[u''(c_2)(Y_2-\xi)] \times \Big[$$
$$\Big\{\Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)]\Big)$$
$$\times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)]\Big)$$
$$-\Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H)$$
$$+ u'(c_2)F_{Hn}(n,H))]\Big)$$
$$\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H)$$
$$+ u'(c_2)F_{nH}(n,H)]\Big)\Big\}$$
$$+F_n(n,H)] \times \Big\{\Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big)$$
$$\times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)]\Big)$$
$$-\Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H)$$
$$+ u'(c_2)F_{Hn}(n,H))]\Big)$$
$$\times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big)\Big\}$$

$$
\begin{aligned}
&-F_H(n,H)] \times \Big\{\Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big) \\
&\quad \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
&\quad + u'(c_2)F_{nH}(n,H)]\Big) \\
&\quad - \big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)]\Big) \\
&\quad \times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big)\Big\}\Big],
\end{aligned} \tag{A-18}
$$

while the numerator for $\frac{dn}{d\gamma}$ becomes

$$
\begin{aligned}
&E[u''(c_2)(Y_2-\xi)] \times \Big[ \\
&\Big\{\Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big) \\
&\times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)]\Big) \\
&- \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big) \\
&\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
&+ u'(c_2)F_{nH}(n,H)]\Big)\Big\} \\
&\quad -F_n(n,H)] \times \Big\{\Big(u''(c_1) + E[u''(c_2)]\Big) \\
&\qquad \times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)]\Big) \\
&\qquad - \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big)^2\Big\} \\
&+F_H(n,H)] \times \Big\{\Big(u''(c_1) + E[u''(c_2)]\Big) \\
&\quad \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
&\quad + u'(c_2)F_{nH}(n,H)]\Big) \\
&\quad - \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big) \\
&\quad \times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big)\Big\}\Big].
\end{aligned} \tag{A-19}
$$

Finally, the numerator for $\frac{dH}{d\gamma}$ is

$$
\begin{aligned}
&-E[u''(c_2)(Y_2-\xi)] \times \Bigg[ \\
&\Big\{\Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big) \\
&\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&+ u'(c_2)F_{Hn}(n,H))]\Big) \\
&- \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big) \\
&\times \Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)]\Big)\Big\} \\
&+F_n(n,H)] \times \Big\{\Big(u''(c_1) + E[u''(c_2)]\Big) \\
&\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&+ u'(c_2)F_{Hn}(n,H))]\Big) \\
&- \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)]\Big) \\
&\times \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big)\Big\} \\
&-F_H(n,H)] \times \Big\{\Big(u''(c_1) + E[u''(c_2)]\Big) \\
&\times \Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)]\Big) \\
&- \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)]\Big)^2\Big\}\Bigg]
\end{aligned}
\tag{A-20}
$$

The second-order sufficient conditions for a maximum are $|H_1| < 0$, $|H_2| > 0$ and $|H| < 0$. Hence, it is not *a priori* possible to sign (A-15), (A-16) and (A-17). Given, however, that $|H| < 0$ the signs are determined by the numerator.

# B Municipality Fixed Effects Results

Table B-1: Effects of Risks and Shocks on Number of Children Born — Municipality Fixed Effects

