Gone With the Wind? Hurricane Risk, Fertility and Education

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Abstract

This paper uses data on hurricanes in Guatemala over the last 120 years combined with a recent household survey to analyse how decisions on education and fertility respond to hurricane risk and shocks. For households with land an increase in the risk of hurricanes lead to both higher fertility and higher education, while households without land have fewer children but also higher education. Hurricane shocks lead to decreases in both fertility and education, and although there is a substantial compensatory effect on fertility later in life, that is not the case for education. The paper examines a number of possible explanations for these patterns and finds that the most likely explanation is insurance considerations through increased available labour and migration.
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1 Introduction

This paper analyses how decisions on education and fertility respond to risk and shocks using data on hurricanes that have hit Guatemala over the last 120 years and a recent household survey. A hurricane is one of the most powerful weather systems and Guatemala faces a very high annual hurricane risk.[1] Hurricanes often have a devastating impact, especially in agricultural areas where crops and infrastructure are frequently destroyed as a result of hurricanes. The hurricane Stan in October 2005 is a good example. Guatemala was the hardest hit country with an official death toll of 652, although numbers as high as 2000 were mentioned, and an estimated 130,000 people were directly affected by the storm. Crops, livelihoods and homes were destroyed, water sources compromised and two villages were completely buried under an avalanche of mud and rock. Furthermore, many areas were cut off by the floodwaters and mudslides.

The study of risk coping strategies has been an active research area in economics over the last couple of decades. Most households in developing countries face significant uncertainty in all aspects of daily life, from income generation to survival. Furthermore, they often have little or no access to standard insurance and are therefore forced to find alternative strategies for dealing with risks and shocks, sometimes at a substantial cost (Morduch 1995).

Researchers have identified a number of risk coping strategies. These include diversification of economic activities, with choice of farm input and crop choice receiving special attention,[2] and migration.[3] A household can also accumulate assets, such as savings, jewelry and farm animals, for sale if

[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). In Guatemala the storms are called hurricanes if they arrive from the east and cyclones if they arrive from the west. Due to the relatively small size of the country is possible to be hit by a hurricane on the west coast of Guatemala and by a cyclones at the east coast.

[2]Examples include Bliss and Stern (1982), Rosenzweig and Binswanger (1993), Dercon (1996) and Fafchamps (1993).

[3]See Stark (1995) for a discussion of transfers between family members and Lucas and Stark (1985), Rosenzweig and Stark (1989), Paulson (2000) and Yang and Choi (2005) for examples of empirical studies.

an adverse income shock occurs[4] or pool risk with other households.[5] Finally, a household can adjust its labour supply to deal with a shock, both for adults as analysed by Kochar (1999) and for children as examined by Jacoby and Skoufias (1997), Guarcello, Mealli, and Rosati (2002) and Beegle, Dehejia, and Gatti (2003).[6]

A reccuring problem in the literature on risk coping is that while data on shocks are often available, it is significantly harder to measure risk. There has been a number of different approaches to this problem. Firstly, a substantial part of the literature in effect deals with how households respond to shocks rather than how they respond to risk. Secondly, those studies that do deal with responses to risk have focused on decisions which are repeated often, such as crop choice, where one can use, for example, rain variability to capture risk. 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. Firstly, 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. 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.

Secondly, without information on risk it is difficult to analyse how "long-term" outcomes, i.e. decisions for which the outcome is only revealed with some delay or where the process is cumulative over time, respond. Two important long-term outcomes are education and fertility, which are the focus

[4]See, for example, Cain (1981), Deaton (1992), Paxson (1992) and Rosenzweig and Wolpin (1993). 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.

[5]Townsend (1994) and Udry (1994) are the seminal papers in this literature.

[6]That shocks do affect a wide variety of activities can been seen in Hoogeveen, Klaauw, and Lomwel (2002), which finds some evidence that the timing of marriage and payment of bride wealth respond to income shocks in Zimbabwe, although the results are somewhat mixed possibly owing to the small sample used. Dekker and Hoogeveen (2002), in a related paper, finds that the timing of the *payment* of the bride wealth also responds to income shocks.

of this paper. Fertility and education are important determinants of both individual welfare and society's growth prospects and are likely to be significantly affected by a household's 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, despite a substantial literature on both.[7]

The major contribution of this paper is that it is the first to analyse the effect of a direct measure of *risk* on education and fertility. Furthermore, it shows how both of those decisions respond to shocks controlling for risk, which should lead to more precise estimates of these responses. Previous research, such as Jacoby and Skoufias (1997) and Beegle, Dehejia, and Gatti (2003), analyse how income shocks and access to credit affect child labour and schooling decisions. How risk affects fertility and schooling have so far not been studied, either theoretically or empirically. Hence, 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 follows and shows that households with land respond to higher risks by having more children. It is also shown that the increase in mortality associated with hurricanes explains only part of this higher fertility. The 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. These results point to a combination of direct insurance through having more children and insurance through migration as the driving forces behind how households' decisions on fertility and education respond to risk.

2 Theory

This section outlines a model of parents' decisions on fertility and schooling under uncertainty. Consider a household that faces a two-period decision problem with uncertainty about outcomes in the second period.[8] The house-

[7]See Schultz (1997) on fertility and Schultz (1988) and Strauss and Thomas (1995) on education. Lindstrom and Berhanu (1999) analyse the effects of shocks, such as war and famine, on fertility in Ethiopia, but that is one of the few studies that examines the effects of shocks on fertility and there is to the best of my knowledge none that have looked at the effect of risk on fertility in developing countries.

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

hold 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 allocated 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 children receive the same amount of education.[9] The first period budget constraint is

$$Y_1 = c_1 + kn_1 + n_1 pH_1 + S. \tag{2}$$

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

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

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. This is especially important since hurricanes destroy crops, buildings and land (the latter mainly through mudslides) and replanting and rebuilding farm buildings are often very time sensitive where delays can ultimately mean a failed harvest followed by food shortage or at least a significant reduction in profit.

It is in principle possible for a farmer to rely on hired labour for help with replanting and rebuilding. It is, however, often difficult or impossible

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

to enforce labour contracts during crisis situations, such as when a hurricane hits. In contrast, family members have two incentives to help: Altruism and that they would otherwise also suffer. This lack of enforceable labour contracts is not only a problem in developing countries as 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 labourers is assumed away.

This model forms the basis for the analyses of three questions. Firstly, what happens when parental income is uncertain but there is no uncertainty with respect to the number of surviving children or their human capital? This situation is examined under two different assumptions: Absent capital markets and perfect capital markets. Secondly, what is the effect of mortality risk on human capital and fertility decisions? Finally, how is risk likely to 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.

2.1 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

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

which is maximised with respect to n and H. The two first order conditions are

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

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

In (5) 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 (6) 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 $v(H,n)$ and the marginal increase in expected second-period consumption from the terms F_n and F_H, respectively.

