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Shocks, Sensitivity and Resilience: Tracking the Economic Impacts of Environmental Disaster on Assets in Ethiopia and Honduras

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October 2004

Abstract

Droughts, hurricanes and other environmental shocks punctuate the lives of poor and vulnerable populations in many parts of the world. The direct impacts can be horrific, but what are the longer-term effects of such shocks on households and their livelihoods? Under what circumstances, and for what types of households, will shocks push households into poverty traps from which recovery is not possible? In an effort to answer these questions, this paper analyzes the asset dynamics of Ethiopian and Honduran households in the wake of severe environmental shocks. While the patterns are different across countries, both reveal worlds in which the poorest households struggle most with shocks, adopting coping strategies which are costly in terms of both short term and long term well-being. There is some evidence that shocks threaten long term poverty traps and that they tend to militate against any tendency of the poor to catch up with wealthier households. Policy implications are discussed in terms of access to markets and the design of government safety net programs.

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I. INTRODUCTION

> Ato Mohammed, 55 and illiterate, resides in Bati woreda of South Wollo (Ethiopia) and heads a household of nine. He has been chronically food insecure for more than ten years when he lost his only oxen due to drought. He sold the animal to buy food at the time and has not been able to acquire another. Currently, Mohammed holds one hectare of farm land and he has no grazing land. Since he owns no oxen, he has been leasing out the land for share-cropping on a 50/50 sharing arrangement. Mohammed and his family members are engaged in various types of daily labor activities for cash and food, and the household is a regular recipient of food aid.
>
> Mohammed asserts "oxen are the crucial productive asset that would liberate me from this insecurity trap". On the other hand, however, he does not want to take credit from a regional credit organization to buy an ox as he does not want to be indebted and fears that the debt may be passed on to his children if he fails to repay. He fears that the ox may die due to lack of adequate feed or animal diseases for which there is no dependable animal health service in the community. He also fears that he may not be able to pay back since crop failure is frequent due to insects and droughts.

The direct impacts of the droughts, hurricanes and other environmental shocks can be horrific. But what are the longer-term effects of such shocks on households and their livelihoods? Do environmental shocks leave some households in a "poverty trap," with so few assets that they cannot engineer an economic recovery, as Atoh Mohammed's story suggests?[1] Does the fear of such traps lead forward-looking households to adopt asset protection strategies which come at the very high cost of immediately reduced consumption? Are patterns of vulnerability and access to market- and socially-based coping mechanisms such that repeated environmental shocks increase community inequality by grinding away at the meager assets of the relatively poor?

[1] See Carter and Barrett (2004) for a discussion of an asset-based approach to poverty traps.

In an effort to answer these questions, this paper analyzes the asset dynamics of Ethiopian and Honduran households in the wake of severe environmental shocks. The work is part of a comparative project that addresses the interrelationships between climatic shocks, markets, and asset recovery strategies among households in developing countries (see Little *et al*., 2002). In Ethiopia, markets are relatively weak (especially for land, labor, and capital), and non-market mechanisms are important. Factor markets are better developed in Honduras, but its inegalitarian agrarian structure may limit the effectiveness and extent of the social assets that may aid recovery in Ethiopia.[2] Data on a sample of 416 rural Ethiopian households track household assets over a seven-year period of pre-drought (1996-1998), drought (1999-2000), and recovery (2001-2003). Data on a sample of 850 rural Honduran households capture the immediate impact of Hurricane Mitch in 1998 on assets and income, as well as these households' economic position in 2001, two and half years after Mitch. While the steady grinding away of economic possibility created by a prolonged drought is clearly quite different from the acute and immediate destruction of a hurricane, analysis of these two disparate cases and countries offers a unique comparative perspective on the role of market-based, socially-based and aid-based coping and recovery strategies.

The remainder of this paper is organized as follows. Section II proposes an anatomy of an environmental shock, tracing the evolution of assets through time in the face of a shock, and presents an empirical model of asset accumulation to investigate households' sensitivity to, and resilience from, shocks. Section III describes the asset and income losses households in northeastern Ethiopia suffered due to the droughts of

[2] Mogues and Carter (2004) theoretically explore the idea that poor households will be less able to accumulate effective social capital in more polarized and inegalitarian economies.

1999/2000 and estimates the determinants of long-term asset recovery in the wake of the droughts. The factors that influence rural Honduran households' exposure to and recovery from the 1998 hurricane are examined in Section IV. Concluding remarks are offered in the final section.

II. SHOCKS, SENSITIVITY AND RESILIENCE

Ato Mohammed's story used to introduce this paper illustrates both asset sensitivity to environmental shocks (Mohammed had to sell off productive assets to survive the shock) and lack of resilience in the wake of shocks (Mohammed has been unable to rebuild his assets and livelihood in the aftermath of the shock). The goal of this section is to think through these twin factors of sensitivity and resilience. Together with the pattern of exposure to shocks, sensitivity and resilience shape the longer term economic impacts of environmental shocks.