| | Model I | Model II | Model III | Model IV | Model V | Model VI | Model VII |
|---|---|---|---|---|---|---|---|
| Age | 0.389*** | 0.389*** | 0.389*** | 0.221*** | 0.452*** | 0.458*** | 0.256*** |
| | (0.017) | (0.017) | (0.017) | (0.084) | (0.033) | (0.033) | (0.086) |
| Age squared | −0.272*** | −0.272*** | −0.272*** | −0.078 | −0.388*** | −0.401*** | −0.148 |
| | (0.028) | (0.028) | (0.028) | (0.136) | (0.063) | (0.063) | (0.140) |
| Indigenous | 0.406*** | 0.406*** | 0.407*** | 0.406*** | 0.406*** | 0.409*** | 0.406*** |
| | (0.083) | (0.083) | (0.083) | (0.082) | (0.083) | (0.082) | (0.082) |
| Owns land | −0.056 | −0.056 | −0.567* | −0.588** | −0.052 | 0.080 | −0.387 |
| | (0.063) | (0.063) | (0.301) | (0.300) | (0.063) | (0.093) | (0.307) |
| Risk × owns land | | | 0.111* | −0.115 | | | −0.155 |
| | | | (0.064) | (0.118) | | | (0.171) |
| Risk × age | | | | 0.032* | | | 0.035* |
| | | | | (0.018) | | | (0.019) |
| Risk × age$^2$ | | | | −0.043 | | | −0.047 |
| | | | | (0.030) | | | (0.032) |
| Risk × age × | | | | 0.008 | | | 0.010 |
| owns land | | | | (0.007) | | | (0.013) |
| Risk × age$^2$ | | | | 0.001 | | | −0.002 |
| owns land | | | | (0.012) | | | (0.025) |
| Hurricane shocks | | | | | −0.431*** | −0.250*** | −0.290** |
| (age 15 - 29) | | | | | (0.075) | (0.091) | (0.101) |
| Shocks × age 35 - 49 | | | | | 0.408*** | 0.119 | 0.294 |
| | | | | | (0.148) | (0.155) | (0.199) |
| Shocks × owns land | | | | | | −0.415*** | −0.324** |
| | | | | | | (0.108) | (0.142) |
| Shocks × age 35 - 49 × | | | | | | 0.665*** | 0.139 |
| owns land | | | | | | (0.102) | (0.277) |
| Observations (individuals) | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 |
| Observations (municipalities) | 205 | 205 | 205 | 205 | 205 | 205 | 205 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variable (not shown) is a rural dummy.

Table B-2: Effects of Risks and Shocks on Number of Children Alive — Fixed Effects

| | Model I | Model II | Model III | Model IV | Model V | Model VI | Model VII |
|---|---|---|---|---|---|---|---|
| Age | 0.406*** | 0.406*** | 0.406*** | 0.220*** | 0.463*** | 0.468*** | 0.256*** |
| | (0.016) | (0.016) | (0.016) | (0.076) | (0.030) | (0.030) | (0.078) |
| Age squared | −0.345*** | −0.345*** | −0.344*** | −0.103 | −0.450*** | −0.459*** | −0.176 |
| | (0.026) | (0.026) | (0.026) | (0.124) | (0.058) | (0.058) | (0.128) |
| Indigenous | 0.301*** | 0.301*** | 0.301*** | 0.301*** | 0.301*** | 0.303*** | 0.300*** |
| | (0.075) | (0.075) | (0.075) | (0.075) | (0.075) | (0.075) | (0.075) |
| Owns land | −0.035 | −0.035 | −0.483* | −0.514* | −0.031 | 0.104 | −0.338 |
| | (0.058) | (0.058) | (0.274) | (0.273) | (0.057) | (0.085) | (0.279) |
| Risk × owns land | | | 0.097* | −0.082 | | | −0.030 |
| | | | (0.058) | (0.107) | | | (0.155) |
| Risk × age | | | | 0.037** | | | 0.043** |
| | | | | (0.017) | | | (0.017) |
| Risk × age$^2$ | | | | −0.053* | | | −0.064** |
| | | | | (0.027) | | | (0.029) |
| Risk × age × | | | | 0.007 | | | 0.000 |
| owns land | | | | (0.007) | | | (0.012) |
| Risk × age$^2$ | | | | 0.000 | | | 0.015 |
| owns land | | | | (0.011) | | | (0.023) |
| Hurricane shocks | | | | | −0.431*** | −0.268*** | −0.335*** |
| (age 15 - 29) | | | | | (0.068) | (0.082) | (0.092) |
| Shocks × age 34 - 49 | | | | | 0.384*** | 0.148 | 0.388** |
| | | | | | (0.135) | (0.141) | (0.181) |
| Shocks × owns land | | | | | | −0.369*** | −0.235* |
| | | | | | | (0.099) | (0.129) |
| Shocks × age 35 - 49 × | | | | | | 0.533*** | −0.070 |
| owns land | | | | | | (0.093) | (0.252) |
| Observations (individuals) | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 | 6648 |
| Observations (municipalities) | 205 | 205 | 205 | 205 | 205 | 205 | 205 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variable (not shown) is a rural dummy.

