Conferencia Interamericana de Seguridad Social

CIESS Centro Interamericano de Estudios de Seguridad Social

VOL. 6 NUM. 1 FIRST SEMESTER 2010

Well-being and Social Policy

10

Natural Disasters and Poverty in Latin America
Guest Editor
Alejandro de la Fuente

Well-being and Social Policy
VOL. 6 NUM. 1 FIRST SEMESTER 2010

WELL-BEING AND SOCIAL POLICY
VOL 6, NUM. 1, pp. 17-54

HURRICANE MITCH AND CONSUMPTION GROWTH OF NICARAGUAN AGRICULTURAL HOUSEHOLDS

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Abstract

There is little micro-evidence on the persistence of natural disasters' welfare impacts. This paper assesses the effect of Hurricane Mitch on consumption of Nicaraguan agricultural households. Mitch occurred in October 1998. Pre-post data is obtained from a nationally representative panel collected in 1998 and 2001. An additional survey was fielded in 1999 for households from the panel affected by the hurricane. The 1999 data contains self-reported measures of hurricane-induced losses. Satellite rainfall observations are used as a complementary measure of the shock. Using the structure of the data, the paper disentangles the idiosyncratic and common dimensions of the shock, together with its short and medium-term impacts. Within the sample of households affected by the hurricane, micro-growth model estimates point to short-term negative effects at most limited to idiosyncratic events such as floods and displacement. Mitch's medium-term common impact is then analyzed as a quasi-experiment. Difference-in-differences estimates do not provide evidence that households affected by Mitch suffered from lower growth between 1998 and 2001. Overall, hurricane Mitch's direct consumption impact thus exhibits little persistence.

Keywords: Natural Disasters, Welfare, Growth, Nicaragua.
JEL classification: I32, Q12, Q54.

Introduction

Given the limitations of formal and informal insurance mechanisms in the uncertain environment where many of the poor live, risk has been singled out not only as a dimension of poverty, but

* This paper was written while I was affiliated with the University of Oxford. The findings, interpretations, and conclusions expressed in this paper are entirely mine. They do not represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent. I am grateful to Alan Beggs, Steve Bond, Stefan Dercon, Chris Elbers, Mans Soderbom, Danila Serra, Thomas Flury, Catherine Porter, Nicolas Van de Sijpe, two anonymous referees as well as seminar participants in Oxford, Rethymno, St-Gallen and Mexico City for useful comments on an earlier version of this paper. All remaining errors are my own. Financial support from the Berrow Foundation and the Swiss National Science Foundation is gratefully acknowledged.

crucially as a cause of low long-term welfare levels (Fafchamps, 2003; Dercon, 2004a; Elbers et al., 2007). With growing availability of panel data, analyses of households' welfare dynamics at the micro-level are multiplying,[1] and the dynamic impact of shocks on welfare changes can be assessed (Dercon, 2004b; Lokshin and Ravallion, 2004). This paper evaluates the impact of hurricane Mitch on consumption growth of Nicaraguan agricultural households by contrasting its idiosyncratic and common effects in the short and medium terms.[2]

The literature on natural disasters is often limited to the determination of victims' profiles or direct damage assessment (ECLAC, 1999; Morris et al., 2002). The degrees to which estimated macro-economic losses shape welfare dynamics at the micro-level are rarely analysed. Two recent papers on hurricane Mitch constitute important exceptions. Baez and Santos (2007) identify a disproportionate adverse medium-run effect of Mitch on Nicaraguan children's well-being by focusing on outcomes related to health, nutrition and labour-force participation. Carter et al. (2007) study the impact of the hurricane on Honduran households' asset trajectories and show that "the effects of the hurricane on assets were of longer duration and felt much more acutely" for the lowest wealth group (p.852). While these recent contributions highlight channels through with disasters might affect welfare in the longer term, this paper tackles the direct effect of the shock on consumption. Little micro-evidence exists on the persistence of natural disasters' welfare impacts and the paper contributes to filling this knowledge gap.

Hurricane Mitch occurred in October 1998. Mitch was a tragic event that claimed thousands of lives and caused extensive damage in Central America in October 1998 (ECLAC, 1999). Beyond the immediate tragedy, Nicaraguan data have appealing features to study the persistence of Mitch's direct consumption impact.[3] The National Statistical Agency (INEC)[4] collected three Living Standards Measurement Surveys (LSMS). A panel of nationally representative LSMS is available in 1998 and 2001. In addition, households from the national panel located in communities damaged by Mitch were also surveyed in 1999 so that a three-round panel can be built for households affected by the storm. The persistence of the shock can be assessed in two complementary ways. First, the impact of idiosyncratic hurricane losses is analysed using the three-round panel of affected households. The focus is on the effect of variations in relative losses on short-term consumption growth. An empirical growth model is estimated using panel data methods. Second, the medium-term persistence of Mitch's common impact is tested in a quasi-experimental set-up built from the nationally representative 1998-2001 panel. A difference-in-differences approach is used to estimate the welfare effect of Mitch by contrasting consumption growth of affected households with various comparison groups. Throughout the analysis, complementary measures of the hurricane shock are used. Self-reported losses are obtained directly from the 1999 LSMS. In addition, innovative satellite rainfall data from NASA tropical rainfall measurement project (TRMM) are interpolated at municipal centres to provide an exogenous measure of the common dimension of the shock.

[1] For instance, Baulch and Hoddinot (2000) or Jalan and Ravallion (1998, 2002, 2004).

[2] In this paper, "short-term" and "medium-term" correspond to 1 and 3 year windows, respectively.

[3] Lokshin and Ravallion (2004) analyse persistence in a time-series perspective, while Carter and Barrett (2006) consider persistence through the impact of shocks on assets. Here, persistence is analysed by relying on the structure of the data to contrast the impact of the shock after one and three years.

[4] The Nicaraguan National Statistical Agency has recently been renamed *INIDE* (National Insitute for Development Information), but was called INEC (National Insitute for Statistics and Census) at the time of collecting the surveys used in this paper. I use the latter acronym throughout the paper.

The main results can be summarised as follows. Within the sample of households affected by the hurricane, micro-growth model estimates point to short-term negative effects at most limited to idiosyncratic events such as floods and displacement. By contrast, higher rainfall or self-reported losses are not associated with lower consumption growth for affected households. In the medium term, difference-in-differences estimates reveal that Mitch did not lower consumption of households located in regions affected by Mitch. While comparison households located in municipalities where some communities were affected by the hurricane exhibit the highest growth rate, the difference with treated households is never significant. Overall, Mitch's direct welfare impact is therefore characterised by little persistence. The analysis does not rule out indirect welfare effects that may unfold through the long-term cost of mitigating mechanisms such as those suggested by Baez and Santos (2007) or Carter et al. (2007).

The structure of this paper is as follows. Section 1 describes the data. Section 2 uses the three-round panel to analyse the short-term effects of idiosyncratic variations in hurricane damage on consumption growth of affected households. Section 3 assesses the medium-term common impact of Mitch using difference-in-differences methods in the two-round national panel. Section 4 concludes. The appendix contains tables and figures.

1. Data

1.1 Nicaraguan LSMS

INEC collected three LSMS in panel in 1998, 1999 and 2001. The 1998 and 2001 LSMS form a nationally representative panel. Hurricane Mitch struck Central America at the end of October 1998, shortly after completion of the 1998 LSMS. In 1999, INEC re-surveyed households from the 1998 LSMS located in communities affected by the hurricane.[5] 1999 data are neither representative of the country nor of the population affected by Mitch, but their availability in conjunction to the 1998 and 2001 nationally representative surveys nevertheless provides unique pre-post data to analyze the welfare effects of a natural disaster. The 1998-1999-2001 panel allows analysing whether the relative magnitude of the shock affects the relative magnitude of welfare losses within the sample of affected households. In parallel, the 1999 LSMS reveals which areas of the countries were hit by the hurricane. Based on this, treatment and comparison groups can be built and Mitch can be studied as a quasi-experiment in the 1998-2001 panel. Therefore, the 1998-2001 and 1998-1999-2001 panels constitute the basis for two complementary steps of the analysis. The short-term and medium-term impacts of the shock (after respectively 1 and 3 years) can be disentangled, while its idiosyncratic and common dimensions can also be contrasted.

The 1998-2001 spell is one of limited welfare improvement in Nicaragua. Both general and extreme poverty decrease in the nationally representative samples (from 44.4% to 40.8%, 19.9% to

[5] Criteria for inclusion of households in 1999 LSMS are discussed in section 3.1.

13.2% respectively). This paper focuses on agricultural households for whom detailed hurricane losses are available and growth models can potentially apply. The 1998-1999-2001 panel contains consumption and shock data for 197 agricultural households located in areas affected by the hurricane, and the 1998-2001 panel for 1016 agricultural households[6] (including 204 households located in areas affected by the hurricane).[7]

Table 1 displays key descriptive statistics for consumption and poverty. The consumption aggregate contains food and non-food items, as detailed in Castro-Leal and Sobrado (2001) or Sobrado (2001, 2003). The food component encompasses the value of food purchased at home and outside of home, as well as non-purchased food obtained from own production or gifts. The non-food component covers housing costs (proxied by a self-reported or estimated monthly rent), expenditures on health, education, consumer goods and household services (water, garbage collection, electricity, cooking fuel, non-electric lighting, and telephone), as well as the annual use value of durable goods.[8] The consumption aggregate is expressed per capita in 1998 prices and corrected for geographical price variations. The paper presents estimations for the consumption aggregate, but the nature of the results remains robust when they are narrowed down to a basic consumption aggregate (excluding durable goods and housing) or its food component.