(a) Economic Anatomy of an Environmental Shock

Figure 1 presents the stylized economic anatomy of an environmental shock from a household's perspective. The *x*-axis measures time and the *y*-axis measures asset stocks and income shocks. The full economic effects of an environmental disaster can be traced through three stages: the period of the shock itself; the coping period in which households deal with the immediate losses created by the shock; and, the recovery period in which households try to rebuild assets lost to the disaster and depleted through coping strategies. While the boundaries between these stages are fuzzy, distinguishing between them is a useful step in thinking through the full impacts of shocks.

The time interval over which an adverse environmental event occurs could be very brief (as with a hurricane), or it could be an extended period (as in the case of a prolonged drought). Households can also be buffeted by a sequence of such events. For illustrative purposes, Figure 1 is drawn as if the shock is a brief, one time event.

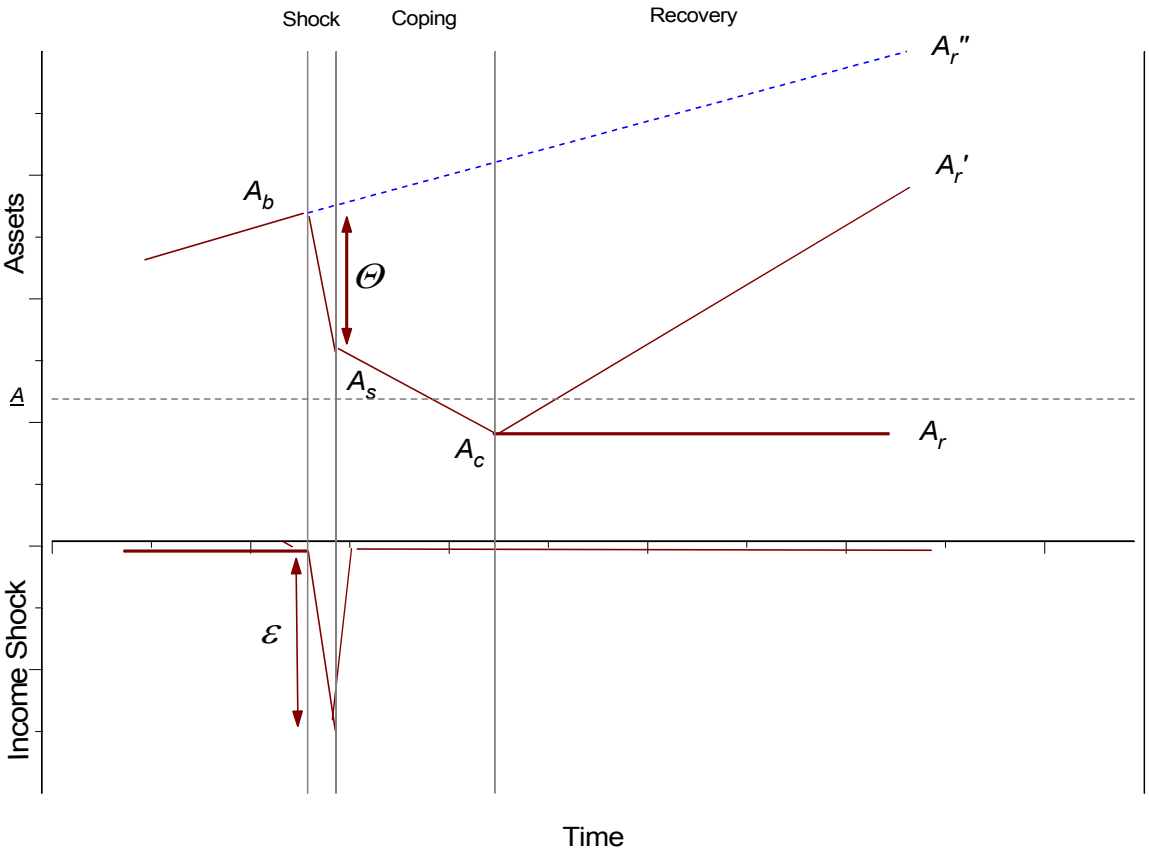

Figure 1. Anatomy of an environmental shock

An environmental shock has two direct impacts. First, it may destroy assets (washing away land, killing livestock) by an amount Θ. In Figure 1, this first impact is shown by the sudden interruption of the household's asset trajectory as its assets decline

from point A_b to point A_s.[3] The second direct impact is that it may reduce disposable household income below its normal level (crops fail or households suddenly must devote income to medical expenses). This deviation from normal disposable income levels is shown in the figure by the negative disposable income shock, ε.

Households' reactions to the direct income and asset losses during the coping phase are structured by the markets and other institutions to which they have access.[4] Households with financial market access might borrow against future earnings to sustain their consumption standard without further asset depletion. Informal finance and insurance arrangements can play the same role, as can receipt of disaster assistance. Another coping strategy is to redirect or increase work time (reduce leisure). The effectiveness of this strategy will depend on access to and depth of labor markets.

Households without access to these markets may sustain their consumption by further drawing down on their assets. While this strategy will help to smooth household consumption over time, it implies that assets will exhibit excess sensitivity to shocks (declining by more than the direct asset shock, Θ). This additional decline in household assets is shown in Figure 1 by the drop in assets from A_s to A_c. Note that two factors will shape the severity of this secondary asset decline. The first is the household's ability to employ the alternative coping strategies listed above. The second is changes in the prices of assets relative to the price of food and other necessities. Unfavorable asset price swings (as would be expected to happen if all households in an area respond to a drought by selling cattle) will serve to further decapitalize households in the wake of a shock.