Table B-3: Effects of Risks and Shocks on Mortality — Municipality Fixed Effects

| | Probability of Mortality | | | Number of Deaths | | |
|---|---|---|---|---|---|---|
| | Model I | Model II | Model III | Model IV | Model V | Model VI |
| Age | −0.000 | 0.009 | −0.003 | 0.001 | −0.009 | 0.004 |
| | (0.025) | (0.006) | (0.025) | (0.053) | (0.012) | (0.053) |
| Age squared / 100 | 0.017 | 0.008 | 0.022 | 0.027 | 0.059*** | 0.023 |
| | (0.038) | (0.010) | (0.038) | (0.080) | (0.020) | (0.080) |
| Indigenous | 0.082*** | 0.082*** | 0.083*** | 0.148*** | 0.149*** | 0.149*** |
| | (0.020) | (0.020) | (0.020) | (0.042) | (0.042) | (0.042) |
| Owns land | −0.031 | −0.046* | −0.116 | −0.056 | −0.176*** | −0.218 |
| | (0.073) | (0.025) | (0.082) | (0.155) | (0.054) | (0.172) |
| Risk × owns land | −0.081** | | −0.109*** | −0.093 | | −0.143* |
| | (0.036) | | (0.038) | (0.076) | | (0.079) |
| Risk × age | 0.000 | | −0.001 | −0.006 | | −0.008 |
| | (0.005) | | (0.005) | (0.011) | | (0.012) |
| Risk × age squared | 0.000 | | 0.004 | 0.011 | | 0.016 |
| | (0.008) | | (0.008) | (0.017) | | (0.017) |
| Risk × age × | 0.005** | | 0.008*** | 0.005 | | 0.010* |
| owns land | (0.002) | | (0.002) | (0.004) | | (0.005) |
| Risk × age squared | −0.007** | | −0.013*** | −0.004 | | −0.015* |
| owns land | (0.003) | | (0.004) | (0.007) | | (0.009) |
| Hurricane shocks | | −0.028* | −0.049** | | −0.024 | −0.047 |
| | | (0.016) | (0.019) | | (0.033) | (0.041) |
| Shocks × owns land | | 0.031** | 0.067** | | 0.105*** | 0.128** |
| | | (0.014) | (0.029) | | (0.031) | (0.060) |
| Observations (individuals) | 4507 | 4507 | 4507 | 4507 | 4507 | 4507 |
| Observations (municipalities) | 205 | 205 | 205 | 205 | 205 | 205 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variable (not shown) is a rural dummy.