Consumption-based poverty lines are computed from the household survey (Castro-Leal and Sobrado, 2001; Sobrado, 2003). The extreme poverty line (2489 cordobas in 1998 prices)[9] represents the cost of the minimum caloric requirement recommended for Nicaragua using observed consumption food basket and prices from the survey. The general poverty line (4223 cordobas in 1998 prices) adds an allowance for the consumption of non-food goods and services. Since poverty is predominantly rural in Nicaragua (World Bank 2001, 2003), poor households are over-represented in the agricultural panels. In the Mitch panel, 74.1% of households are poor and 32% extremely poor at baseline.

While the 1998-2001 agricultural panel echoes national welfare trends in terms of poverty reduction, average consumption growth remains negative. Patterns are also mixed in the Mitch panel. General poverty decreases in both spells, but extreme poverty increases in 1998-1999. In addition, average consumption growth is higher in 1998-1999 than in 1999-2001. There are also substantial variations in growth rates but they are largely symmetric: some households suffer large consumption decrease between 1998 and 1999, but others enjoy large consumption growth during the same period. No aggregate impact of hurricane Mitch on consumption therefore appears from descriptive statistics. There is substantial variation in welfare changes, however. Section 1.3 will analyse whether households' diverse welfare experiences are explained by variations in the hurricane-induced losses they suffer.

[6] The final panels are formed of households involved in agriculture in all rounds. In the Mitch panel, 13% of 1998 agricultural households are not active in agriculture in 2001 (22% in the 1998-2001 panel). Where possible, estimations were replicated on the panel of households initially active in agriculture and results remain unaffected. Attrition is discussed in section 2.4.

[7] This includes the 197 households from the Mitch panel, plus 7 who were only surveyed in 1998 and 2001.

[8] The use value of durable goods is estimated by dividing the current value of a durable good by its remaining useful lifetime (twice the estimated average age for each good under study) (Sobrado, 2001).

[9] The cordoba-dollar exchange rate averaged 10.58 in 1998.

1.2 Self-reported hurricane damage

The 1999 LSMS contains self-reported hurricane-induced losses for the 197 agricultural households of the Mitch panel. Almost all households report losses, consistent with the fact that households were re-surveyed precisely because they were located in communities damaged by the hurricane. 96% of households in the sample report losses from hurricane Mitch in the form of asset (including livestock and capital) or output. Self-reported losses are described in Table 2.

Capital losses are reported by 29% of households in the sample, averaging 1182 cordobas across all households.[10] Livestock constitutes an important component of households' assets.[11] 64% of households lost livestock (mainly cattle), the average loss amounting to 1978 cordobas across all households. Asset losses aggregate both capital and livestock, affecting 72% of household and averaging 3160 cordobas.

Output losses are more frequent than capital losses. Losses of output comprise seeds and crops. Because the hurricane struck in most places before the end of the 2nd agricultural cycle, both the incidence and aggregate value of seed losses are much higher than crop losses. In total, 94% of households suffered from output losses, averaging 5211 cordobas. These output losses appear large in comparison to the average baseline consumption of a household member (3600 cordobas, Table 1).

Adding self-reported asset losses to output losses yields a total measure of hurricane-induced losses. This measure consolidates the value of a stock with the value of a flow and as such has limited economic content, but nevertheless provides an indication of the large magnitude of total self-reported hurricane-induced losses,[12] which average 8371 cordobas in the sample.

In addition to output and productive asset losses, the hurricane caused widespread housing damage. A housing damage index is built by adding values of 0 (no), 1 (limited) and 2 (serious) for damage to dwelling's roof, floor, walls and water system (Table 2). Housing damage led to displacement of some households. The survey tracked displaced households that remained in the same municipality. 10% of households were permanently displaced at the time of the 1999 survey, and 24% had been temporarily displaced but had returned to their household by the time of the survey.[13]

Finally, a flood dummy constitutes a last self-reported measure of the shock. In the agricultural section of the Nicaraguan LSMS survey, households report whether they suffered from floods over the last 12 months. The high incidence of floods in 1998-9 (15%, compared to 4% in 1997-8 and 5% in 2000-1) suggests that the 1999 dummy mostly captures floods caused by hurricane Mitch.

[10] Capital includes agricultural property, agricultural equipment, agricultural installations, tools and work animals.
[11] Livestock includes cattle, pigs, poultry, horses and other animals.
[12] Both measures will also be considered separately in the econometric analysis.
[13] Households who were displaced or migrated to another municipality dropped from the survey and became attritors. Attrition is discussed in section 2.4.

On the whole, losses and damage induced by hurricane Mitch appear large for agricultural households, but significant variation remains in both their incidence and magnitude. The econometric analysis will test whether direct damage translate into subsequent welfare losses, and whether relative magnitude of losses explain the heterogeneity of welfare outcomes described above. It will also test for differentiated impacts across dimensions of the shock.

1.3 Satellite rainfall data

Since survey-based hurricane losses can suffer from reporting bias, a complementary exogenous measure of the shock is useful. Mitch's track did not enter the Nicaraguan territory and intensive rainfall constituted the principal cause of damage (INETER, 1998; Hellin et al., 1999). Gauge data are particularly unreliable during extreme events (Hellin et al., 1999) and sparsely available in Nicaragua. Innovative satellite rainfall data are used instead. NASA's tropical rainfall measurement mission (TRMM) provides satellite monthly accumulated rainfall starting in 1998. The shortness of TRMM series is by far outweighed by its sharp geographical coverage: rainfall observations are available on a grid of 0.25 degrees of longitude by 0.25 degrees of latitude. TRMM satellite rainfall data therefore have attractive characteristics for use in conjunction with household surveys of national coverage, but to my knowledge TRMM data have not been used in the economic literature.[14] Bilinear interpolation is applied to estimate municipal rainfall for each set of municipal coordinates within the grid (see annex). The Mitch panel covers almost 40 municipalities and therefore contains substantial variation in the rainfall measures, particularly since rainfall also varies a lot across space during the hurricane. Figure (2) presents average municipal monthly rainfall as interpolated from TRMM. Extraordinary rainfalls due to hurricane Mitch are clearly visible in October 1998. Average rainfall amounts to 539mm for agricultural households in the Mitch panel, an excess of 353mm.

Most shock measures are positively correlated but remain complementary. For instance, correlation coefficients between rainfall and monetary losses are typically in the 0.1-0.2 range. Besides rainfall, local geographical idiosyncrasies such as steepness of slopes or proximity to rivers can also explain the heterogeneous impact of the shock. This reflects variation of the shock's incidence at the local level, as will be further discussed in Section 3.

[14] Miguel et al. (2004) use satellite rainfall data from the Global Precipitation Climatology Project (GPCP). GPCP series is longer but 10 times less precise than TRMM data.

2. Mitch's short-term idiosyncratic impact

2.1 Micro-growth models

Welfare changes at the micro-level can be analysed through empirical growth models. Theoretically, a range of theoretical growth models can be applied to the micro-level, including endogenous growth through externalities (Jalan and Ravallion, 2002). Absence of within-country capital mobility is often required for neo-classical models to carry through.[15] For instance, Ravallion (2005) assumes in typical fashion a common separable utility function, in addition to a concave household production function. Micro-growth regressions can be directly derived from such theoretical models under additional assumptions, among which a constant discount and time preference rate (Ravallion, 2005).

Risk and shocks have also been built into theoretical micro-growth models. Elbers et al. (2007) develop a structural framework to analyse households' consumption growth in a stochastic Ramsey model. They incorporate both output and asset shocks and importantly disentangle the ex ante and ex post effects of risk on growth. Elbers and Gunning (2002) stress that strong assumptions are required for empirical identification of stochastic growth models: "the canonical growth regression is consistent with a model in which risk affects investment decisions only ex post, when the agent experiences a shock" (p.2). Dercon (2004b) takes this route by modelling shocks ex post into an empirical consumption growth model.

In this paper, I use the micro-growth model developed by Dercon (2004b), which constitutes one of the models fulfilling the conditions highlighted by Elbers and Gunning (2002) for an empirical growth model to be identified. This paper does not aim to recover structural parameters of the underlying model (nor a convergence coefficient), but rather to estimate the impact of an observed shock. The reader is invited to refer to Dercon (2004b) for a derivation and discussion of the model. Testable hypotheses from this model can in first approximation be seen as derived from a standard deterministic neoclassical framework where shocks result from uncertainty and households are considered non-responsive. The ex post focus is justified by the rare occurrence of extreme events such as hurricanes. In deterministic models, the impact of shocks on welfare can be analysed through transitional dynamics: while the shock can have a positive impact on growth during the recovery spell, it has a negative impact on growth as measured from pre-shock consumption levels. In the next section, the empirical growth model is set-out and used to estimate the impact of the hurricane shock on consumption growth.

One of the reasons why the discussion in this paper is framed within a consumption growth model is that no comprehensive income aggregate can be built from the 1999 LSMS. The estimation strategy still directly relates to the consumption smoothing literature. As will be further discussed below, empirical growth models can also be seen as a more general version of the reduced form test of the permanent income hypothesis, in particular Cochrane's (1991) full insurance test.

[15] This should not be seen as a limitation. In fact, Banerjee and Duflo (2005) stress the necessity to build macro-growth models allowing for misallocation of resources at the micro-level.