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 the following must hold

$$dE[\gamma Y_2 + \theta] = E[Y_2 d\gamma + d\theta] = 0, \quad (7)$$

which leads to

$$\frac{d\theta}{d\gamma} = -E[Y_2] = -\xi. \quad (8)$$

Inserting $\gamma Y_2 + \theta$ for Y_2 in the first order conditions and total differentiating with respect to n, H and γ (given $\frac{\partial\theta}{\partial\gamma} = -\xi$) leads to a system of equations

$$\begin{bmatrix} \Psi_{nn} & \Psi_{nH} \\ \Psi_{Hn} & \Psi_{HH} \end{bmatrix} \begin{bmatrix} dn \\ dH \end{bmatrix} = \begin{bmatrix} -\Psi_{n\gamma} \\ -\Psi_{H\gamma} \end{bmatrix} d\gamma \quad (9)$$

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

$$\frac{dn}{d\gamma} = \frac{-\Psi_{n\gamma}\Psi_{HH} + \Psi_{H\gamma}\Psi_{nH}}{|H|} \quad (10)$$

and

$$\frac{dH}{d\gamma} = \frac{-\Psi_{nn}\Psi_{H\gamma} + \Psi_{Hn}\Psi_{n\gamma}}{|H|} \quad (11)$$

The individual terms are shown in Appendix A.

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 (10) and (11), but given that $|H| > 0$ the signs of (10) and

(11) 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 (10), which leads to

$$\begin{aligned}
E\Big[u''(c_2)(Y_2-\xi)\Big] \times \\
&\Big[F_H(n,H) \times \Big\{u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) \\
&\qquad + E\big[u''(c_2)F_H(n,H)F_n(n,H) + u'(c_2)F_{nH}(n,H)\big]\Big\} \\
&-F_n(n,H) \times \Big\{u''(c_1)np + v''_{HH}(H,n) \\
&\qquad + E\big[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)\big]\Big\}\Big].
\end{aligned} \tag{12}$$

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 Ψ_{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 Ψ_{nH}, relative to Ψ_{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 (11) leads to

$$\begin{aligned}
E\Big[u''(c_2)(Y_2-\xi)\Big] \times \\
&\Big[F_n(n,H) \times \Big\{u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) \\
&\qquad + E\big[u''(c_2)F_n(n,H)F_H(n,H) + u'(c_2)F_{Hn}(n,H)\big]\Big\} \\
&-F_H(n,H) \times \Big\{u''(c_1)(k+pH) + v''_{nn}(H,n) \\
&\qquad + E\big[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)\big]\Big\}\Big].
\end{aligned} \tag{13}$$

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 Ψ_{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 Ψ_{Hn}, relative to Ψ_{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.

In order to draw inferences relevant for the empirical analysis it is worthwhile summarising the discussions above by whether a household owns land or not. In general the cost of children, k 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.[10] 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.

Finally, 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.

2.1.1 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

$$\begin{aligned} E[U] &= u(c_1) + v(H,n) + E[u(c_2)] \\ &= u(Y_1 - kn - npH - S) + v(H,n) \\ &\quad + E[u(Y_2 + F(n,H) + S)], \end{aligned} \tag{14}$$

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

$$\Psi_n : -u'(c_1)(k + pH) + v'_n(H,n) + E[u'(c_2)F_n(n,H)] = 0 \tag{15}$$

$$\Psi_H : -u'(c_1)np + v'_H(H,n) + E[u'(c_2)F_H(n,H)] = 0 \tag{16}$$

$$\Psi_S : -u'(c_1) + E[u'(c_2)] = 0 \tag{17}$$

Both (15) and (16) are essentially the same as the first order conditions for the absent market case above. The last condition (17) 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.

[10] 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 this does not allow for returns to education because of risk. I discuss the return to human capital and how it is influenced by risk in more detail below.

Inserting $\gamma Y_2 + \theta$ for Y_2 and total differentiating with respect to S, n, H and γ (given that $\frac{\partial\theta}{\partial\gamma} = -\xi$) leads a system of equations

$$\begin{bmatrix} \Psi_{SS} & \Psi_{Sn} & \Psi_{SH} \\ \Psi_{nS} & \Psi_{nn} & \Psi_{nH} \\ \Psi_{HS} & \Psi_{Hn} & \Psi_{HH} \end{bmatrix} \begin{bmatrix} dS \\ dn \\ dH \end{bmatrix} = \begin{bmatrix} -\Psi_{S\gamma} \\ -\Psi_{n\gamma} \\ -\Psi_{H\gamma} \end{bmatrix} d\gamma \tag{18}$$

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

$$\frac{dS}{d\gamma} = \frac{-\Psi_{S\gamma} \begin{vmatrix} \Psi_{nn} & \Psi_{nH} \\ \Psi_{Hn} & \Psi_{HH} \end{vmatrix} + \Psi_{n\gamma} \begin{vmatrix} \Psi_{Sn} & \Psi_{SH} \\ \Psi_{Hn} & \Psi_{HH} \end{vmatrix} - \Psi_{H\gamma} \begin{vmatrix} \Psi_{Sn} & \Psi_{SH} \\ \Psi_{nn} & \Psi_{nH} \end{vmatrix}}{|H|} \tag{19}$$

and

$$\frac{dn}{d\gamma} = \frac{\Psi_{S\gamma} \begin{vmatrix} \Psi_{nS} & \Psi_{nH} \\ \Psi_{HS} & \Psi_{HH} \end{vmatrix} - \Psi_{n\gamma} \begin{vmatrix} \Psi_{SS} & \Psi_{SH} \\ \Psi_{HS} & \Psi_{HH} \end{vmatrix} + \Psi_{H\gamma} \begin{vmatrix} \Psi_{SS} & \Psi_{SH} \\ \Psi_{nS} & \Psi_{nH} \end{vmatrix}}{|H|} \tag{20}$$

and

$$\frac{dH}{d\gamma} = \frac{-\Psi_{S\gamma} \begin{vmatrix} \Psi_{nS} & \Psi_{nn} \\ \Psi_{HS} & \Psi_{Hn} \end{vmatrix} + \Psi_{n\gamma} \begin{vmatrix} \Psi_{SS} & \Psi_{Sn} \\ \Psi_{HS} & \Psi_{Hn} \end{vmatrix} - \Psi_{H\gamma} \begin{vmatrix} \Psi_{SS} & \Psi_{Sn} \\ \Psi_{nS} & \Psi_{nn} \end{vmatrix}}{|H|} \tag{21}$$

The individual terms are shown in Appendix A.

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 (19), (20) and (21). Given, however, that $|H| < 0$ the signs are determined by the numerator. Again, although none of those have unambiguous signs it is possible to establish how parameters are likely to affect the decisions on savings, fertility and education.[11]

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), 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

[11] The numerators for (19), (20) and (21) are shown in Appendix A.

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.

2.2 Mortality

Beside affecting parental income hurricanes might also change the mortality risk of both children and adults. This, in turn, is likely to affect fertility and human capital decisions. 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.

As shown in, for example, 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 future income and child survival are uncertain. In Pörtner (2001) parents who are sufficiently risk averse will respond to an increase in child mortality risk by increasing fertility. Hence, it is possible that higher hurricane risk can lead parents to increase their fertility to compensate for the 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.

2.3 Risk and the Return to Human Capital

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. Hurricanes might force school closures or displace the teachers or students. This leads to an increase in the cost of achieving a given level of human capital (captured by p in the model above). 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.

There are, however, two pathways through which higher risk may lead to an increase in education. The first is suggested by Schultz (1975), who argued that education might increase the ability to deal with disequilibrium. Although the original argument was mainly aimed at individuals in modernising economies a similar argument can be made for risky areas in developing countries:[12] 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. The same would be the case for analytic skills to the extent that they can be acquired through schooling.