[3] The subscript "*b*" will be used to denote levels before a shock, the subscript "*s*" levels immediately following a shock, "*c*" levels after the coping period (discussed more below), and "*r*" after the recovery period.

[4] While the discussion which follows lists coping strategies in a rough order of decreasing desirability for discursive purposes, any household's true preferences will depend on a number of factors.

Finally, households may cope by reducing consumption. While this strategy may be a last resort for households that lack other assets or options, it may also be pursued by households reluctant to increase their future vulnerability by further depleting their stock of assets. Drèze and Sen (1989) comment on the empirical significance of such "asset smoothing" that necessarily destabilizes consumption, while Zimmerman and Carter (2003) provide a theoretical foundation for such behavior. As Hoddinott (2004) stresses, the costs of such a coping strategy is not only immediate hunger, but that it may also permanently reduce the growth and future capacity of younger children.

The third and final stage is termed the recovery phase in Figure 1. The market and social mechanisms that broker access to employment and financial services will also shape a household's resilience and its post-shock asset accumulation trajectory. A household with good access to capital (via markets, or via informal social arrangements) can borrow against future earnings to immediately rebuild asset stocks. A key question is whether the household is able to rebuild its asset base (shown in Figure 1 as the movement from A_c to A_r'), or whether it gets trapped at a low asset level (shown by the A_c to A_r trajectory).

The story of Ato Mohammed not only suggests sensitivity to shocks, but also the existence of a poverty trap, understood as a minimum asset threshold below which it is not possible to engineer successful asset accumulation. The dashed horizontal line in Figure 1, drawn at a poverty trap threshold of $\underline{A}$, illustrates the idea of such a threshold. As illustrated in that figure, a household falling below that threshold—either from a direct asset shock, or from coping strategies that further reduced its asset holdings—would be unable to accumulate assets and would be observed over time to follow a path

from point A_c to A_r.[5] As discussed earlier, we might expect to see poor households pursue asset smoothing strategies when facing the risk of falling into such traps. Alternatively, if no such trap exists, we would expect that households at the bottom of the asset distribution would be able to accumulate assets and move ahead over time, irrespective of their level of asset depletion. Similarly, we would not expect to see signs of asset smoothing by low wealth households.[6]

In summary, the longer term effect of an environmental shock on household productive assets will depend on both sensitivity to, and resilience from, shocks. Sensitivity and resilience in turn are likely to depend on a household's own wealth prior to and in the wake of the shock, and on its access to employment and capital, as mediated by either market or social mechanisms.

(b) Empirical Strategy

This section puts forward an econometric approach for exploring the longer run economic impacts of environmental shocks in Ethiopia and Honduras. The data available for both countries includes measures of pre-shock and post-recovery assets stocks (A_b and A_r, respectively), as well as indicators of the magnitude of the shocks received. Information is not consistently available on intermediate asset stocks (A_c), and hence it is not possible to directly explore household coping strategies. Instead, we adopt a reduced form

[5] The notion that some households might remain mired in a trap of persistent poverty is surprising from the perspective of some dynamic economic theory that suggests that less well-off households would be expected to have every incentive to try to save, accumulate and catch up economically with their better off fellow citizens. Barrett and Carter (2004) discuss the forces that could offset convergence, identifying lack of access to market or socially mediated access as the key force.

[6] Fafchamps *et al.* (1998) find seemingly puzzling regression evidence that at least some households in their West African sample do not manage their livestock so as to smooth consumption over time in the face of shocks. One explanation of their finding is that a subset of their households are at a threshold where asset smoothing becomes a rational response to shocks.

approach, examining the overall change in assets from the pre-shock period to the post-recovery period.

In order to test for the sensitivity and resilience effects discussed above, we will build on the following model of household asset growth from the pre-shock to the recovery period:

$$A_{ri} = A_{bi}[1 + r(\Theta_i, \varepsilon_i, x_i \mid A_{bi}, A_{si}, K_i, L_i)] \quad (1)$$

Where A_{ri} is recovery period assets of household i, A_{bi} is the household's pre-shock asset stock, and the function $r(\cdot)$ specifies the household growth rate as a function the asset (Θ_i) and income shocks (ε_i) experienced by household i, as well as of other household characteristics x_i. such as age that might shape desired asset levels.

Conditioning the impact of these factors on asset growth are wealth, and labor market and capital access variables. To explore the idea that post-shock growth (resilience) differs by wealth, the growth rate is specified to depend on the post-shock wealth of the household, A_{si}. The existence of a poverty trap would be signaled by a negligible post-shock growth for the poorest households, while a convergent process would be signaled by higher rates of asset growth for poorer households.

To explore differential sensitivity of assets to shocks, the impact of the shock variables are conditioned by the pre-shock wealth level of the household, denoted A_{bi}. A highly sensitive household would be one where shocks have large and lingering effects on household productive assets. Controlling for post-shock resilience, high sensitivity of assets to shocks for a particular wealth level would signal reliance on asset sales to smooth consumption, and most likely a lack of access to market- or socially-mediated access to capital or insurance. Evidence of the insensitivity of assets to shocks would

indicate either access to finance, or the existence of an asset smoothing strategy provoked by a poverty trap (most likely for lower wealth households).