2.2 Benchmark specifications

This section analyses the impact of idiosyncratic hurricane losses on contemporaneous consumption growth of affected households in the Mitch agricultural panel. The focus is on identifying whether variations in the magnitude of losses affect short-term growth and explain the heterogeneous welfare outcomes discussed in Section 1.1. An empirical micro-growth model is estimated for the 197 agricultural households of the Mitch panel. The basic specification is as follows:[16]

$$\ln(c_{i,1999})-\ln(c_{i,1998})=\alpha+\beta\ln(c_{i,1998})+\gamma M_{i,1999}+\delta X_{i,1999}+\upsilon_{i,1999}+\eta_i \qquad (1)$$

The aim is to test the impact of variations in hurricane losses ($M_{i,1999}$ standing for "Mitch") on contemporaneous consumption growth (in particular, $\gamma<0$), allowing for differentiated impacts of the various dimensions of the shock. Since initial consumption is measured before the shock, a negative coefficient is expected. Importantly, γ captures the impact of the shock after mitigation strategies are used. Satellite municipal rainfall and self-reported measures of losses are used as alternative shock variables. Unobserved household-level time-invariant heterogeneity (η_i) is introduced in the model. The OLS estimator cannot deal with such unobserved heterogeneity, but it will be tackled in Section 2.3 with a first-difference specification.

The following control variables are included. Lagged consumption $\ln(c_{i,1998})$ serves as control for households' pre-disaster welfare.[17] Including lagged consumption provides the least restrictive empirical model and the implications of this choice for estimation will be further discussed below. In each survey round, agricultural households report whether they suffered from drought, pest or other agricultural shocks. I control for the difference in the incidence of these shocks between rounds. The set of controls also accounts for changes in household composition, measured by the difference in the number of children and adults (separately for male and female) between rounds. Three additional variables are entered as lags in level[18] in order to capture life-cycle effects: household head's age and sex, as well as highest education for an adult in the household.[19] Descriptive statistics for control variables are displayed in Table 3.

Benchmark OLS estimates of Equation (1) are presented in Table 4. The validity of these OLS estimates depends on the shock variables being exogenous, an assumption that is relaxed in the next section. Among the hurricane shock variables, only the flood dummy is negative and significant

[16] However, section 2.4 discusses the robustness of the results to alternative specifications, including without lag consumption terms.
[17] Results are robust to controlling for initial assets or dropping the lagged dependent variable, as discussed in section 2.4.
[18] This is justified by the fact that these variables change little over time.
[19] This captures the number of years to achieve the highest grade for the most educated household member.

in explaining variations in consumption growth over the 1998-1999 spell. The marginal effect is large, however: households having suffered from a flood in 1998-1999 (mostly attributable to Mitch) have a growth rate 20% lower than other households. The evidence of a negative impact of Mitch-induced damage on consumption growth appears limited to the effect of floods. Displacement variables have negative coefficients but remain insignificant. Self-reported and housing damage have positive but insignificant coefficients. Rainfall measures of the shock have positive coefficients,[20] even significant when rainfall during the month of the hurricane is entered in level. The coefficient of lagged consumption is equal to -0.44, reflecting large consumption variability in the Mitch sample. β is not interpreted as convergence coefficients here, but constitute a useful indicator of the validity of the estimated model, as will be further discussed below.

Since the hurricane only occurs once in 1998, the contemporaneous loss variables take a value of 0 for the 1999-2001 period ($M_{i,2001}=0$). Translated to the 1999-2001 spell, Equation (1) becomes:

$$\ln(c_{i,2001})-\ln(c_{i,1999})=\alpha+\beta\ln(c_{i,1999})+\gamma{*}0+\delta X_{i,2001}+\upsilon_{i,2001}+\eta_i \quad (2)$$

However, households' consumption growth in the period following the hurricane contains information regarding the effect of the lag shock, which can be studied as follows:

$$\ln(c_{i,2001})-\ln(c_{i,1999})=\alpha+\beta\ln(c_{i,1999})+\omega M_{i,1999}+\delta X_{i,2001}+\upsilon_{i,2001}+\eta_i \quad (3)$$

Equation (3) supports tests that the shock has a persistent negative impact ($\omega<0$) and that there is a post-shock rebound for the most affected households ($\omega>0$).

Table 5 contains OLS estimates of Equation (2) (in column 0) and Equation (3) (columns I through IX). Results show that a persistent negative impact of the hurricane can be strongly rejected since no coefficient is negative and significant. By contrast, Table 5 presents evidence that agricultural households who suffered the highest capital losses, the heaviest rainfalls or permanent displacement grow faster between 1999 and 2001 compared to the less affected households. This result could be seen as suggesting that those households are rebounding from a short-term shock, but such interpretation can only be fully tested by jointly analysing households' growth experience over the two spells, the focus of the next section.

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[20] The fact that there are no significant effects of the rainfall variables is not inconsistent with the results on floods since the two variables capture different events. In the context of Mitch, floods mainly happened because of rivers, which can be driven by rainfall in other municipalities.

2.3 First-difference estimates

OLS estimates exploit cross-sectional variation in households' consumption growth to identify the effect of the shock, but may suffer from biases due to a correlation between some of the shock variables and unobserved time-invariant heterogeneity (η_i). Since the sign of the bias cannot be determined, this section presents a first-difference specification dealing with time-invariant heterogeneity in the consumption growth process.[21] Compared to section 2.2, the first-difference specification is best seen as an alternative approach since it focuses on the variations in consumption growth between the hurricane and post-hurricane spells. The first-difference specification is built from Equations (1) and (2):

$$[\ln(c_{i,2001})-\ln(c_{i,1999})]-[\ln(c_{i,1999})-\ln(c_{i,1998})]=\beta[\ln(c_{i,1999})-\ln(c_{i,1998})] + \gamma[M_{i,2001}-M_{i,1999}]+\delta[X_{i,2001}-X_{i,1999}]+[\upsilon_{i,2001}-\upsilon_{i,1999}] \quad (4)$$

As discussed in Section 2.2, contemporaneous losses due to hurricane Mitch are equal to 0 for the 1999-2001 period ($M_{i,2001}=0$). The first-difference equation becomes:

$$[\ln(c_{i,2001})-\ln(c_{i,1999})]-[\ln(c_{i,1999})-\ln(c_{i,1998})]=\beta[\ln(c_{i,1999})-\ln(c_{i,1998})] + \gamma[-M_{i,1999}]+\delta[X_{i,2001}-X_{i,1999}]+[\upsilon_{i,2001}-\upsilon_{i,1999}] \quad (5)$$

The difference in growth rates between the two spells is informative to identify the short-term impact of the hurricane. Equation (5) allows testing whether larger hurricane-induced losses imply larger differences in growth rates between the 1998-1999 and 1999-2001 spells. This can be interpreted as using growth between 1999 and 2001 as a counterfactual for growth over the 1998-1999 period. Any consumption recovery or rebound in the period after the hurricane would imply that the counterfactual growth rate is overestimated. As a result, the methodology provides upper-bound for the estimated welfare effect of the hurricane. Estimation relies on the absence of lasting negative effects of the shock in the medium term, which is apparent from results in Table 4 and will be formally tested below.

[21] Random-effect models could unambiguously be discarded. Correlation between unobserved heterogeneity and controls makes OLS estimates inconsistent.

Pooled OLS estimates of Equation (5) are presented in Table 6.[22] Results are consistent with those for the 1998-1999 spell (Table 4), where the flood variable has the only significant negative effect, but a coefficient of large magnitude. However, the strict exogeneity assumption on which classical panel data estimation builds is violated in dynamic models (Nickell, 1981). While pooled OLS estimates are biased upwards, simple first-difference estimation of Equation (5) suffers from a downward bias. The dynamic panel data literature mainly focuses on the impact of the Nickell bias on the convergence coefficient (Kiviet, 1995; Judson and Owen, 1999). Crucially, Nickell (1981) stresses that coefficients of other explanatory variables can also be biased: not only is β underestimated, but first-difference estimates of γ are also inconsistent. For instance, all estimated coefficients from first-difference equations (not presented) are strongly negative and coefficients of initial consumption are equal to -1.42. Although β should therefore be large in absolute value,[23] coefficients smaller than -1 are of nonsensical magnitude and constitute a clear indication of the presence of a downward Nickell-type bias. Correcting for the Nickell bias is therefore crucial for consistent identification of the impact of the shock in Equation (5).

The traditional response to the Nickell bias is to use past observations to instrument the lagged value of the dependent variable (Anderson and Hsiao, 1982; Arellano and Bond, 1991). Consistent estimates can be obtained using 2SLS with instrumental variables that are both uncorrelated with the lagged dependent variables and orthogonal to the error terms, under predetermined initial conditions (Bond, 2002). With three time-series observations, the Arellano and Bond (1991) GMM estimator collapses to the exactly identified Anderson and Hsiao (1982) estimator: $\ln(c_{i,1998})$ serves as an instrument for $\ln(c_{i,1999})-\ln(c_{i,1998})$ under the assumption it is uncorrelated with $\upsilon_{i,2001}-\upsilon_{i,1999}$.