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, however, 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.[13] Interestingly, given the relative higher investment in human capital it could in this case 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.

2.4 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 briefly 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

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

[13] An example at the national level, is the relatively quick recovery of Europe after the second world war, which is attributed to the high level of human capital, which had suffered less from the war than the physical capital.

(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 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 once they have migrated they might have more children than they otherwise would.[14]

The previous discussion has mainly 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 behaviour. 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 question of the timing of both education and fertility. Parents can, at least partly, make up for the temporary reduction by having children at older ages than originally anticipated and by making their children work less in subsequent periods.

In sum, while a direct test of the model is not possible, the model is important in 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. The two main empirical analyses examine the effect of risk and shocks on fertility and education, but since the discussion above suggests that both mortality and the return to education are potentially important parts of the picture those are also examined. Furthermore, 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 more important dif-

[14] 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).

ferences between people in rural areas is whether they own land or not, and, as discussed above, there might be substantially differences in the response to risk depending on land ownership status. The dependent and explanatory variables are discussed in detail below.

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 actual shocks occurred which can be used to calculate risk measures for specific geographical areas. This section discusses both data set, starting with the latter.

The data on 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. While other types of events than hurricanes were originally considered they either suffer from having less data available, being less likely to be exogenous or from being harder to predict.[15] 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.[16]

The main variable of interest here is the measure of risk of hurricanes.[17] Risk is calculated as the percentage probability of an hurricane occurring in a year, based on events from 1880 to 1997.[18] Although there clearly are

[15]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).

[16]The household and the associated community survey 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, however, too short for to create a believable measure of risk.

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

[18]The longest period covered is for earthquakes and volcanoes, which covers the period 1530-1999.

problems with relying on data as far back as these, this is one of few ways to get a reasonable measure of the risks in an area. Hurricanes can hit essential 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.

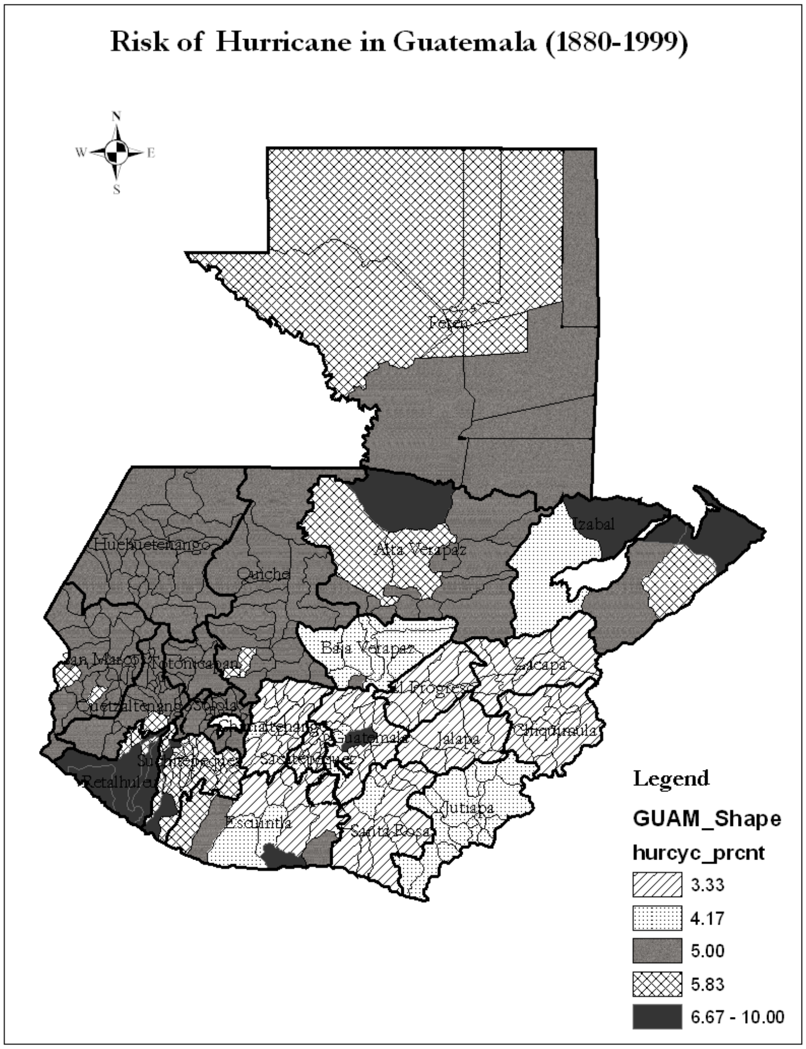


Figure 1: Hurricane Risk by Municipality

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 levels and for urban and rural areas.

From the household survey information is needed on education and fertility. Since these decisions are jointly made 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 educational attainment of 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 are no sample selection bias from lack of information on children who have already died or left home, that their education can reasonably be assumed to be completed and that the sample size is larger.

ENCOVI 2000 collected information on three aspects of fertility behaviour from all women between 12 and 49 years of age: The number of pregnancies, the number of children ever born and the number of children alive at the time of the survey. One drawback is the lack of information on the timing of births, which is restricted to a question about when the last birth took place. It is, in principle, possible to get more information on timing by using the date of birth for children. As mentioned above, there is, however, no information on children who have either died or left the households, which would make the timing information incomplete.

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. Secondly, 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

$$F_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \tag{22}$$

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. 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.[19]

Even though data on fertility is available from all women aged 12 to 49 years of age we restrict the sample to women aged 15 to 49, since the number of births is very small between age 12 and 14. Furthermore, since the effects of risk on fertility and education are likely to be larger in rural areas than in urban areas since insurance is less likely to be available the focus here is on rural areas. Guatemala has, however, a relatively low level of urbanisation and even areas that are officially characterised as urban often have a very strong rural component.[20] The sample therefore excludes all highly urbanised areas.[21] 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 (22). The explanatory variables fall into three groups: Individual and household variables, risks 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 obviously 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 "in-

[19]The results are available from the author on request.

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

[21]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.

surance" as discussed above (either through their labour when a hurricane hits a farm or through their income as migrants). The majority of women surveyed were still in their fertile years, 15-44 years of age, at the time of the survey and hence, what is used are not the completed fertility measures, but the cumulative age-specific fertility.

Even though Guatemala has a total fertility rate of around 4.6 the average number of births in the sample is 2.8, which is due to the the large number of women still in their reproductive ages in the sample.[22] 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.

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
$\text{Age}^2/100$	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 × $\text{age}^2/100$	40.78	29.77
Risk of hurricane × age × owns land	62.45	76.06
Risk of hurricane × $\text{age}^2/100$ × 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		

Risk is calculated as the percentage annual risk of a hurricane. The mean probability is around 4.6 percent per year, with the minimum being

[22]The average number of births for women aged 45 and older is 5.5.

3.4 and the maximum 7.6 and a standard deviation just shy of 1. While these numbers may not appear very substantial, there are two things to consider. Firstly, for the highest risk areas a woman would 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 the lowest risk areas are one and just below two. Second, a higher risk of hurricanes is most likely correlated with a higher risk of other storms. Only those storms with strong enough winds will be 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.