Finally, expression (1) indicates that the asset growth is conditioned by labor market access and capital access variables, L_i and K_i. Both factors are likely to shape both resilience and sensitivity. Note that K_i can include what is commonly referred to as social capital assets.

III. LIVESTOCK DECLINE AND RECOVERY FOLLOWING DROUGHT SEASONS IN NORTH-EASTERN ETHIOPIA

In the study area of eastern Amhara Region (South Wollo and Oromiya Zones), the drought of the late 1990s was a prolonged event with uneven consequences, and its onset was gradual. Indeed, the first signs of disaster can be traced to the poor short rains (January-April, called the Belg season) of 1998 where it is estimated that harvests were only 60 percent of normal yields in the main Belg growing areas (Government of Ethiopia,1997; 1998a; and 1998b). That year the long rainy season (June-September, called the Meher) was near normal for all areas except in the Belg growing zones where there is also some dependence on the Meher season. Because the Meher rains of 1998 were near normal in some locations, drought and relief agencies in Ethiopia failed to see the looming disaster until the Belg season of 1999 emerged as a massive failure, resulting in 90 percent loss of crops (see Castro *et al*., 1999). National and regional estimates for food relief in 1999 were drastically altered when it was observed that the Belg season of 1999 was going to be an almost complete disaster (Government of Ethiopia, 1998a and 2000).

The 1999 Meher season was only somewhat better but not good, yielding about 40 percent of normal harvests in six of the eight study *kebeles* (an administrative unit comprised of four or five villages). Food aid distribution started in the region in June 1999, but was not widespread until August 1999. To make matters worse, the Belg season of 2000 was very poor (75 percent reduction of normal yields). With massive imports of food aid and the recovery of the long rains in 2000, the nutritional status of the area's population had returned to near normal by early 2001. Thus, the drought of the late 1990s was keyed by the failure or near failure of three successive short rainy seasons. The first of the crop failures was only 40 percent, but with such widespread poverty it was enough to initiate the downward spiral of extensive food insecurity and distress sales of assets (mainly livestock) that characterized the region for the better part of 30 months.

The long term possibilities of asset recovery from this series of shocks are conditioned by several community and household characteristics. The study region (as indeed large parts of Ethiopia) is characterized by relatively weak labor markets and nearly absent credit markets. Land markets are severely restricted in that private ownership is prohibited, and legal constraints on land rentals were only recently relaxed. In part because insurance against crop loss is practically absent and market-based coping mechanisms are limited, food aid makes up a relatively large portion of food consumption, as indicated above. Social institutions such as burial societies and religious associations are highly prevalent in South Wollo. We will explore their importance, along with those market and aid-based mechanisms that enhance a household's ability to weather shocks in the short term as well as recover in the long term. Data are from a seven round household survey conducted over three-and-half years in eight peasant

associations (*kebeles*) in South Wollo and Oromiya zones. The dataset also includes recall questions on livestock holdings during 1996 to 1999, which assess how households fared in terms of their assets prior to the onset of the drought.

(a) Crop and livestock losses and their recovery

It is obviously difficult to gauge the full extent of losses as a result of the droughts. Based on government reports, meteorological data, and household information, it is possible to estimate losses and to show the kind of cumulative impacts of the disaster. As Table 1 shows, drought-induced losses in crop and livestock among sample households in the study area were $119,124 during 1998 to 2000, or $266 per household. This figure exceeds the annual average cash income for more than 75 percent of households in the study region. Livestock losses account for about half of total losses.

Table 1: Time Sequence of Economic Losses from Drought (US$)[a]

Type of loss (per hh)	*1998*		*1999*		*2000*		**TOTAL**
	Belg	Meher	Belg	Meher	Belg	Meher	
Crop losses	$5,734	$4,319	12,903	17,877	$10,753	$9,284	$60,870 ($136)
Livestock losses	0	$5,826	$26,214	$26,214	0	0	$58,254 ($130)
Total Losses	$5,734	$10,145	$39,117	$44,091	$10,753	$9,284	$119,124 ($266)

[a] Based on 1999 exchange rate of 8.5 Ethiopian birr to US$1.

1999 was the year of heaviest livestock losses.[9] Based on interviews it is estimated that 25 percent of livestock losses in 1999 were distress sales at which the seller received less than 50 percent of the normal price of the animal sold (cattle prices, for example, dropped from an average of 625 birr to 291 birr). Price swings of this

[9] For livestock losses, Table 1 focuses on 1998 and 1999, and for simplicity sets losses in 2000 equal to zero, even though drought-induced livestock deaths and distress sales did not end in 1999.

magnitude constituted a huge capital loss for those forced to sell livestock during this period. Adding this capital loss to the full value of animals lost to disease and death permits us to estimate the value of livestock assets lost during the 1999 drought year. Natural causes clearly precipitated the drought disaster of 1999, which resulted in a massive humanitarian effort, but the population's vulnerability to relatively small perturbations in climatic events is 'unnatural' and highlights the extreme poverty in the area.