Table 7 presents Anderson-Hsiao instrumented first-difference estimates for each shock variable.[24] Instrumenting the lagged dependent variable in first-difference estimation appears to correct at least part of the Nickell bias. Most hurricane shock coefficients are negative and insignificant. The displacement and flood coefficients are large, however. Permanent displacement and time of displacement are the only significant effects at a 10% level: households permanently displaced have a growth rate 30% higher in 1999-2001 than in 1998-1999. These variables have

[22] When the first-difference equation is estimated or Equations (1) and (2) pooled, the coefficients of control variables are imposed to be the same in the two growth spells. When Equation (1) and (2) are pooled and estimated by OLS with an interaction between each control variables and a dummy for the second data spell, none of the interaction term is significant. This suggests that pooling is acceptable. The fact that the growth rate between 1999 and 2001 is not annualised requires a specific comment. The coefficient of the lag consumption variable is equal to -0.44 for Equation (1), and -0.50 for Equation (2). If the growth rate in Equation (2) is annualised, the coefficient of lag consumption is equal to -0.25. When the lag-consumption variable is interacted with a round-dummy, pooling the two rounds of data cannot be rejected in either case. The p-value of the interaction term is higher in the non-annualised model than in the annualised model, but there is no evidence to prefer one specification over the other. While non-annualised models are presented here, results based on the annualised model remain consistent.

[23] A consistent estimate of the initial consumption coefficient should lie below the pooled OLS estimates (-0.47, see Table 6).

[24] Other control variables are treated as exogenous. Estimates for other controls are not displayed but diminutions of household's size (particularly female adults and male children) have positive effects on consumption growth throughout.

negative insignificant coefficients in Table 4, and positive significant coefficients in Table 5. As explained above, 1999-2001 growth can be used as counterfactual for growth over the 1998-1999 spell, so that Table 7 yields an upper bound for the negative impact of hurricane-induced displacement. Based on this conservative interpretation, evidence would suggest a large short-term negative effect of the hurricane through households' displacement.

The interpretation of the flood coefficient is more straightforward. The p-value of that coefficient is 0.102, which should still be taken seriously given the limited statistical power implied by the small number of observations in the sample. Households suffering from a flood at the time of Mitch grow 20% slower in 1998-1999 than in 1999-2001. Given results in Table 4, Table 7 reinforces evidence of a large short-term effect of the hurricane on consumption growth for households affected by floods.

Overall, a conservative interpretation of these results reveals a short-term direct welfare impact of hurricane Mitch limited to the effects of floods and displacement. By contrast, higher rainfall or self-reported losses are not associated with lower consumption growth for affected households.

2.4 Sensitivity analysis

Sensitivity of results to potential misspecifications such as violations of assumptions behind the Anderson-Hsiao estimator, weakness of the instruments, small sample, time-varying unobserved heterogeneity and attrition bias are now successively discussed. The validity of the Anderson-Hsiao estimator relies on specific time-series properties of the error terms. The key identifying assumption is that residuals are serially uncorrelated, so that residuals in the first-difference equation are no more than MA(1).[25] Tests for second-order serial correlation in first-difference residuals or alternative Sargan tests cannot be implemented in the exactly identified three time-observation case. The fact that the Anderson-Hsiao estimates lie between first-difference and OLS estimates provides an informal confirmation of the validity of the model (Bond, 2002).

Anderson-Hsiao estimates can suffer from weak instruments which inflate standard errors and create a bias in direction of OLS estimates, even in large samples (Bound et al., 1995). In the context of dynamic panel data GMM estimators, high persistence in the endogenous variable can generate weak instruments problems (Blundell and Bond, 2000). Here, the model yields an estimate of β close to -1. This reflects the relative lack of persistence in the consumption series re-expressed in level.[26] The strength of the instruments is confirmed by first-stage diagnostics in Table 7.[27]

[25] In growth models, measurement error also leads to serial correlation in residuals (Bond et al., 2001). In the context of this paper, the effect of measurement error was also considered by re-estimating all results with narrower consumption aggregates. Results proved consistent throughout.
[26] I interpret this as reflecting the large heterogeneity in welfare outcomes in the sample. Other micro studies find similar patterns (e.g. Jalan and Ravallion, 1998).
[27] Alternative instruments from the past were also considered. Municipal averages of private or public assets were obtained from a 1995 Nicaraguan census. However, these additional instruments proved weak (if at all significant in the first-stage regression) and did not help correct the Nickell bias.

Another potential issue is that semi-asymptotic consistency of Anderson-Hsiao estimators requires a large number of cross-sections. In small samples, the 2SLS estimator is biased toward the OLS estimator of the first-differenced equation (Bond, 2002). Since the size of the available sample is limited, Anderson-Hsiao estimates can therefore suffer from a residual small-sample bias, probably downward. While such a bias could explain the magnitude of the lagged consumption coefficient, it should only lead to overestimation of the identified negative impact of the hurricane.

Given Anderson-Hsiao identifying assumptions cannot be tested and the panel is small, alternative specifications have also been considered. Suppressing the lagged consumption term in the estimated growth equations directly relates to Cochrane's (1991) full insurance test, and can also be seen as a reduced form test of the permanent income hypothesis (Deaton, 1992, 1997). The interpretation of the above results is robust to suppression of the dynamic structure of the estimated models.[28] This is illustrated in Table 8, which contains estimates of Equation (1) without the lag consumption term. The flood variable is the only one taking a negative sign, but remains insignificant. Similar patterns appear for Equation (1), (2) or (3). These results are consistent with the interpretation of earlier findings as upper bounds for the negative impact of the hurricane on consumption growth.

Attrition constitutes a potential source of concern for the interpretation of the results. The panel includes households that were displaced but remained in the same municipality, but does not include households that were displaced or migrated to other municipalities after the hurricane and never returned. Attrition is 21.3% between 1998 and 1999 for agricultural households in the Mitch communities (25.9% between 1998 and 2001). If attrition is associated with the magnitude of the hurricane shock, in particular higher for households who suffered most from the hurricane, micro-growth model estimates in the panel of affected households could suffer from an omitted variable bias. The rainfall measure can be used to test for shock-induced attrition between 1998 and 1999. October 1998 rainfall average 421.5mm (an average excess of 238.8mm) among attritors and 553.2mm (an average excess of 370.4mm) for households surveyed in 1999. Differences are always significant at the 1% level between the two groups. Therefore, attrition is not correlated with higher rainfall. For households in the panel, rainfall is positively associated with other shock measures. Attrition should not create an upward bias in the results presented above[29] under the assumption that rainfall and other shock measures are also positively associated for attritors. While this assumption is likely to hold, it cannot be formally tested. Any remaining concerns about attrition bias could reinforce the cautious conclusions of this section on the effect of displacement on welfare.

[28] It is also robust to the use of lagged assets as controls for initial conditions.

[29] There is only limited difference in baseline characteristics between attritors and non-attritors: baseline consumption is higher amongst attritors and demographics larger for non-attritors. Baez and Santos (2007) also present reassuring evidence with this respect.

The shock variables in the analysis are not necessarily purely exogenous. The first-difference specification allows ruling out bias due to a correlation between the shock variables and unobserved time-invariant heterogeneity. It remains that time-varying unobserved heterogeneity could create bias if it is correlated with the shock measure and with consumption, as well as unaccounted for by controlling for other shocks, demographics and lag consumption. There is a strong case to consider the rainfall and the flood measure exogenous once time-invariant heterogeneity (among other things related to location) is accounted for. Any remaining concern would therefore apply to the self-reported loss, displacement and housing damage variable. In any case, the rainfall shock variable can be used as instruments for variables potentially suffering from time-varying unobserved heterogeneity. While the rainfall variables constitute valid instrument for both the housing damage variables and for the total loss variable, results remain unchanged after instrumenting those variables in the first-difference specification. Bias due to unobserved time-varying heterogeneity can therefore be ruled out for the self-reported total loss variables and the for the housing damage variable. However, rainfalls are only weak instruments for the displacement variables,[30] so that bias due to unobserved heterogeneity cannot be ruled out for that variable. The possibility of a bias in the results on displacement has to be acknowledged, but is consistent with the conservative conclusion that any short-term welfare impact of the hurricane happened *at most* through channels such as floods and displacement.

Finally, the estimation strategy relying on the first-difference specification can only consistently estimate the negative idiosyncratic impact of the shock if it does not last until 2001. As already stressed, persistence of the idiosyncratic component of the shock can be tested by introducing lagged shocks in the 1999-2001 growth equation (Table 2). It can also be considered in a 1998-2001 growth equation:[31]

$$\ln(c_{i,2001})-\ln(c_{i,1998})=\alpha+\beta\ln(c_{i,1998})+\varphi M_{i,1999}+\delta_{i,2001}+\upsilon_{i,2001}+\eta_i \qquad (6)$$

Results are presented in Table 9. None of the shock measures has a negative coefficient close to being significant, ruling out persistent negative effects of the shock in the treated sample. Importantly, Table 4 suggests that households who suffered the largest capital losses, the heaviest rainfalls or displacement are in fact those who exhibited the highest consumption growth between 1998 and 2001.[32] Section 3 will show that there is no persistency in the medium term common effects of the shock until 2001 either.

[30] The correlation between rainfall and displacement is lower than the correlation between rainfall and the other variables.

[31] Controls entered in difference in $X_{i,2001}$ are taken in difference between 2001 and 1998.

[32] Results again remain robust when dropping the lag consumption variable.