Shocks, once controlling for risk, have a predicted 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, whatever is first. The reason for the 29 year cutoff is that the majority of women have most of their children before they turn 30. Furthermore, it allows us to examine 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.[23] There are three ways that higher risks can affect the age profile of fertility. Firstly, women can begin having children earlier than they would otherwise have. Secondly, 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 relatively young could compensate for the negative impacts on fertility when older.[24] To capture this a dummy

[23] An alternative is to use age dummies. That would be more flexible, but would not easily allow for interactions with the risk measure.

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

for being between 35 and 49 years old at the time of the survey is interacted with the number of shocks experienced when the woman 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 risks 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 serve 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 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. 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 problem dummies for the 22 departments are included, with the Guatemala Department, where Guatemala City is located, being the excluded category.[25]

[25]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 may have a substantial impact on both fertility and education, but finding a suitable way of capturing these effects is difficult. The five

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 in meters. The main reason for included altitude is that it is an important factor in what type of crops can be grown in an area, something which might affect the fertility decision directly.[26] Finally, a dummy for the household being in a purely rural area is included.[27]

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 be 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 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 women surveyed were likely faced with the same risk environment as the women and this influenced their decisions on fertility and education, the woman's education is endogenous and it therefore excluded. Furthermore, the following section presents the determinants of adult education below using the same risk measure and it would therefore be inconsistent to assume that the mother's education is exogenous here.[28]

Most of the regularly included community variables have also been left

departments with the highest number of massacres were Chimaltenango, Huehuetenango, Quiche, Baja Verapaz and Alta Verapaz.

[26]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 from the author on request.

[27]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 that are included in the sample have a substantial amount of agricultural activity in them. Results with the interactions are available from the author on request.

[28]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.

out, since the risk environment is likely to have a significant effect on how a community develops. A community which has a significant risk of hurricanes 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' behaviour would not be captured.

Finally, there are no controls for infant and child mortality in the area. There are two reasons for this. Firstly, and most importantly, it is highly likely that infant and child mortality is significantly affected by the risks and shocks that an area is exposed to making it endogenous. Secondly, in order to assess the effects of hurricanes and hurricane risk on mortality this precise relationship is estimated below to examine if higher mortality can explain the effect of the risk of hurricanes on fertility.

4.2 Results

Table 2 presents the results for the number of children born and the results for the number of children alive in Table 3. Each table show seven different specifications or models. The first is the baseline regression with 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-VII are the same as II-IV, but with the shocks added. Model V has just the shocks and shocks interacted with being 35 to 49 years of age, while VI and VII also include these two shocks variables interacted with land ownership.

Overall the results for the two outcomes are very similar. In the basic models (II and V) there are no significant effects of risk on fertility. This, however, changes dramatically if one adds an interaction between risk and land ownership (III and VI). 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.

For both Models III and VI the sizes of the effects are, however, relatively small. To provide an idea of the magnitude consider a one percentage point increase in the risk of a hurricane. This would lead to increase in the number of children of only about 0.05 for land-owning households. Recall, however, that this result is based on the entire sample of women aged 15 to 49 and it is likely that the main way to increase fertility is by continuing to have children later in life. One way to get capture this possibility is to introduce

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**	0.452***	0.458***	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	−0.389***	−0.403***	−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***	0.459***	0.460***	0.456***
	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)	(0.068)
Owns land	0.031	0.032	−0.504*	−0.537*	0.031	−0.311	−0.316
	(0.062)	(0.062)	(0.296)	(0.294)	(0.062)	(0.308)	(0.308)
Hurricane risk (%)		−0.016	−0.052	−0.615**	−0.014	−0.047	−0.648**
		(0.069)	(0.070)	(0.251)	(0.069)	(0.070)	(0.269)
Risk × owns land			0.116*	−0.100		0.102	−0.162
			(0.062)	(0.115)		(0.062)	(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)					−0.438***	−0.251***	−0.291***
					(0.082)	(0.095)	(0.113)
Shocks × age 35 - 49					0.404**	0.099	0.268
					(0.200)	(0.211)	(0.276)
Shocks × owns land						−0.426***	−0.332**
						(0.098)	(0.162)
Shocks × age 35 - 49 × owns land						0.702***	0.174
						(0.123)	(0.399)
Constant	−6.501***	−6.436***	−6.286***	−3.154***	−6.959***	−6.937***	−3.345***
	(0.320)	(0.439)	(0.442)	(1.149)	(0.612)	(0.616)	(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

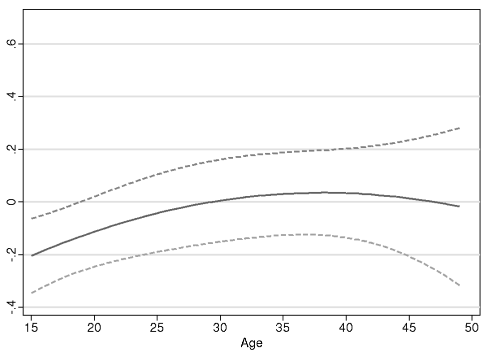
NOTE: * significant at 10%; ** significant at 5%; *** significant at 1%; Robust standard errors in parentheses, clustered at the household level. Additional variables (not shown) are department and rural dummies and a fourth-order polynomial in altitude.

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

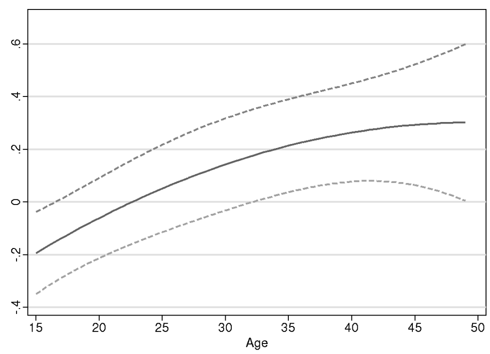
	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Age	0.406***	0.406***	0.406***	0.214***	0.462***	0.466***	0.248***
	(0.017)	(0.017)	(0.017)	(0.078)	(0.041)	(0.041)	(0.082)
Age squared	−0.346***	−0.346***	−0.346***	−0.099	−0.449***	−0.458***	−0.169
	(0.030)	(0.030)	(0.030)	(0.137)	(0.079)	(0.080)	(0.145)
Indigenous	0.317***	0.315***	0.313***	0.314***	0.311***	0.312***	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**	0.038	−0.299	−0.326
	(0.056)	(0.056)	(0.266)	(0.264)	(0.055)	(0.277)	(0.276)
Hurricane risk (%)		−0.030	−0.066	−0.667***	−0.027	−0.061	−0.744***
		(0.062)	(0.063)	(0.225)	(0.062)	(0.063)	(0.241)
Risk × owns land			0.113**	−0.054		0.102*	−0.012
			(0.056)	(0.103)		(0.056)	(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					−0.436***	−0.269***	−0.339***
(age 15 - 29)					(0.074)	(0.085)	(0.101)
Shocks × age 34 - 49					0.380**	0.133	0.376
					(0.182)	(0.191)	(0.251)
Shocks × owns land						−0.375***	−0.233
						(0.090)	(0.144)
Shocks × age 35 - 49 ×						0.562***	−0.059
owns land						(0.111)	(0.355)
Constant	−6.500***	−6.376***	−6.230***	−3.037***	−6.849***	−6.807***	−3.235***
	(0.290)	(0.393)	(0.397)	(1.035)	(0.553)	(0.557)	(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: * significant at 10%; ** significant at 5%; *** significant at 1%; Robust standard errors in parentheses, clustered at the household level. Additional variables (not shown) are department and rural dummies and a fourth-order polynomial in altitude.