Figure 2 gives a first indication of how the weather shocks discussed above impacted poorer and wealthier households. The top panel shows the evolution of mean livestock by households in the four, pre-drought wealth quartiles. Following the onset of the drought in 1998, the top two wealth quartiles appear to exhibit classic consumption smoothing behavior, as livestock assets begins to dip sharply. In contrast, the two lowest quartiles appear to more stubbornly hold on to their livestock, showing on average only small decreases in livestock near the end of the drought period.

The bottom panel of Figure 2 displays post-drought livestock trajectories based on wealth quartiles defined according to animal holdings at the end of the drought (mid-2000). As can be seen, average holdings of the poorest quartile were essentially zero at that time. Interestingly, however, this group on average managed to add substantially to their livestock holdings over the span of the following three years.

While this descriptive look at the data does not control for other factors that influenced these trajectories, it is suggestive of interesting patterns, with the highest wealth households exhibiting greater asset sensitivity to shocks, and the lower wealth households destabilizing consumption and perhaps defending their modest livestock

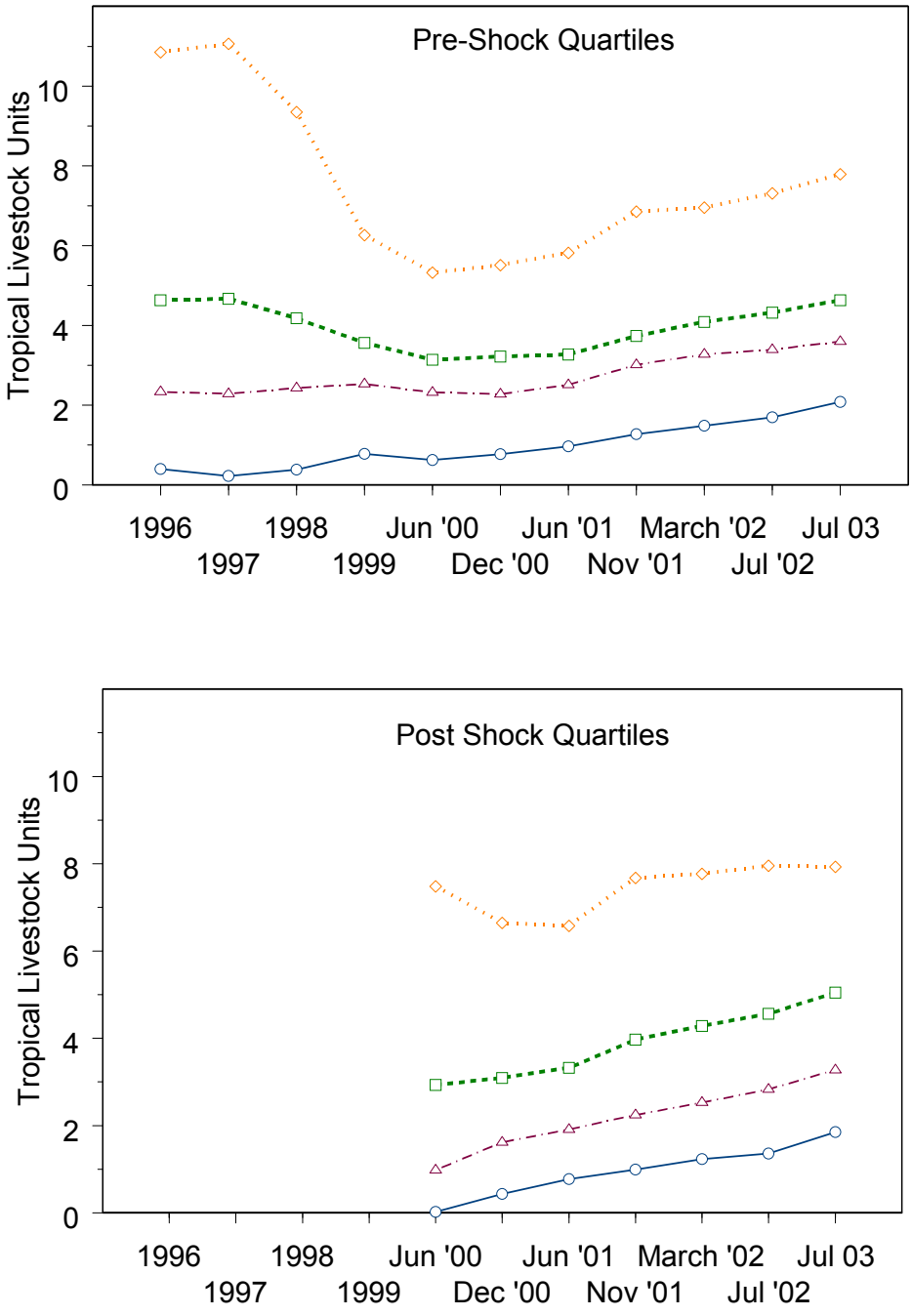

Figure 2. Evolution of Mean Livestock Holdings by Wealth Quartiles

holdings over the course of the drought. Yet, despite this asset smoothing behavior which would seem to signal the existence of a poverty trap, post-shock growth appears to be relatively robust, even for those households that were completely without livestock at the end of the drought.