In general, while caution is warranted given the shortness of the panel and the attrition rate, sensitivity analysis suggests that Anderson-Hsiao estimates are most likely to suffer from a downward bias which would lead to an overestimation of the observed negative effect the hurricane. Sensitivity analysis is not as clear for the displacement variables since upward bias from time-varying heterogeneity cannot be ruled out for this variable. In the end, the analysis of variations in idiosyncratic hurricane-induced losses thus points to a short-term welfare impact that occurred at most through the effects of floods and households' displacement.

Results are consistent with findings that the Nicaraguan overall poverty profile did not change between 1998 and 1999 (World Bank, 2001). It is also consistent with contextual information gathered in the field. For instance, some microfinance institutions[33] noted low default rate on loans in the year after the hurricane.

3. Mitch's Medium-Term Common Impact

The analysis has so far focused on assessing the idiosyncratic effects of hurricane Mitch on consumption growth of affected agricultural households (a "treated" sample). This section considers the hurricane as a quasi-experiment. In 1999, INEC only re-visited households surveyed in 1998 and located in communities hit by the hurricane (INEC, 2000). INEC's assessment of whether a community was damaged or not in 1999 can be used to define treatment status (Baez and Santos, 2007).[34] Specifically, agricultural households located in communities re-surveyed in 1999 constitute the treatment group, while agricultural households in other communities form the comparison group. The impact of Mitch between 1998 and 2001 can be evaluated by comparing consumption growth between treated and comparison groups. The approach differs from the analysis of the short-term impact of the idiosyncratic dimensions of the shock, which focused on the panel of affected households re-surveyed in 1999. While variations in the idiosyncratic effects of the shock can be analysed in the three-round panel, the 1998-2001 quasi-experimental set-up can identify persistence of the impact common to all affected households. The two alternative approaches raise complementary questions. A medium-term impact between treatment and comparison groups does not necessarily imply a short-term impact of larger losses within the treatment group. Finding no medium-term impact between treatment and comparison groups does not rule out short-term effects either.

[33] For instance, FDL, Managua (personal communication).

[34] Baez and Santos (2007) study Mitch's impact on children's well-being. This section focuses on different outcomes and unveils additional spatial patterns.

3.1 Treatment group

The composition of the treatment group warrants careful consideration. The criteria used by INEC (2000) to determine which communities were damaged by Mitch and therefore re-surveyed in 1999 are not entirely transparent.[35] An important feature of the data is that at times INEC revisited some communities but not others in the same municipality. This section considers whether a higher-level definition of treatment is required because the direct negative effects of the shock propagated from re-surveyed to non-resurveyed communities in a same municipality.

The sample can be divided in three groups: households re-surveyed in 1999 (treated households), households located in non-resurveyed municipalities (comparison households outside affected municipalities), and households located in non-resurveyed communities but in partly re-surveyed municipalities ("borderline group"). Table 10 contains descriptive statistics for welfare measures in these subgroups before and after Mitch. Those descriptive statistics can be used to scrutinise INEC's definition of damaged communities in 1999. A priori, low post-hurricane outcomes for the borderline group could suggest that the treatment group based on INEC definition is defined too narrowly.

Table 10 highlights important contrasts. Initial consumption is largest for comparison households outside affected municipalities and smallest in the treatment group. 2001 consumption is highest in the borderline group and still smallest in the treatment group. Although the initial difference between treatment and borderline group is not significant, the borderline group has significantly higher consumption in 2001.[36] Descriptive statistics thus show no evidence of propagation of the negative impact of the shock at the local level.

The relevance of using a broader definition of the treatment group can nevertheless be considered. TRMM October 1998 rainfall ($M_{i,1999}$) provide a municipal measure of Mitch's incidence and can be modelled in 1998-2001 growth equations:[37]

$$\ln(c_{i,2001})-\ln(c_{i,1998})=\alpha+\xi M_{i,1999}+\delta X_{i,2001}+\varepsilon_{i,2001} \qquad (7)$$

---

[35] "Households were selected for inclusion in the post-Mitch survey strictly on the basis that they were located in areas that were: (a) affected by the hurricane; and (b) included in the original 1998 LSMS" (World Bank, 2001).

[36] The difference in consumption between treatment and borderline groups is marginally insignificant in 1998 (p=0.15), but significant in 2001 (p=0.05). The difference in growth rate is insignificant, as discussed further in the next section.

[37] $X_{i,2001}$ contains the same set of controls as in section 2. Three specifications are considered: no controls (I), $X_{i,2001}$ as controls (II), $X_{i,2001}$ and lag consumption as controls (III). Specification (III) makes results comparable with those from section 1.3. In this section, controls entered in difference in $X_{i,2001}$ are taken as a difference between 2001 and 1998. Additional variables are available in the 1998-2001 panel compared to the 1998-1999-2001 panel (since the 1999 survey was not a full LSMS) and could be included as regressors in the difference-in-differences regression. I prefer presenting the same specification as in section 2 for the sake of comparability. Results are robust to the inclusion of additional regressors in Equation (7).

In Table 11, municipal-level rainfall measures take a positive but insignificant coefficient. Similar results appear when a municipal dummy is used to characterise Mitch's incidence. There is no evidence of a negative common impact of the shock when it is measured at the municipal level. Based on these results, there is no ground to reject INEC community-level definition of treatment status in favour of a higher-level definition.[38] However, Table 10 points to the presence of substantial spatial heterogeneity, which is further tackled in the next section.

3.2 Difference-in-differences estimates

This section presents difference-in-differences estimates of the hurricane's welfare impact by comparing consumption growth in treatment and comparison groups between 1998 and 2001. Three alternative comparisons groups are considered. The first comparison group contains "all comparison units" (812 households) and is taken as the complement of the treatment group (204 households). The second comparison group is formed by the 136 households of the borderline group, i.e. households located in communities that were not damaged by the storm but in municipalities where other communities were damaged. The third comparison group contains 676 households in municipalities were no communities from the 1998 survey were damaged, i.e. comparison households outside municipalities affected by the hurricane.

Table 12 displays descriptive welfare statistics for the treatment and comparison groups. 1998 consumption is significantly lower for the treatment group, but not in comparison to within-municipality comparison households. This suggests that differences in observed characteristics need to be accounted for when using households outside affected municipalities as comparison. By contrast, equality of 2001 consumption can only be rejected between the treatment group and the within-municipality comparison group. While the non-significant initial consumption differential within municipalities has broadened, the corresponding difference in growth is not significant. In other words, the positive municipal-level effects identified in section 3.1 are driven by households located in non-damaged communities but in municipalities where some other communities were affected. The treatment group displays significantly higher growth compared to comparison households outside of the municipality, however.

Difference-in-differences estimates can be obtained by OLS as follows:[39]

$$\ln(c_{i,2001})-\ln(c_{i,1998})=\alpha+\tau M_{i,1999}+\delta X_{i,2001}+\varepsilon_{i,2001} \quad (8)$$

[38] Within-municipality variation of the incidence of the hurricane implies that the rainfall measure is not generally accurate enough. However, it remains relevant when focusing on the treated sample as in section 2.
[39] Again, $X_{i,2001}$ contains the same set of controls as in section 2 and Equation (7). Three specifications are considered: no controls (I), $X_{i,2001}$ as controls (II), $X_{i,2001}$ and lag consumption as controls (III). Specification (III) makes results comparable with those from section 2. In this section, controls entered in difference in $X_{i,2001}$ are taken in difference between 2001 and 1998.

Medium-term impacts (τ) are estimated using three alternative comparison groups and presented in Table 13.[40] Estimates can be compared to growth equations for the three-round panel. Control variables are included to account for differences between treated and comparison households observed at baseline (Table 14). The results reveal no significant medium-term effects of the hurricane common to all affected households. A negative coefficient appears when within-municipalities comparison households are used, but remains insignificant. Coefficients are even positive when considering all comparison households or only comparison households outside the affected municipalities.

Two sets of earlier results reveal substantial spatial variations. First, municipal measures of the shock incidence (such as TRMM rainfalls) are associated with larger consumption growth, which is driven by comparison households in affected municipalities. Second the treatment group exhibits lower growth than comparison households within affected municipalities, even though the difference is insignificant. Importantly, the estimated impact of the hurricane could be biased if initial growth potentials differ between treatment or comparison groups. Jalan and Ravallion (1998) show how spatial dependence in the growth process leads to underestimation of development program benefits when growth paths of areas not covered by the program do not provide an adequate counterfactual. By the same token, higher initial growth potential for affected households could explain both vanishing hurricane losses and some of the positive effects uncovered in Tables 11 or 12.

Differences in underlying growth paths for treated households could be driven by heterogeneity at both the household and municipal levels. Table 14 displays differences in baseline control variables between treatment and comparison groups. While initial consumption is not different between treatment and within-municipality comparison households, patterns regarding other variables are less clear and reveal slightly more within-municipality than between-municipality differences. Such observed household-level differences are accounted for in difference-in-differences estimates. Common municipal trends can also be introduced when the within-municipality comparison group is used. Table 13 shows that controlling for observed household-level differences and municipal trends does not change the results, but accounts for some of the variation in growth rates noted above. The analysis shows that there are no significant effects of hurricane Mitch on consumption in the medium term, even after controlling for observed differences in household characteristics and unobserved municipal heterogeneity.