Table B-4: Effects of Risks and Shocks on Education — Municipality Fixed Effect

| | Model I | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|---|
| Female | −0.960*** | −0.962*** | −0.451 | −0.961*** | −0.738*** | −0.331 |
| | (0.078) | (0.078) | (0.301) | (0.078) | (0.107) | (0.304) |
| Age 30-39 | −0.955*** | −0.957*** | −0.958*** | −0.577*** | −0.567*** | −0.562*** |
| | (0.086) | (0.086) | (0.086) | (0.142) | (0.142) | (0.142) |
| Age 40-49 | −1.632*** | −1.638*** | −1.640*** | −1.483*** | −1.479*** | −1.485*** |
| | (0.093) | (0.093) | (0.093) | (0.103) | (0.103) | (0.102) |
| Age 50-59 | −2.647*** | −2.651*** | −2.652*** | −2.574*** | −2.565*** | −2.568*** |
| | (0.104) | (0.104) | (0.104) | (0.111) | (0.111) | (0.111) |
| Age 60-69 | −3.236*** | −3.244*** | −3.248*** | −3.301*** | −3.290*** | −3.302*** |
| | (0.124) | (0.124) | (0.124) | (0.127) | (0.127) | (0.127) |
| Indigenous | −2.576*** | −2.576*** | −2.576*** | −2.574*** | −2.565*** | −2.568*** |
| | (0.112) | (0.112) | (0.112) | (0.112) | (0.112) | (0.112) |
| Parents owned land | −0.010 | 0.986*** | 1.006*** | 0.067 | 0.085 | 1.056*** |
| | (0.078) | (0.366) | (0.366) | (0.110) | (0.111) | (0.369) |
| Female × owned land | −0.752*** | −0.756*** | −0.768*** | −0.751*** | −0.784*** | −0.777*** |
| | (0.100) | (0.100) | (0.102) | (0.100) | (0.101) | (0.102) |
| Risk of hurricane × owned land | | −0.217*** | −0.236*** | | | −0.212*** |
| | | (0.078) | (0.080) | | | (0.082) |
| Risk of hurricane × female | | | −0.118* | | | −0.090 |
| | | | (0.064) | | | (0.065) |
| Risk of hurricane × owned land × female | | | 0.028 | | | −0.011 |
| | | | (0.031) | | | (0.046) |
| Hurricane shocks (age 0-6) | | | | −0.158** | 0.017 | 0.002 |
| | | | | (0.073) | (0.092) | (0.095) |
| Hurricane shocks (age 0-6) × owned land | | | | −0.156 | −0.331** | −0.319** |
| | | | | (0.103) | (0.132) | (0.146) |
| Hurricane shocks (age 0-6) × female | | | | | −0.322*** | −0.314*** |
| | | | | | (0.103) | (0.110) |
| Hurricane shocks (age 0-6) × owned land × female | | | | | 0.314* | 0.338 |
| | | | | | (0.164) | (0.206) |
| Hurricane shocks (age 7-12) | | | | −0.256*** | −0.154 | −0.169 |
| | | | | (0.089) | (0.109) | (0.111) |
| Hurricane shocks (age 7-12) × owned land | | | | 0.001 | 0.012 | 0.017 |
| | | | | (0.118) | (0.159) | (0.171) |
| Hurricane shocks (age 7-12) × female | | | | | −0.190* | −0.183 |
| | | | | | (0.114) | (0.120) |
| Hurricane shocks (age 7-12) × owned land × female | | | | | −0.040 | −0.013 |
| | | | | | (0.201) | (0.235) |
| Observations (individuals) | 12331 | 12331 | 12331 | 12331 | 12331 | 12331 |
| Observations (municipalities) | 326 | 326 | 326 | 326 | 326 | 326 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variable (not shown) is a rural dummy.

Table B-5: Returns to Education and Hurricane Risks — Municipality Fixed Effects

| | Model I | Model II | Model III (Males) | Model IV (Females) |
|---|---|---|---|---|
| Female | 0.099 | 0.102 | | |
| | (0.213) | (0.213) | | |
| Age | 0.331*** | 0.330*** | 0.355*** | 0.326*** |
| | (0.068) | (0.068) | (0.082) | (0.126) |
| Age squared /100 | −0.333*** | −0.333*** | −0.352*** | −0.354** |
| | (0.084) | (0.084) | (0.101) | (0.155) |
| Indigenous | −0.513** | −0.523** | −0.484* | −0.439 |
| | (0.233) | (0.233) | (0.281) | (0.431) |
| Rural | −0.848*** | −0.848*** | −0.973*** | −0.570 |
| | (0.199) | (0.199) | (0.246) | (0.360) |
| Education (years) | 0.753*** | 0.812*** | 0.874*** | 0.555*** |
| | (0.022) | (0.072) | (0.092) | (0.113) |
| Education × Female | −0.145*** | −0.145*** | | |
| | (0.031) | (0.031) | | |
| Risk × education | | −0.013 | −0.027 | 0.011 |
| | | (0.015) | (0.019) | (0.024) |
| Observations (individuals) | 6561 | 6561 | 4321 | 2240 |
| Observations (municipalities) | 210 | 210 | 210 | 199 |

**Note.** Robust standard errors in parentheses, clustered at the household level.; * significant at 10%; ** significant at 5%; *** significant at 1%. Additional variable (not shown) is a rural dummy.