One possible explanation for the apparent inconsistency in these findings is that those households that had completely stocked out by mid-2000 were precisely those households that enjoyed good social capital and perhaps other assets. Confident that they could borrow animals to rebuild depleted herds, they had no reason to fear becoming mired in a poverty trap. In contrast, those households that apparently defended their livestock could be isolated households who—like Ato Mohammed—would have been trapped by low post-shock resilience and growth had they let their stocks deplete to almost nothing. Employing the asset growth model put forward before, we turn now to a more thorough analysis of the data using multiple regression methods that permit us to control for these multiple factors that influence observed outcomes.

(b) Estimation Results

To estimate the determinants of the long-term rate of growth of livestock assets from A_b to A_r, we adopt the asset growth model (1) as follows:

$$A_{ri} = A_{bi}[1 + r(,\Theta_i, \varepsilon_i, x_i \mid A_{bi}, A_{si}, K_i, L_i)] + \beta_0(A_{bi}) + \omega_i, \qquad (2)$$

where the error term ω_i is assumed to be normally, independently and identically distributed across observations, and an additive term, $\beta_0(A_{bi})$, that captures factors that affect households' livestock holdings but do not operate through expanding growth of existing stock. Sources of such additional livestock assets could include social transfers or gifts, as well as non-livestock assets which can be sold and transformed into livestock

assets. Unfortunately, we lack data on these other assets, and instead specify that the magnitude of this additive term depends on the household's pre-drought livestock holdings (taken as a proxy of overall household wealth).

To estimate (2), we subtract pre-drought assets from both sides of (2) (so that the change in livestock assets over time becomes the left-hand side variable) and employ the following functional specifications for the growth rate and additive term:

$$A_{ri} - A_{bi} = A_{bi} \cdot \left\{ x_i\beta + A_{si}\beta_A + A_{si}^2\beta_{A2} + \sum_{j=1}^{4}[(Q_{bi}^j\varepsilon_i)\beta_\varepsilon^j + (Q_{si}^j L_i)\delta_L^j + (Q_{si}^j S_i)\delta_{SK}^j + (Q_{si}^j F_i)\delta_F^j] \right\} + \sum_{j=1}^{4}[Q_{bi}^j\beta_0^j] + \omega_i$$

The growth rate terms in the curly brackets include basic household demographic information that would be expected to affect desired household livestock holdings (the x_i). The possibility of wealth-differentiated resilience and poverty traps is explored by including a quadratic specification of post-shock wealth level, A_{si}. Differential sensitivity to the environmental shock, ε_i, is explored by letting the coefficient on the magnitude of the shock depend on the 1997, pre-shock wealth quartile of the household, Q_{bi}^j (j=1, 4 where 1 is the lowest quartile). While the available data lack a measure of the severity of the shock received by each household, we approximate it with the share of households in the community of household i that suffered crop losses from June to December 2000.

Finally, we let the impact of social institutions S_i, food aid F_i, and labor markets L_i on the growth rate depend on the household's asset quartile. Social institutions measured as community average membership in social organizations.[10] Food aid is measured as the percentage of a community participating in food for work programs. While this

[10] These include for example burial societies (kire), informal credit associations (iqqub), and religious groups (mehaber and senbete).

community level variable bypasses individual-level endogeneity problems created when more severely shocked households choose to participate in the program, it may still suffer from the fact that programs are placed in communities where the drought was most severe. The labor market indicator is an average of off-farm earnings for all households within a village. This number was then normalized to vary between zero and one by dividing it by the highest level of average earnings among the eight villages in the sample. Note that for estimation purposes, all of these growth rate variables were interacted with A_{bi}, as shown in the equation.

Table 2 gives the results of the ordinary least squares estimation of the model. The first column presents the unrestricted model that allows for wealth effects for all potential conditioning factors of livestock asset growth. The second model restricts the wealth-differentiation of the role of those mediating factors where such restrictions do not weaken the explanatory power of the model. We will concentrate on the results for the restricted model, but include the full model for completeness.

Demographic factors have their expected effects on livestock growth, though surprisingly the gender of the household head appears to be irrelevant. Post-shock resilience displays a strongly wealth-differentiated pattern. The estimated coefficient indicates that the growth rate of livestock is increasing in herd size up to a level of 25 tropical livestock units (TLUs).[11] Other things equal, these estimates indicate that households that exited the drought with few livestock were strongly disadvantaged in their rate of recovery period growth.

[11] A tropical livestock unit is a measure that weights together different kinds of animals into cattle equivalents.