3.3 Sensitivity analysis

The difference-in-differences approach relies on important assumptions. First, INEC's (2000) community-level classification needs to accurately characterise the hurricane's incidence. As explained above, available data do not suggest otherwise. Second, the difference-in-differences

[40] The sensitivity of results to unobserved heterogeneity is discussed in section 3.3.

estimator builds on a "same time-effect assumption", according to which outcomes would have changed by the same magnitude on average for the treatment and comparison groups in absence of the treatment (Lee, 2005, p.101). In particular, identification relies on the absence of within-municipality time-varying heterogeneity other than observed differences in household characteristics. Beyond its direct incidence, the hurricane can generate time-varying heterogeneity through indirect effects within municipalities. The implications of post-disaster mitigation (e.g. aid), spill-over effects (e.g. local economic downturn) and local spatial dynamics are discussed next. These sources of time-varying within-municipality heterogeneity can be analysed in terms of omitted variable bias through the error term of Equation (8).

First, municipalities affected by hurricane Mitch received substantial aid.[41] Well-targeted aid can improve welfare of treatment households, but comparison households may also benefit. The consideration of aid or private mitigation strategies does not justify revising the conclusion that the shock had no welfare effect in the medium-term. Rather, the estimated welfare effects should be interpreted as net of mitigation mechanisms. As such, they suggest that mitigation was effective. Mitigation mechanisms can explain why the observed difference in growth rates between comparison and treatment groups is limited, but do not create inconsistencies in the estimation procedure.[42]

Second, spill-over effects beyond the direct incidence of the shock can arise, for instance through a local economic downturn. If the comparison group is strongly affected, the consumption shortfall generated by the direct incidence of the hurricane would be underestimated for the treatment group. Still, strong spill-over effects would be required to overturn the results and section 3.1 above provides no evidence of such effects. In addition, spill-over are less likely to affect comparison households outside municipalities where communities were damaged, based on which results remain unchanged.

Finally, within-municipality variation in the direct incidence of the shock can be correlated with geographical idiosyncrasies that may themselves be associated with differences in underlying welfare dynamics between communities. Higher growth potential in treatment communities at baseline could bias the estimated impact of the hurricane. Beyond controlling for observed household-level characteristics, such within-municipality unobserved heterogeneity cannot formally be ruled out. However, rural communities in a same municipality often face similar climatic factors or economic opportunities, so that spatial dynamics remain rather homogeneous. In this sense, it would appear likely that controlling for observed household characteristics accounts for most within-municipality differences in spatial dynamics.

[41] The survey data on aid is too limited to perform heterogeneity analysis.

[42] Results could also theoretically be biased by a within-municipality re-allocation of public resources from affected communities to unaffected communities between 1998 and 2001. While this is a theoretical possibility, the large magnitude of resource reallocations or aid mis-targeting needed to overturn the results makes this source of bias unlikely.

Section 3.2 concludes that hurricane Mitch had no significant medium-term impact on consumption growth. This section has stressed that the methodology identifies the combined effect of the shock net of mitigation mechanisms and should be interpreted as such. Besides, it appears unlikely that unobserved within-municipality heterogeneity or spill-overs explain the absence of a significant negative impact of hurricane Mitch on medium-term consumption growth, but these factors cannot be formally ruled out. With these words of caution, the analysis concludes that Mitch did not have a significant persistent common negative impact on consumption of Nicaraguan agricultural households after three years.

Tracing back to section 2, the quasi-experimental analysis suggests that the 1999 sample on which the three-round panel is built adequately to contain affected households. Section 3 also confirms that 1998-1999-2001 consumption growth equations do not fail to identify the effect of the shock because of its persistence. Finally, the quasi-experimental analysis echoes results from section 3 on the limited persistence of hurricane Mitch's direct welfare impact.

4. Conclusions

This paper provides rare micro-evidence regarding the persistence of a natural disaster's welfare effects. Hurricane Mitch was a tragic event that claimed thousands of lives and caused extensive damage in Central America. Based on the unique structure of Nicaraguan data, the analysis unpacks hurricane Mitch's short and medium term impacts (after 1 and 3 years), disentangles its idiosyncratic from its common effects and highlights the main channels through which Mitch affects agricultural households' consumption growth. Descriptive statistics show no evidence of a large consumption downturn post-Mitch and welfare is very variable in the panel of households affected by the hurricane. The analysis tests whether relative variations in the idiosyncratic effects of the shock explain short-term consumption changes. Estimates from a micro-growth model reveal short-term welfare impacts at most limited to the effects of floods and displacement. By contrast, higher rainfall or self-reported losses are not associated with lower consumption growth for affected households. These results highlight the idiosyncratic dimensions of the shock that private and public mitigation mechanisms are least effective in dealing with and that complementary policy interventions should target in priority.

A complementary quasi-experimental approach analyses Mitch's common medium-term impacts between 1998 and 2001. Difference-in-differences methods are used to contrast consumption growth between households in communities damaged by Mitch and various comparison groups. Results show that consumption growth between 1998 and 2001 is never statistically lower for treated households. While comparison households located in municipalities where some communities were affected by the hurricane exhibit the highest growth rate, the difference with treated households is never significant.

Beyond the short-term idiosyncratic effects of floods and displacement, the two parts of the analysis consistently point to limited persistence of the welfare impact of the shock. In sharp contrast with the large magnitude of reported losses at both the macro (ECLAC, 1999) and micro levels (Morris et al., 2002), Mitch's direct welfare impact exhibits little persistence. While these results may appear surprising in the context of a large common shock, they contrast with evidence on other types of natural disasters, particularly rainfall shortages and drought, for which impacts appear more persistent and existing mitigation mechanisms less effective (Dercon, 2004b; Premand and Vakis, 2010).[43]

Finally, these conclusions do not rule out indirect channels trough which a natural disaster can alter welfare dynamics. This paper analyses the combined effects of Mitch and any mitigation strategies used by households to cope with the shock. As such, results suggest that mitigation was relatively effective. In the context of hurricane Mitch, public aid was substantial and mitigation has been documented through a variety of channels including social networks (Carter and Castillo, 2005), asset liquidation (Carter et al., 2007) and diminution of investment in children's human capital (Baez and Santos, 2007). Importantly, lack of persistence in the medium-term does not rule out future indirect effects since risk-coping can be costly over the longer term. In this sense, results in this paper complement rather than contradict recent evidence on diminution of children's human capital (Baez and Santos, 2007) or asset liquidation (Carter et al., 2007). It remains possible for hurricane Mitch to have welfare effects through those indirect channels over the longer term.

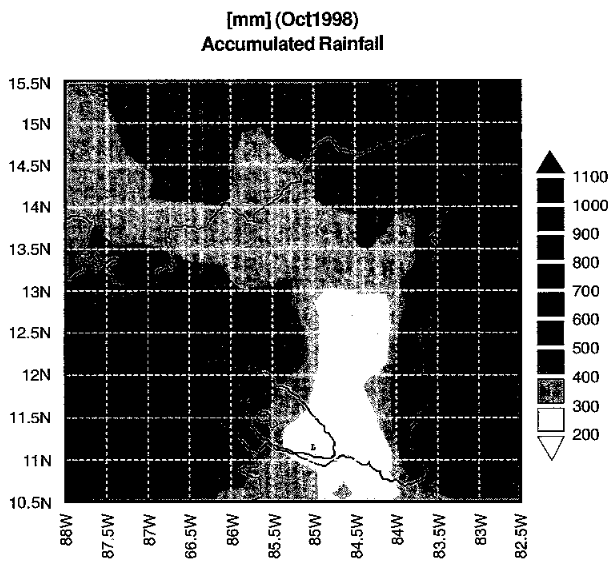
[43] Interestingly, Mitch struck Nicaragua just before the six-month dry season. While the hypothesis cannot be directly tested in absence of a full agricultural module in the 1999 LSMS data, MAGFOR (1999) suggests that rainfall excesses induced by the hurricane might prolonged the fertility of soils and allowed a third harvest in regions where drought usually makes it impossible.

Annex

Satellite Rainfall Data

NASA Tropical Rainfall Measurement Mission's (TRMM) interface provides worldwide satellite monthly accumulated rainfall observations on a grid of 0.25 degrees of longitude by 0.25 degrees of latitude (approximately 28 km^2 in Nicaragua) starting in 1998.[44] TRMM rainfall observations are obtained from a precipitation radar and a microwave radiometer (Adler et al., 2000). Figure 1 reproduces rainfall for October 1998 for a window covering the Nicaraguan territory (-88 to -82.5 degrees of longitude West; 10.5 to 15.5 degrees of latitude North). The window contains 483 data points, and each depicted square 9 observations. Municipal coordinates do not correspond to grid nodes and bilinear interpolation is used to infer municipal rainfall. Figure 2 summarises interpolated average monthly rainfall for 123 Nicaraguan municipalities. Interpolated values from TRMM data were also compared to gauge data from Nicaraguan rainfall stations and performed well: the correlation coefficient between observed and predicted rainfall at the stations' coordinates is 0.62 on average.