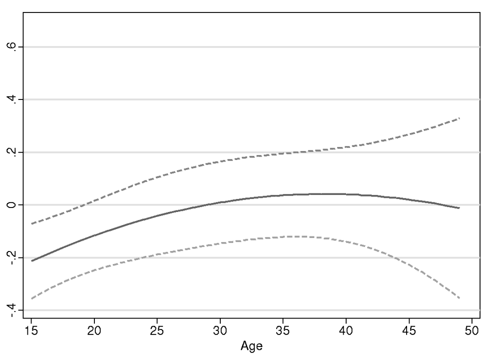
the interactions between the two age variables and the risk and risk interacted with land. This is done in Models IV and VII. The main drawback is that since the effect is no longer linear it is more difficult to interpret the effects of an increase in hurricane risk. Figures 2 and 3 therefore graph the estimated marginal effects of an increase in hurricane risk by age for number of children born and children alive at the time of the survey together with the upper and lower bounds of the 95 percent confidence interval.[29] In both figures, panel (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.



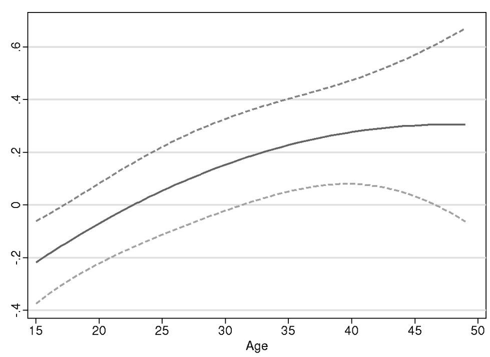
(a) Model IV for Landless



(b) Model IV for Land Owners



(c) Model VII for Landless

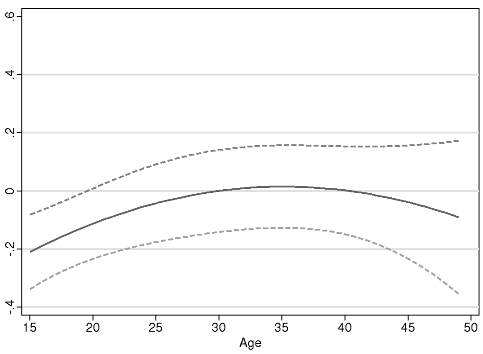


(d) Model VII for Land Owners

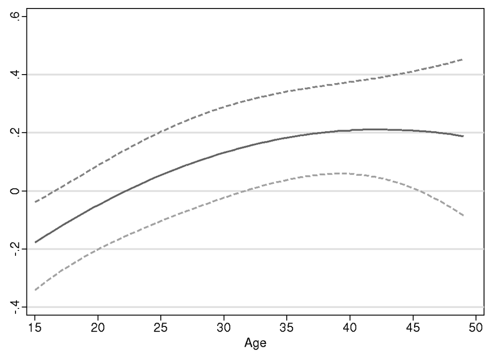
Figure 2: Marginal Effect of Hurricane Risk on Number of Children Born

The main result is how the risk of hurricanes affects the number of chil-

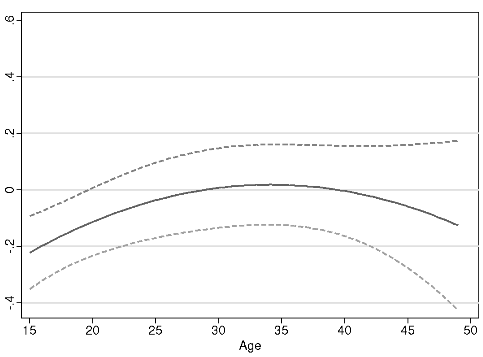
[29]The confidence interval is calculated using the delta method.



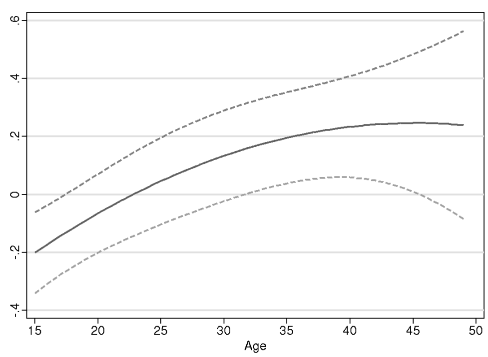
(a) Model IV for Landless



(b) Model IV for Land Owners



(c) Model VII for Landless



(d) Model VII for Land Owners

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

dren born and the number of children alive for households that own land.[30] The predicted marginal effect of hurricane risk on fertility is positive from around age 23, and becomes statistically significant at age 32 and remains statistically significant after that.[31] Hence, there is clear evidence that higher

[30]Since the results are essentially the same for the four different versions focus here is on Figure 2(b).

[31]For the other three figures the effect becomes statistically insignificant at the 95 percent level although only slightly so at or after age 45. The most likely explanation for this increase in 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. While it is clear that women in higher risk areas continue to have children longer it is not possible to determine if the children are also more closely spaced.

hurricane risk leads to higher fertility for households with land. Furthermore, the estimated effect of hurricane risk on fertility is now substantial. Take the number of children born to a woman aged 45 or above as a close approximation to the completed fertility then the marginal effect of a one percentage point increase in fertility is now about 0.3 children.[32] With a more than four percentage points difference between the highest and the lowest risk areas this corresponds to an difference of more than one child. For comparison the average number of births in the sample 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.[33]

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 compared with women with similar characteristics in less risk prone areas, for example because of pursuing education. The analysis of the effect of risk on educational attainment discusses this below.

Models VI-VII 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 all three 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 Models VI and VII shows that most of the reduction is due to lower fertility in 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 land owning households is around 0.65 per hurricane, which is very strongly statistically significant.

The reduction in fertility following a hurricane is, however, only part of the story. The interaction between the number of hurricanes and being

[32]Recall that a one percentage point increase is about one standard deviation.

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

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 the shock by having the children later. It is impossible to reject that the combined effect of the number of hurricanes and the interaction with being older is statistically significantly different from zero, since Model VII shows a only a small net effect of -0.03 and -0.18 for women without land and women with land, respectively. Note, however, that for shocks that take place later it clearly becomes less likely that the mother will be able to fully compensate for the reduction in fertility.[34]

4.3 The Relation between Hurricanes and Mortality

As Section 2 discusses one possible explanation why higher risk leads to higher fertility is the 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 analysing 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 had one child or more 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 the number of children who have died. The estimated equation is

$$M_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \tag{23}$$

[34] 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.

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.[35] Table 4 provides the descriptive statistics.

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		

Table 5 presents the results of OLS estimation of (23) with robust standard errors where the cluster level is the household.[36] There are two different

[35] 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.

[36] 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.

specifications for each of the two outcomes. All of the models use the number of hurricanes and the number of hurricanes interacted with owning land. Models I and III include the annual risk of a hurricane in percent and the annual risk interacted with owning land while Models II and IV in addition also have age and age squared interacted with risk and interacted with owning land.