Table 2: Determinants of livestock holdings after recovery from the drought period

Sample: n=416	Full Model	Restricted Model
Factors Affecting Livestock Growth Rate		
Demographic Factors		
Age of household head	0.020*	0.021**
Squared age of head	-0.0001*	-0.0002*
Gender of household head	0.039	0.030
Land assets (in timad=$^1/_4$ ha)	0.026**	0.027**
Resilience		
A_s	0.06**	0.055**
A_s^2	-0.001**	-0.001*
Sensitivity to Shocks, ε		
$Q_b^1 \; x \; \varepsilon$	-0.14	-0.08
$Q_b^2 \; x \; \varepsilon$	-1.12**	-1.07**
$Q_b^3 \; x \; \varepsilon$	-2.39**	-2.36**
$Q_b^4 \; x \; \varepsilon$	-2.30**	-2.20**
Community social capital, SK		
$Q_s^1 \; x \; SK$	-0.14	0.08
$Q_s^2 \; x \; SK$	0.05	0.08*
$Q_s^3 \; x \; SK$	0.14**	0.12**
$Q_s^4 \; x \; SK$	0.12**	0.09**
Labor market access, L		
L	--	0.20*
$Q_s^1 \; x \; L$	-0.12	--
$Q_s^2 \; x \; L$	0.09	--
$Q_s^3 \; x \; L$	0.28	--
$Q_s^4 \; x \; L$	0.19	--
Access to food aid, F		
F	--	-0.83**
$Q_s^1 \; x \; F$	0.63	--
$Q_s^2 \; x \; F$	-0.44	--
$Q_s^3 \; x \; F$	-0.95**	--
$Q_s^4 \; x \; F$	-0.97**	--
Additive Term		
Q_b^1	1.7**	1.7**
Q_b^2	1.6*	1.5*

Q_b^3	5.5**	5.5**
Q_b^4	6.5**	6.3**
F- test	F(26,390) = 33.5**	F(20,396) = 43.2**
Adj. R^2	67.0%	67.0%

The sensitivity of assets to shocks also shows a pronounced wealth-differentiated pattern. For the lowest wealth quartile, shocks have an insignificant effect on livestock, signaling the presence of asset smoothing behavior. Asset sensitivity is then increasing with pre-shock wealth. The magnitude of the estimated coefficients are such that a 10 percentage point increase in the proportion of households in a community suffering crop losses is estimated to decrease the asset growth rate of the wealthiest group by 23 percentage points. For a second quartile household, the decrease would be only 12% points, whereas it would be almost zero for a bottom quartile household. This greater asset-sensitivity of the wealthier groups does not imply that welfare of the initially better off group is more vulnerable to shocks. On the contrary, these results are consistent with the initially better endowed households pursuing a consumption-smoothing strategy, whereas the already asset-poor may be protecting their meager wealth in the face of adverse conditions, following the asset-smoothing strategy discussed above.

The estimated model also explores the degree to which social mechanisms, food aid and labor markets bolster asset growth, controlling for shocks, etc. Community membership in social organizations (social capital) increases the rate of growth (or limits the rate of loss) of livestock over the six years, but does so primarily for households in the higher wealth groups. In contrast, there is only weak evidence that labor market access significantly affects the rate of growth of livestock. While the average effect (from the restricted model) is positive and statistically significant, the full model shows

that this positive effect appears to be strongest for wealthier households. Finally, availability of food aid in the community does not appear to protect households' future assets, and in fact seems to have the opposite effect.[12]

In addition to factors affecting the growth rate of livestock, the econometric model also includes an additive term meant to capture other sources of livestock replenishment (including own non-livestock wealth and social transfers). As can be seen in Table 2, these additive terms are quite significant and amount to 1.7 TLUs for the poorest households and rise to over 6 TLUs for the initially wealthiest households. While somewhat puzzling, the magnitude of these coefficients suggest a major force that potentially offsets the low estimated resilience of less well-off households.

In summary, the econometric results in Table 2 provide some evidence of poverty traps, including the relatively low resilience of poorer households, the apparent patterns of asset, not consumption smoothing, by the poorest; and, social capital that is less effective for the poor. At the same time, other factors point to possibly net positive livestock recovery for the poorest households, especially the additive constant term. In order to assemble these countervailing forces into a single indicator of asset recovery, Table 3 uses the table 2 estimated coefficients to create predicted recovery period assets for poor and rich households under several scenarios. Holding other explanatory

[12] This result is somewhat surprising, especially since the direction of the impact cannot arise from endogeneity with food aid being often provided to those households with fewer assets (Quisumbing, 2003) since the measure used here is a community aggregate rather than individual participation in food-for-work. A study focusing on the impact on food aid on welfare in three regions in Ethiopia including South Wollo (Mathys, 1999) points in a similar direction (though less pointedly), finding that while in the short term asset sales are somewhat reduced with food aid, months later households tend to resort back to elevated sales. Also, other work on South Wollo points to the limitations of food aid in enabling recovery from disasters in the long run (Little *et al.*, 2003).

variables at their mean, Table 3 isolates the impact of shocks and social capital on the asset recovery of initially poor and initially better-off households.[13]

The Table 3 results show that the rate of recovery of livestock assets is slower where shocks are higher, and better in an environment of better access to community social capital. This table also reveals the net effect in terms of long-term growth rates of the two forces of sensitivity and resilience: We saw above that the better endowed decumulate assets faster in the course of experiencing a series of droughts, but that this group is also relatively better equipped to rebuild assets in the wake of these shocks.