# C Hypotheses Tests

Table C-1: Effects of Risks and Shocks on Number of Children Born and Children Alive — F-tests

| | Fertility | Alive |
|---|---|---|
| Model III | | |
| Hurricane risk + Risk × owns land = 0 | 0.064 | 0.047 |
| | [0.62] | [0.42] |
| | (0.432) | (0.515) |
| Model V | | |
| Hurricane shocks + Hurricane shocks × age 35 - 49 = 0 | −0.036 | −0.059 |
| | [0.07] | [0.22] |
| | (0.796) | (0.641) |
| Model VI | | |
| Hurricane shocks + shocks × land = 0 | −0.678*** | −0.644*** |
| | [47.94] | [52.55] |
| | (0.000) | (0.000) |
| Hurricane shocks + shocks × age 35 - 49 = 0 | −0.156 | −0.142 |
| | [1.09] | [1.10] |
| | (0.297) | (0.295) |
| Hurricane shocks + shocks × age 35 - 49 + shocks × land + shocks × 35 - 49 × land = 0 | 0.124 | 0.048 |
| | [0.65] | [0.12] |
| | (0.42) | (0.732) |
| Model VII | | |
| Hurricane shocks + shocks × land = 0 | −0.623*** | −0.572*** |
| | [26.32] | [28.14] |
| | (0.000) | (0.000) |
| Hurricane shocks + shocks × age 35 - 49 = 0 | −0.023 | −0.037 |
| | [0.01] | [0.04] |
| | (0.903) | (0.833) |
| Hurricane shocks + shocks × age 35 - 49 + shocks × land + shocks × 35 - 49 × land = 0 | −0.182 | −0.256 |
| | [0.72] | [1.77] |
| | (0.397) | (0.183) |

**Note.** Combined parameter value, F-statistic in brackets and p-value in parenthese. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table C-2: Effects of Risks and Shocks on Mortality — F-tests

| | Probability | Number of Deaths |
|---|---|---|
| Models II and V | | |
| Hurricane shocks + shocks × land = 0 | 0.007 | 0.080** |
| | [0.14] | [3.02] |
| | (0.705) | (0.082) |
| Models III and VI | | |
| Hurricane shocks + shocks × land = 0 | 0.020 | 0.080 |
| | [0.74] | [1.50] |
| | (0.391) | (0.221) |

**Note.** Combined parameter value, F-statistic in brackets and p-value in parenthese. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table C-3: Effects of Risks and Shocks on Education — F-tests

| | Model II | Model III | Model IV | Model V | Model VI |
|---|---|---|---|---|---|
| Hurricane risk + risk × owns land = 0 | 0.093 | 0.135 | | | 0.188* |
| | [0.77] | [1.46] | | | [2.74] |
| | (0.382) | (0.228) | | | (0.098) |
| Hurricane risk + risk × female = 0 | | 0.257*** | | | 0.308*** |
| | | [6.85] | | | [9.57] |
| | | (0.009) | | | (0.002) |
| Hurricane risk + risk × owns land + | | 0.054 | | | 0.084 |
| risk × female + risk × land × female = 0 | | [0.24] | | | [0.57] |
| | | (0.624) | | | (0.452) |
| Hurricane shocks (0-6) + | | | −0.252** | −0.282** | −0.324** |
| shocks (0-6) × land = 0 | | | [5.99] | [4.80] | [5.46] |
| | | | (0.014) | (0.029) | (0.019) |
| Hurricane shocks (0-6) + | | | | −0.220** | −0.283*** |
| shocks (0-6) × female = 0 | | | | [5.47] | [8.68] |
| | | | | (0.019) | (0.003) |
| Hurricane shocks (0-6) + shocks (0-6) × land + | | | | −0.225* | −0.238* |
| shocks (0-6) × female + | | | | [3.38] | [3.51] |
| shocks (0-6) × female × land = 0 | | | | (0.066) | (0.061) |
| Hurricane shocks (7-12) + | | | −0.123 | −0.050 | −0.114 |
| shocks (7-12) × land = 0 | | | [0.94] | [0.08] | [0.39] |
| | | | (0.333) | (0.777) | (0.532) |
| Hurricane shocks (7-12) + | | | | −0.253** | −0.327*** |
| shocks (7-12) × female = 0 | | | | [6.21] | [10.00] |
| | | | | (0.013) | (0.002) |
| Hurricane shocks (7-12) + shocks (7-12) × land + | | | | −0.204 | −0.243* |
| shocks (7-12) × female + | | | | [2.08] | [2.75] |
| shocks (7-12) × female × land = 0 | | | | (0.149) | (0.097) |

**Note.** Combined parameter value, F-statistic in brackets and p-value in parenthese. * significant at 10%; ** significant at 5%; *** significant at 1%.