The main variables of interests are the two shock variables. For all models the interaction between the number of hurricanes and land ownership is positive and statistically significant, although the net effects are relatively small. One extra hurricane leads only to an increase of about two percentage point increase in the probability of having a child die. Looking at the number of children who have died an additional hurricane increases the number of dead children by less than 0.1 child.

There appears to be little effect of the number of hurricanes on the mortality of children born to women who live in households without land. All of the effects are negative and in Model II the effect is significant, which might appear counterintuitive. One possible explanation for this is as follows. Firstly, women from households without land on average have lower fertility, which in itself should lead to lower mortality risk. Secondly, higher number of hurricanes means that it is more likely that a woman has experienced a hurricane shock before she begins childbearing. Since the results from 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. Hence, the decrease mortality probability may be a result of this combination of a lower number of children from not having land combined with the possibility of delayed and reduced childbearing from a higher number of hurricanes.

This explanation points to a problem with analysing 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 3 hurricane 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

Table 5: Effects of Risks and Shocks on Mortality

	Probability of Mortality		Number of Deaths	
	Model I	Model II	Model III	Model IV
Age	0.009*	−0.004	−0.010	0.003
	(0.005)	(0.024)	(0.013)	(0.048)
Age squared / 100	0.008	0.021	0.060**	0.021
	(0.009)	(0.038)	(0.024)	(0.079)
Indigenous	0.106***	0.106***	0.209***	0.210***
	(0.016)	(0.016)	(0.034)	(0.034)
Owns land	0.010	−0.031	−0.124	−0.140
	(0.073)	(0.078)	(0.143)	(0.157)
Rural	0.067***	0.065***	0.173***	0.171***
	(0.013)	(0.013)	(0.028)	(0.028)
Hurricane risk (%)	0.024	0.025	0.024	0.104
	(0.016)	(0.078)	(0.030)	(0.148)
Risk × owns land	−0.008	−0.118***	−0.008	−0.166**
	(0.015)	(0.033)	(0.029)	(0.080)
Risk × age		−0.001		−0.008
		(0.005)		(0.011)
Risk × age squared		0.003		0.017
		(0.008)		(0.018)
Risk × age × owns land		0.008***		0.010*
		(0.002)		(0.006)
Risk × age squared owns land		−0.012***		−0.016
		(0.004)		(0.011)
Hurricane shocks	−0.027	−0.047**	−0.033	−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	−0.270**	0.010	−0.145	−0.093
	(0.117)	(0.376)	(0.264)	(0.702)
Observations	4507	4507	4507	4507
R-squared	0.12	0.13	0.14	0.14
Adj. R-squared	0.12	0.12	0.13	0.13

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

significantly biased downward there is still a substantial gap to the increase in fertility that results from going from the lowest to the highest hurricane risk, which is about 1.2 children, especially since a woman in the lowest risk areas can still expect more than one hurricane during a 40 year period.

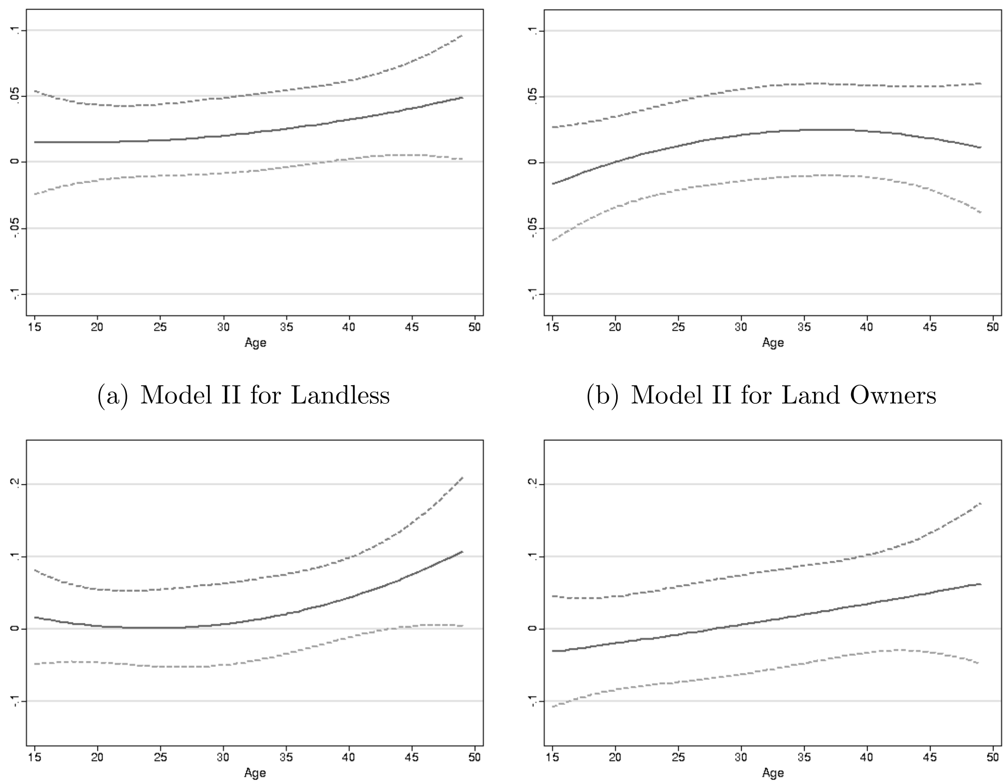
Before turning to how risk affects investment in education, it is worth briefly looking at the effect of hurricane risk on mortality. Since higher risk leads to higher fertility one might also expect a higher mortality if less resources are devoted to each child as a result. This "second-order" effect has attracted some attention in the literature on child mortality in developing countries, although it generally has been hard to identify (Wolpin 1997). In both Models I and III an increase in the risk of hurricanes leads to an increase in mortality, although the effect is not statistically significant and the effect is lower for households that own land than for those who do not.[37] Figure 4 shows the marginal effect of risk by age for Models II and IV for households without land and households with land. 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.

5 Education, Risks and Shocks

This section presents results of the effects of hurricane risks and shocks on educational attainment. It first discusses the econometric model and the selection of the sample. Secondly, presents the variables and their expected effects. Thirdly, the results are presented and discussed. 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 and level reached. Hence, repeating a year does not count as additional

[37]The closest to being statistically significant is the parameter on risk in Model I, where the p-value is 0.14.



(a) Model II for Landless

(b) Model II for Land Owners

(c) Model IV for Landless

(d) Model IV for Land Owners

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

education.[38] The estimated equation is

$$E_i = \alpha + X_i'\beta + R_i'\gamma + S_i'\delta + \varepsilon_i, \tag{24}$$

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.

[38]Alternative measures are be dummies 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.

The sample consists of all adults aged 20 to 69 years of age, who were not born in a city or a town and who were not born in the Municipality of Guatemala (the capital and surrounding areas). This is the sample that corresponds best to the sample used in the fertility estimations above. Hence, selection is strictly by place of birth, not where somebody currently resides. 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 closely resemble a representative sample of educational attainment for the areas of interest.

Migration is also one of the main reason why the information on the children born to the women in the sample is not useable. As mentioned above this is not the complete sample of children born, since the survey does not collect information on children who have either left the household or died. With a 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.[39] On the other hand, it is also possible that children from household 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.