Figure 1
Accumulated Rainfall in October 1998



[44] The rainfall data used in this paper were acquired as part of the Tropical Rainfall Measuring Mission (TRMM, http://disc2.nascom.nasa.gov/Giovanni/tovas/). The algorithms were developed by the TRMM Science Team. The data were processed by the TRMM Science Data and Information System (TSDIS) and the TRMM Office;

Figure 2
Municipal Monthly Rainfall Interpolated from NASA TRMM

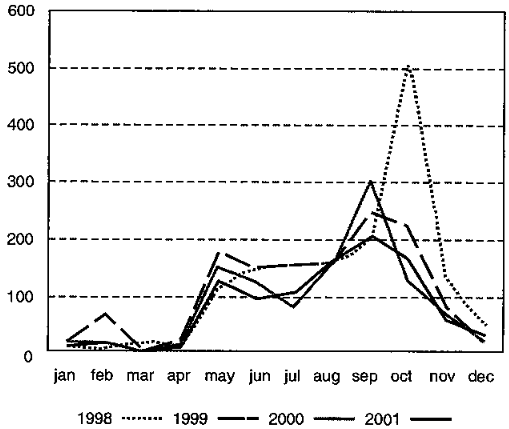


Table 1
Welfare in 1998-2001 and Mitch Agricultural Panels

	1998-2001 panel	Mitch panel	Mitch panel	Mitch panel	1998-2001 panel
	1998		1999	2001	
Poverty	68.7%	74.1%	73.1%	70.6%	63.6%
Extreme poverty	28.6%	32.0%	34.5%	25.9%	25.4%
Consumption (C$)	4149.4 (3982.7)	3599.7 (2625.6)	3687.3 (3124.3)	3516.6 (2496.8)	3965.5 (3971.0)
Consumption (ln, C$)	8.08 (0.67)	7.99 (0.62)	8.00 (0.63)	7.99 (0.57)	8.04 (0.66)
Consumption growth	. .	. .	0.01 (0.58)	-0.01 (0.60)	0.04 (0.61)
Observations	1016	197	197	197	1016

Note: Household per capita consumption, 1998 prices (in log cordobas); poverty line: 4223C$, extreme poverty line: 2489C$; average cordoba-dollar exchange rate in 1998: 10.58; standard deviations in parenthesis; growth from previous round; all values computed from Nicaraguan LSMS. The Mitch panel contains 197 households located in communities affected by Mitch with observations in 1998, 1999 and 2001. The 1998-2001 panel contains 204 households located in communities affected by Mitch (197 households from the Mitch panel and 7 who were only surveyed in 1998 and 2001).

they are archived and distributed by the Goddard Distributed Active Archive Center. TRMM is an international project jointly sponsored by the Japan National Space Development Agency (NASDA) and the U.S. National Aeronautics and Space Administration (NASA) Office of Earth Sciences. Bilinear interpolation of TRMM data at Nicaraguan municipal centres was programmed by myself using STATA.

Table 2
Hurricane Shock Measures

	Incidence		Average per household	
Self-reported losses	N	%	Mean	St.Dev.
Capital losses (ln, C$)	57	29	1182.1	3636.0
Livestock losses (ln, C$)	127	64	1977.6	6254.9
Total asset losses (ln, C$)	141	72	3159.7	9053.4
Output losses (ln, C$)	186	94	5211.2	8409.8
Total losses (ln, C$)	190	96	8370.9	13287.1
Displacement and housing destruction	N	%	Mean	St.Dev.
Permanent displacement	19	10	0.10	.
Temporary displacement	48	24	0.24	.
Displacement	67	34	0.34	0.47
Displacement days (ln, days)	67	34	28.26	71.94
Housing damage index (0-8)	96	49	3.69	4.96
Rainfall shock measures	N	%	Mean	St.Dev.
Rainfall October 1998 (mm)	197	100	538.74	200.42
Rainfall excess October 1998 (mm)	197	100	352.67	188.25
Rainfall October 1998 (ln, mm)	197	100	6.23	0.35
Rainfall excess October 1998 (ln, mm)	197	100	5.69	0.66
Flood	30	15	0.15	.

Note: Shock measures for 197 agricultural households in 1998-1999-2001 panel; self-reported losses in cordobas; asset losses aggregate capital and livestock; housing destuction index ranges from 0 to 8; all measures from 1999 LSMS apart from rainfall; rainfall interpolated at municipal centre from NASA TRMM observations. The average per households is taken across all 197 households in the sample.

Table 3
Control Variables for Growth Regressions

	1999 ($X_{i,1999}$)		2001 ($X_{i,2001}$)	
	Mean	**St.Dev.**	**Mean**	**St.Dev.**
Drought (Δ)	-0.41	0.61	0.21	0.64
Pest (Δ)	-0.06	0.69	0.24	0.68
Other shocks (Δ)	-0.05	0.40	0.02	0.35
N male children (Δ)	0.04	0.85	-0.19	0.99
N male adults (Δ)	-0.04	0.74	0.10	0.87
N female children (Δ)	-0.04	0.62	-0.12	1.04
N female adults (Δ)	0.01	0.61	0.03	0.81
Female household head (lag)	0.09	0.29	0.13	0.33
Household head's age (lag)	48.17	15.04	49.23	15.11
Education per adult (lag)	2.50	1.99	2.63	1.91

Note: Control variables for 197 agricultural households in 1998-1999-2001 panel; shocks and demographics in difference between t and t-1, other variables at t-1.

Table 4
OLS Estimates
(Consumption Growth in 1998-1999)

	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
Initial consumption	-0.44*** (0.06)	-0.44*** (0.06)	-0.43*** (0.06)	-0.43*** (0.06)	-0.44*** (0.06)	-0.43*** (0.06)	-0.44*** (0.06)	-0.43*** (0.06)	-0.46*** (0.06)
Total hurricane losses (ln C$)	0.02 (0.02)								
Total capital losses (ln C$)		0.01 (0.01)							
Total output losses (ln C$)		0.01 (0.02)							
October 1998 rainfall (ln mm)			0.19* (0.11)						
October 1998 excess rainfall (ln mm)				0.07 (0.06)					
Pemanent displacement					-0.08 (0.12)				
Displacement						0.01 (0.08)			
Displacement time (ln days)							-0.01 (0.02)		
Housing damage index								0.01 (0.01)	
Floods									-0.20* (0.10)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.265	0.260	0.270	0.265	0.260	0.259	0.260	0.260	0.273
F	6.88	6.29	7.05	6.88	6.75	6.70	6.75	6.75	7.14

Note: Significance at the level .01 - ***; .05 - **; .1 - *; OLS for household per capita consumption growth in 1998-1999; robust standard errors; controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 5
OLS Estimates (Consumption Growth in 1999-2001)

	O coef/sd	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
Initial consumption	-0.50*** (0.06)	-0.51*** (0.06)	-0.52*** (0.06)	-0.53*** (0.06)	-0.51*** (0.06)	-0.50*** (0.06)	-0.50*** (0.06)	-0.49*** (0.06)	-0.51*** (0.06)	-0.51*** (0.06)
Total hurricane losses (ln C$)		0.02 (0.02)								
Total capital losses (ln C$)			0.02** (0.01)							
Total output losses (ln C$)			-0.01 (0.02)							
October 1998 rainfall (ln mm)				0.27*** (0.10)						
October 1998 excess rainfall (ln mm)					0.10* (0.05)					
Pemanent displacement						0.19* (0.11)				
Displacement							0.09 (0.07)			
Displacement time (ln days)								0.03 (0.02)		
Housing damage index									-0.00 (0.01)	
Floods										-0.01 (0.10)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.415	0.416	0.427	0.436	0.422	0.421	0.417	0.419	0.413	0.412
F	13.66	12.63	12.25	13.62	12.94	12.88	12.68	12.76	12.49	12.45

Note: Significance at the level .01 - ***; .05 - **; .1 - *; OLS for household per capita consumption growth in 1998-1999; robust standard errors; controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 6
OLS Estimates for Pooled Model

	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
Initial consumption	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.47*** (0.04)	-0.48*** (0.04)
Total hurricane losses (ln, C$)	0.01 (0.01)								
Total capital losses (ln, C$)		0.01 (0.01)							
Total output losses (ln, C$)		0.00 (0.01)							
October 1998 rainfall (ln, mm)			0.00 (0.01)						
October 1998 excess rainfall (ln, mm)				0.01 (0.01)					
Pemanent displacement					-0.07 (0.11)				
Displacement						0.01 (0.07)			
Displacement time (ln, days)							-0.01 (0.02)		
Housing damage index								0.00 (0.01)	
Floods									-0.19** (0.09)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	394	394	394	394	394	394	394	394	394
Adjusted R^2	0.356	0.355	0.356	0.356	0.356	0.355	0.356	0.356	0.362
F	19.14	17.66	19.07	19.09	19.09	19.04	19.09	19.10	19.57

Note: Significance at the level .01 - ***; .05 - **; .1 - *; Pooled OLS for household per capita consumption growth in 1998-1999 and 1999-2001; robust standard errors; controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 7
Anderson-Hsiao 2SLS Estimates

	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
Second-stage									
Initial consumption	-0.74*** (0.17)	-0.73*** (0.17)	-0.74*** (0.17)	-0.74*** (0.17)	-0.76*** (0.17)	-0.78*** (0.17)	-0.80*** (0.17)	-0.73*** (0.18)	-0.79*** (0.16)
Total hurricane losses (ln, C$)	0.00 (0.02)								
Total capital losses (ln, C$)		-0.01 (0.01)							
Total output losses (ln, C$)		0.01 (0.02)							
October 1998 rainfall (ln, mm)			-0.10 (0.14)						
October 1998 excess rainfall (ln, mm)				-0.04 (0.08)					
Pemanent displacement					-0.30* (0.15)				
Displacement						-0.14 (0.10)			
Displacement time (ln, days)							-0.05** (0.02)		
Housing damage index								0.00 (0.01)	
Flood (Δ)									-0.20 (0.12)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.614	0.610	0.616	0.615	0.630	0.638	0.648	0.609	0.640
F	9.41	8.57	9.35	9.32	10.11	9.99	10.58	9.24	10.57