5.1 Variables

Table 6 presents the descriptive statistics for the variables. 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 ex-

[39] 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.

amining 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.

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		

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. Firstly, for those who are born in the area they are currently living in there is no problems. Secondly, for those who moved into their current municipality after turning 13 years old or older, the risk measure 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 the sex of person.

Deciding on a measure of shocks is more complicated. 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. Hence, 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 here 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 going back to 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.[40] There are five 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 II with the two measures of hurricane shocks and the interaction with land ownership. Finally, Model V allows the effects of risk and shocks to vary by sex.

There is a statistically significant and substantial positive effect of hurricane risk on educational 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. There are at least two possible explanations for this. Firstly, returns to education might be higher in areas that are more risk prone. Secondly, if migration as an insurance mechanism is important it may be more beneficial to families in higher risk areas to have fewer children and educate them more. Furthermore, while the effect of risk on education is lower for women and than for men this effect is not significant if shocks are included as in Model V. The total effect of increasing hurricane risk by one percentage point is equal to 0.4 years of school for men and 0.3 for women.[41]

The main result of interest is, however, how hurricane risks affect the schooling of individuals from households with land. While the estimated parameter for men is negative and statistically significant the total effect is 0.19, which is statistically significant different from zero![42] Hence, not only do households with land who live in more risk prone areas have more children, they also educated their boys more than households in less risky areas. Furthermore, while the effect might not appear large 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

[40]The results for the Tobit model are shown in Table 9.

[41]The latter is statistically different from zero at the one percent level.

[42]The F-statistics is 2.74, which is statistically significant at the 10 percent level with 6017 degrees of freedom (recall that there is clustering at the household level). The result for the same hypothesis for the Tobit model yields a Chi-square statistics of 4.08, which is statistically significant at the five percent level.

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

	Model I	Model II	Model III	Model IV	Model V
Female	−1.285***	−1.291***	−0.335	−1.291***	−0.221
	(0.056)	(0.056)	(0.297)	(0.056)	(0.301)
Age 30-39	−0.928***	−0.933***	−0.942***	−0.599***	−0.604***
	(0.105)	(0.105)	(0.105)	(0.158)	(0.157)
Age 40-49	−1.622***	−1.632***	−1.607***	−1.500***	−1.472***
	(0.108)	(0.108)	(0.108)	(0.119)	(0.118)
Age 50-59	−2.629***	−2.638***	−2.625***	−2.579***	−2.558***
	(0.103)	(0.103)	(0.103)	(0.111)	(0.110)
Age 60-69	−3.186***	−3.197***	−3.178***	−3.259***	−3.224***
	(0.114)	(0.114)	(0.114)	(0.116)	(0.117)
Indigenous	−2.444***	−2.421***	−2.289***	−2.419***	−2.287***
	(0.121)	(0.121)	(0.120)	(0.121)	(0.120)
Parents owned land	−0.175**	0.786*	0.966**	0.820**	1.006**
	(0.087)	(0.414)	(0.413)	(0.413)	(0.413)
Female × owned land			−0.982***		−0.988***
			(0.097)		(0.097)
Risk of hurricane (percent)		0.318***	0.385***	0.355***	0.407***
		(0.095)	(0.102)	(0.097)	(0.103)
Risk of hurricane × owned land		−0.209**	−0.249***	−0.208**	−0.219**
		(0.087)	(0.088)	(0.087)	(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)				−0.151*	0.015
				(0.084)	(0.108)
Hurricane shocks (age 0-6) × owned land				−0.127	−0.338**
				(0.110)	(0.161)
Hurricane shocks (age 0-6) × female					−0.298**
					(0.116)
Hurricane shocks (age 0-6) × owned land × female					0.383*
					(0.206)
Hurricane shocks (age 7-12)				−0.241**	−0.120
				(0.096)	(0.126)
Hurricane shocks (age 7-12) × owned land				0.071	0.006
				(0.127)	(0.199)
Hurricane shocks (age 7-12) × female					−0.208*
					(0.125)
Hurricane shocks (age 7-12) × owned land × female					0.078
					(0.244)
Constant	6.744***	5.390***	4.836***	5.309***	4.686***
	(0.352)	(0.546)	(0.572)	(0.547)	(0.574)
Observations	12331	12331	12331	12331	12331
R-squared	0.18	0.19	0.19	0.19	0.19
Adj. R-squared	0.18	0.18	0.19	0.18	0.19
Risk + Risk × owns land = 0		1.04	1.46	1.86	2.74*
Risk + Risk × female = 0			6.85***		9.57***
Risk + Risk × land + Risk × female + Risk × land × female = 0			0.24		0.57

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

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. Note, however, that this is not because households with land invest less in girls' education than those with land. The additional effect of being female in a household with land is very small, so most of the negative effect is common to households with and without land.

As for the households without land, there are at least the same two possible explanations for the increase in both fertility and education with increasing risk of hurricanes as were mentioned above. In addition it is possible that landed households have a higher "internal" return to human capital. The argument for this follows the suggestion in Schultz (1975) that education might increase the ability to deal with disequilibrium as was discussed in Section 2. One can imagine a situation in which a household needs both more people to help with post-hurricane reconstruction and these people to be better trained to deal with the lack of resources likely after a hurricane. Without more detailed panel data it is, however, difficult to disentangle these different explanations.

Shocks that occur before an individual begins school appear to have more of an impact than those that occur while the person is in 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. Hardest hit are men from household with land, although the effect is relatively similar to the effect for women in households both with and without land. One hurricane shock has an estimated negative effect on years of schooling of 0.3. For the hurricanes that occur between age 7 and 12 there is little effect on men's schooling, no matter if 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.

While it is hard to distinguish between the migration and the ability to deal with disequilibrium stories 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.[43] The sample consists of

[43]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

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 its 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.

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: * significant at 10%; ** significant at 5%; *** significant at 1%
Additional variables (not shown) are department dummies and a fourth-order polynomial in altitude.

What is clear is that 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 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 more investment in human capital *and* the possibility that higher education leads to individuals being better at dealing with shocks.

own land.

6 Conclusion

With risk a significant fact of life in developing countries it is important to analyse what effects risk have on households' decisions. Two areas that are especially important are education and fertility since both have a substantial impact both on individuals' welfare and on a country's growth prospects. A reccuring 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, which are unique in that they can be used to measure both risk *and* shocks. These data are combined with a household survey to analyse how decisions on fertility and education respond to both risk and shocks. For households with land, an increase in the *risk* of hurricanes lead to *both* higher fertility and higher education, while households without land have fewer children but also higher education. That education is also increasing in risk is especially fascinating and even more so since fertility also increases for the households with land. Hurricane *shocks* lead to decreases in both fertility and education, and although there is a substantial compensatory effect on fertility later in life, that is not the case for education.

What explains these patterns? A 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 the relatively low mortality following hurricane shocks found here and especially the higher education levels in areas with higher hurricane risk.[44]

Another possible explanation is that changes in risk may lead to changes 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 fall educational attainment is higher for households both with and without land.

It is also possible that the risk measure, because of the way it is con-

[44]This is not to argue that there is no effect of the mortality, but rather that it cannot be the main explanation.

structed, 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 (since a hurricane would be more likely to be reported). There are two problems with this explanation. Firstly, if the areas are indeed richer then it is not clear why fertility falls for households with land, while it increases for households with land. Secondly, the return to education appears to be lower in higher risk areas leading to lower household for those who depend on wage labour.

Hence, it is most likely that a combination of direct insurance through having more children and insurance through migration that explains the higher number of children for households with land and the higher levels of education for both groups. The increase can be attributed to both the increased ability to deal with disequilibrium and the increased opportunities if a person migrates. This explanation best fits the available evidence since it can explain both the changes in fertility and the higher level of schooling. It also fits the observed lower return to education in higher risk areas since education in this case is mainly aimed at dealing with adverse situations and in years where there are no shocks such as the survey year, this 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.

One caveat is that this paper only covers one specific risk, namely hurricanes. This is important given that children, or families more generally, might play a special role in the aftermath of hurricanes that cannot readily be fulfilled by the labour market. Hence, one worthwhile direction for future research would be to look at how other types of risks affects these same behaviours. Furthermore, it is possible to use the hurricane data to look at other decisions, such as crop choice or the decision to migrate.

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A Model Details

The individual terms for the model with imperfect capital markets are

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

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

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

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

$$
\begin{aligned}
&-E[u''(c_2)(Y_2-\xi)] \times \Bigg[\\
&\quad \Bigg\{ \Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)] \Big) \\
&\quad \times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)] \Big) \\
&\quad - \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&\quad + u'(c_2)F_{Hn}(n,H))] \Big) \\
&\quad \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
&\quad + u'(c_2)F_{nH}(n,H)] \Big) \Bigg\} \\
&+F_n(n,H)] \times \Bigg\{ \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \\
&\quad \times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)] \Big) \\
&\quad - \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&\quad + u'(c_2)F_{Hn}(n,H))] \Big) \\
&\quad \times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \Bigg\} \\
&-F_H(n,H)] \times \Bigg\{ \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \\
&\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
&+ u'(c_2)F_{nH}(n,H)] \Big) \\
&- \big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)] \Big) \\
&\times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \Bigg\} \Bigg],
\end{aligned}
\tag{25}
$$

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

$$
\begin{aligned}
& E[u''(c_2)(Y_2-\xi)] \times \Bigg[\\
& \Big\{ \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \\
& \times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)] \Big) \\
& - \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \\
& \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
& + u'(c_2)F_{nH}(n,H)] \Big) \Big\} \\
& -F_n(n,H)] \times \Big\{ \Big(u''(c_1) + E[u''(c_2)] \Big) \\
& \quad \times \Big(u''(c_1)np + v''_{HH}(H,n) + E[u''(c_2)(F_H(n,H))^2 + u'(c_2)F_{HH}(n,H)] \Big) \\
& \quad - \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big)^2 \Big\} \\
& +F_H(n,H)] \times \Big\{ \Big(u''(c_1) + E[u''(c_2)] \Big) \\
& \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{nH}(H,n) + E[u''(c_2)F_H(n,H)F_n(n,H) \\
& + u'(c_2)F_{nH}(n,H)] \Big) \\
& - \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \\
& \times \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \Big\} \Bigg].
\end{aligned} \tag{26}
$$

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

$$
\begin{aligned}
&-E[u''(c_2)(Y_2-\xi)] \times \Bigg[\\
&\Bigg\{ \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \\
&\times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&+ u'(c_2)F_{Hn}(n,H))] \Big) \\
&- \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \\
&\times \Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)] \Big) \Bigg\} \\
&+F_n(n,H)] \times \Bigg\{ \Big(u''(c_1) + E[u''(c_2)] \Big) \\
&\quad \times \Big(u''(c_1)(k+pH)np - u'(c_1)p + v''_{Hn}(H,n) + E[u''(c_2)F_n(n,H)F_H(n,H) \\
&\quad + u'(c_2)F_{Hn}(n,H))] \Big) \\
&\quad - \Big(u''(c_1)np + E[u''(c_2)F_H(n,H)] \Big) \\
&\quad \times \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big) \Bigg\} \\
&-F_H(n,H)] \times \Bigg\{ \Big(u''(c_1) + E[u''(c_2)] \Big) \\
&\times \Big(u''(c_1)(k+pH) + v''_{nn}(H,n) + E[u''(c_2)(F_n(n,H))^2 + u'(c_2)F_{nn}(n,H)] \Big) \\
&- \Big(u''(c_1)(k+pH) + E[u''(c_2)F_n(n,H)] \Big)^2 \Bigg\} \Bigg]
\end{aligned} \tag{27}
$$

B Estimation Results

Table 9: Effects of Risks and Shocks on Education — Tobit

	Model I	Model II	Model III	Model IV	Model V
Female	−2.439***	−2.447***	−0.154	−2.448***	−0.031
	(0.107)	(0.107)	(0.484)	(0.107)	(0.488)
Age 30-39	−1.508***	−1.518***	−1.537***	−0.952***	−0.967***
	(0.137)	(0.137)	(0.136)	(0.229)	(0.228)
Age 40-49	−2.751***	−2.767***	−2.726***	−2.544***	−2.498***
	(0.151)	(0.151)	(0.151)	(0.167)	(0.167)
Age 50-59	−4.915***	−4.927***	−4.908***	−4.804***	−4.778***
	(0.181)	(0.181)	(0.180)	(0.191)	(0.190)
Age 60-69	−6.241***	−6.263***	−6.230***	−6.349***	−6.292***
	(0.228)	(0.228)	(0.227)	(0.231)	(0.230)
Indigenous	−4.081***	−4.046***	−3.795***	−4.045***	−3.795***
	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)
Parents owned land	−0.103	1.351**	1.758***	1.428**	1.848***
	(0.123)	(0.570)	(0.568)	(0.575)	(0.573)
Female × owned land			−1.995***		−1.997***
			(0.171)		(0.172)
Risk of hurricane (percent)		0.469***	0.642***	0.531***	0.691***
		(0.108)	(0.121)	(0.111)	(0.124)
Risk of hurricane × owned land		−0.318***	−0.395***	−0.318***	−0.359***
		(0.122)	(0.124)	(0.122)	(0.127)
Risk of hurricane × female			−0.344***		−0.317***
			(0.103)		(0.105)
Risk of hurricane × owned land × female			0.070		0.008
			(0.052)		(0.076)
Hurricane shocks (age 0-6)				−0.230**	−0.107
				(0.117)	(0.149)
Hurricane shocks (age 0-6) × owned land				−0.187	−0.474**
				(0.170)	(0.232)
Hurricane shocks (age 0-6) × female					−0.222
					(0.177)
Hurricane shocks (age 0-6) × owned land × female					0.535
					(0.336)
Hurricane shocks (age 7-12)				−0.407***	−0.229
				(0.145)	(0.176)
Hurricane shocks (age 7-12) × owned land				0.049	0.021
				(0.195)	(0.270)
Hurricane shocks (age 7-12) × female					−0.305
					(0.194)
Hurricane shocks (age 7-12) × owned land × female					−0.073
					(0.386)
Constant	7.177***	5.148***	3.916***	4.999***	3.690***
	(0.469)	(0.661)	(0.702)	(0.663)	(0.705)
Observations	12331	12331	12331	12331	12331
Log-Likelihood	−26172.67	−26162.19	−26087.61	−26156.79	−26078.95

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