Table 7 (continued)

	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
First-stage: instrument coefficient and diagnostics									
Initial consumption (lag)	-0.43*** (0.06)	-0.43*** (0.06)	-0.43*** (0.06)	-0.43*** (0.06)	-0.43*** (0.06)	-0.43*** (0.06)	-0.44*** (0.06)	-0.42*** (0.06)	-0.45*** (0.06)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.279	0.274	0.288	0.278	0.265	0.265	0.264	0.267	0.275
F	7.32	6.69	7.62	7.30	6.89	6.87	6.86	6.96	7.20

Note: Significance at the level .01 - ***; .05 - **; .1 - *; Anderson-Hsiao 2SLS estimates for difference in household per capita consumption growth between 1999-2001 and 1998-1999; 1998 consumption serves as instrument for difference in initial conditions (along with other controls); controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 8
OLS Estimates for First-Difference Specification
(Without Control for Lag Consumption)

	I coef/sd	II coef/sd	III coef/sd	IV coef/sd	V coef/sd	VI coef/sd	VII coef/sd	VIII coef/sd	IX coef/sd
Total hurricane losses (ln, C$)	0.02 (0.02)								
Total capital losses (ln, C$)		0.01 (0.01)							
Total output losses (ln, C$)		0.01 (0.02)							
October 1998 rainfall (ln, mm)			0.19 (0.12)						
October 1998 excess rainfall (ln, mm)				0.08 (0.06)					
Pemanent displacement					0.02 (0.14)				
Displacement						0.14 (0.09)			
Displacement time (ln, days)							0.02 (0.02)		
Housing damage index								0.01 (0.01)	
Flood									-0.04 (0.12)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.059	0.053	0.065	0.060	0.053	0.066	0.058	0.067	0.054
F	2.12	1.91	2.24	2.14	2.01	2.26	2.09	2.27	2.02

Note: Significance at the level .01 - ***; .05 - **; .1 - *; first-difference estimates for consumption growth in 1998-1999 and 1999-2001; robust standard errors; controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 9
OLS Estimates
(Consumption Growth in 1998-2001)

	I	II	III	IV	V	VI	VII	VIII	IX
	coef/sd	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**
Initial consumption	-0.55***	-0.56***	-0.55***	-0.55***	-0.54***	-0.53***	-0.53***	-0.55***	-0.56***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
Total hurricane losses (ln C$)	0.02								
	(0.02)								
Total capital losses (ln C$)		0.02**							
		(0.01)							
Total output losses (ln C$)		0.00							
		(0.02)							
October 1998 rainfall (ln mm)			0.32***						
			(0.10)						
October 1998 excess rainfall (ln mm)				0.11**					
				(0.05)					
Pemanent displacement					0.18				
					(0.11)				
Displacement						0.15**			
						(0.07)			
Displacement time (ln days)							0.03*		
							(0.02)		
Housing damage index								0.00	
								(0.01)	
Flood									-0.07
									(0.09)
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of observations	197	197	197	197	197	197	197	197	197
Adjusted R^2	0.435	0.442	0.460	0.442	0.437	0.442	0.439	0.429	0.430
F	13.60	12.96	14.91	13.93	13.66	13.94	13.78	13.26	13.32

Note: Significance at the level .01 - ***; .05 - **; .1 - *; OLS; robust standard errors; controls include initial education, household head's age and sex, as well as differences between rouunds for drought, pest and other agricultural shocks in number of male adults, female adults, male children and female children.

Table 10
Consumption across Space in 1998-2001 Panel

		1998		2001		Growth 1998-2001	
	N	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Treatment group	204	8.00	0.62	7.99	0.57	0.00	0.60
Borderline group	136	8.04	0.63	8.11	0.64	0.06	0.57
Outside municipality comparison group	676	8.11	0.69	8.04	0.69	-0.07	0.62

Note: Descriptive statistics for 1998-2001 agricultural panel; household per capita consumption, 1998 prices (in log cordobas); treated households are those re-surveyed in 1999; borderline group contains non-resurveyed households located in municipalities with some re-surveyed households; outside municipality comparison group contain households located in municipalities without re-surveyed households.

Table 11
1998-2001 Consumption Growth and Municipal Shocks

	I	II	III	I	II	III
	coef/sd	coef/sd	coef/sd	coef/sd	coef/sd	coef/sd
Rainfall October 1998 (ln, mm)	0.10 (0.06)	0.06 (0.06)	0.05 (0.05)			
Muncipal Mitch dummy				0.10* (0.05)	0.07 (0.05)	0.01 (0.04)
Controls		yes	yes		yes	yes
Initial consumption			yes			yes
Number of observations	1,016	1,013	1,013	1,016	1,013	1,013
Adjusted R^2	0.002	0.128	0.365	0.005	0.130	0.365

Note: Significance at the level .01 - ***; .05 - **; .1 - *; OLS for household per capita consumption growth; clustered standard errors; controls include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 12
Consumption in Treatment and Comparison Groups

		1998		2001		1998-2001 growth	
	N	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Treatment group	204	8.00	0.62	7.99	0.57	-0.00	0.60
All comparison households	812	8.10	0.68	8.05	0.68	-0.05	0.62
Difference	.	-0.104**	0.05	-0.06	0.05	0.05	0.05
Treatment group	204	8.00	0.62	7.99	0.57	-0.00	0.60
Within municipality comparison households	136	8.04	0.63	8.11	0.64	0.06	0.57
Difference	.	-0.045	0.07	-0.114**	0.07	-0.069	0.07
Treatment group	204	8.00	0.62	7.99	0.57	-0.00	0.60
Outside municipality comparison households	676	8.11	0.69	8.04	0.69	-0.07	0.62
Difference	.	-0.115**	0.05	-0.045	0.05	0.070*	0.05

Note: Significance at the level .01 - ***; .05 - **; .1 - *; Descriptive statistics for 1998-2001 agricultural panel; household per capita consumption, 1998 prices (in log cordobas); treated households are those re-surveyed in 1999; within-municipality comparison households are located in municipalities with some treated households; outside municipality comparison households are located in municipalities without treated households.

Table 13
Difference-in-Differences Estimates

	I	II	III	I	II	III	I	II	III	I	II	III
	coef/sd	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**	**coef/sd**
All comparison households	0.05 (0.07)	0.06 (0.06)	0.02 (0.05)									
Within municipality comparison households				-0.07 (0.07)	0.01 (0.06)	-0.00 (0.05)				-0.05 (0.08)	0.05 (0.07)	0.02 (0.07)
Outside municipality comparison households							0.07 (0.07)	0.07 (0.06)	0.02 (0.05)			
Controls		yes	yes		yes	yes		yes	yes		yes	yes
Initial consumption			yes			yes			yes			yes
Municipal trend										yes	yes	yes
Number of observations	1,016	1,013	1,013	340	338	338	880	878	878	340	338	338
Adjusted R^2	-0.000	0.129	0.365	0.000	0.106	0.373	0.001	0.126	0.372	0.059	0.154	0.401

Note: Significance at the level .01 - ***; .05 - **; .1 - *; OLS for household per capita consumption growth; 1998-2001 agricultural panel; clustered standard errors; treated households are those re-surveyed in 1999; within-municipality comparison households are located in municipalities with some treated households; outside municipality comparison households are located in municipalities without treated households; control variables include initial education, household head's age and sex, as well as differences between rounds for drought, pest, other agricultural shocks, number of male adults, female adults, male children and female children.

Table 14
Baseline Characteristics in Treatment and Comparison Groups

	All comparison households			Within municipality comparison households			Outside municipality comparison households		
	Comparison	Treatment	p	Comparison	Treatment	p	Comparison	Treatment	p
Drought	0.89	0.85	0.10	0.93	0.85	0.01	0.88	0.85	0.20
Pest	0.57	0.55	0.27	0.72	0.55	0.00	0.54	0.55	0.56
Floods	0.07	0.04	0.07	0.03	0.04	0.76	0.08	0.04	0.04
Other shocks	0.13	0.11	0.18	0.09	0.11	0.72	0.14	0.11	0.11
N male children	1.51	1.51	0.53	1.52	1.51	0.48	1.50	1.51	0.54
N male adults	1.91	1.95	0.64	2.06	1.95	0.19	1.88	1.95	0.76
N female children	1.48	1.49	0.54	1.69	1.49	0.11	1.44	1.49	0.69
N female adults	1.67	1.71	0.70	2.03	1.71	0.01	1.60	1.71	0.93
Female hh head	0.10	0.10	0.39	0.13	0.10	0.22	0.10	0.10	0.46
Hh head's age	46.47	47.54	0.81	48.85	47.54	0.22	45.99	47.54	0.89
Education per adult	2.76	2.51	0.09	3.36	2.51	0.00	2.64	2.51	0.24
Assets per adult (ln, C$)	6.67	6.51	0.18	6.53	6.51	0.46	6.70	6.51	0.15
Assets (ln, C$)	7.80	7.68	0.26	7.79	7.68	0.31	7.80	7.68	0.26
Livestock (ln, C$)	6.69	6.57	0.32	6.52	6.57	0.56	6.72	6.57	0.28
Durable goods (ln, C$)	5.33	5.25	0.31	5.48	5.25	0.15	5.30	5.25	0.38

Note: N=1016 (agricultural households in 1998-2001 panel), p-value for test of difference in means between treatment and comparison groups.

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