Table 3: Sensitivity to and Resilience from Shocks in Ethiopia

	Lowest Wealth Quartile				*Highest Wealth Quartile*			
	Access to social institutions				Access to social institutions			
	Low		High		Low		High	
	No shock	*High shock*	*No shock*	*High shock*	*No shock*	*High shock*	*No shock*	*High shock*
Pre-shock assets	0.22	0.22	0.22	0.22	11.06	11.06	11.06	11.06
Post-recovery assets	2.09	2.12	2.07	2.10	26.59	28.08	2.71	4.19

These two forces combine to point to an overall faster growth of the initially poor as compared to the highest-wealth group: the former expands assets on average from 0.2 TLUs eightfold to about 2.1 TLUs, whereas the highest quartile increases its initial asset base of 11 TLUs to reach 28 TLUs under a scenario in which they do not face collective

[13] Shocks and social capital are measured in the same way as in the regression estimation of Table 2. For the latter, low and high levels use the 10th and 90th percentiles, respectively. High shocks are represented also by the 90th percentile in the data.

shocks, and in fact lose livestock over the six-year time period where shocks are high. In all cases, the predicted livestock holdings for low quartile households is driven by the additive constant term, which by itself accounts for 1.7 TLUs.

IV. GAUGING THE LONGER TERM IMPACTS OF HURRICANE MITCH ON RURAL HOUSEHOLDS

Hurricane Mitch carved a path of destruction across Honduras in 1998. Unlike the Ethiopian drought described in the previous section, the impact of the hurricane was almost instantaneous. Drawing on data collected shortly after the hurricane, Morris *et al*. (2001) report that poor rural households lost 30% to 40% of their crop income and measured poverty immediately increased 5.5 percentage points, rising from 69.2% of households to 74.6%. They also report that lower wealth households lost 15% to 20% of their productive assets (land, livestock and plantations), compromising their capacity to generate earnings and livelihood. Unclear, however, from these early studies is whether households were able to recover from losses of this magnitude and rebuild their assets and livelihoods. While labor and other markets are deeper and better developed in Honduras than in Ethiopia, it is less obvious that local social relationships would function as effectively to mitigate the longer term effects of an environmental disaster.

The data available for this study provide a window into these longer term questions. Some 30 months after Mitch, a sample of 850 rural Honduran households (clustered in 30 municipalities spread across 6 provinces) was surveyed as part of a study on the impact of land market liberalization and asset accumulation.[14] Included in the

[14] This sample is comprised of two distinct sub-samples: panel and cross section. The panel households (500) originate from a study conducted in 1994 (Lopez and Valdes, 2000) in which 450 farm households were interviewed to analyze the impacts of the initial land titling programs. The 2001 survey attempted to follow both these baseline households and the land they cultivated. Of the original baseline households, 362 were resurveyed. In addition, 138 ”new” panel households were added. In 2000, these households were

questionnaire were a number of retrospective questions that probed the direct impacts of Mitch on household assets and income. The study also collected data on household assets in 2000/2001, giving a window into the longer term patterns of asset cycles and poverty traps.

(a) The Impact of Hurricane Mitch on Asset Stocks and Growth

Table 4 presents descriptive statistical indicators of the impact of Hurricane Mitch. Information is provided both for the overall sample and for households broken up by asset quartiles. Quartiles were defined based on households' pre-Mitch holdings of productive assets (A_b), where productive assets are defined as the value of land, plantations, machinery and livestock. All assets were valued using 2000 price information and were converted to $US using the market exchange rate. As can be seen, wealth varies substantially averaging $650 for the poorest quartile and just over $75,000 for the wealthiest quartile. Annual household income in 2000/01was six times higher for wealthier households than it was for poorer households ($996 versus $5,967). These low figures are consistent with the high poverty rates typical of rural Honduras. The variation in them is also a small reflection of the sharp levels of inequality found across much of rural Honduras.

As can be seen, 44% of households suffered a loss of productive assets from Hurricane Mitch. The percentage of households increases with household wealth (rising from 22% to 68% from the first to the fourth wealth quartile). This finding contradicts the notion that poorer households are more vulnerable to shocks, though it may be an

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cultivating land that had been worked by the original panel households in 1994. The remaining 350 cross-sectional households were added in regions that were not covered in the 1994 study. Households that were not operating their own farm in 1998 were eliminated from the sample for purposes of this study, reducing the total number of households to 821.

artifact of the fact that poorer households had relatively little to lose. Indeed, as can be seen, among those households suffering asset losses, poorer households lost a greater

Table 4: Losses due to Hurricane Mitch *(Mean values unless otherwise noted)*

	All House-holds	Pre-Mitch Asset Quartiles			
		I	II	III	IV
Pre-Mitch Productive Assets (US$)	23,769	653	3,998	13,718	76,821
Annual Household Income 2000/01 (US$)	2,440	996	1,127	1,716	5,927
Loss of Productive Assets					
% Households with Losses	44.3	21.8	31.7	55.6	68.3
% of Pre-Mitch Assets Lost[a]	12.0	31.1	13.9	12.2	7.5
Structure of Asset Loss* (% of total assets lost)					
Land	29.6	22.6	16.5	25.1	31.4
Plantations Loss	60.5	62.2	75.4	65.3	58.6
Livestock	8.6	13.8	8.1	9.6	8.3
Machine	1.3	1.5	0.0	0.1	1.7
Households that Lost Productive Assets					
Income Shock (US$)	428	144	164	328	722
Housing Loss (US$)	442	58	310	481	596
Aid received (US$)	232	154	330	98	320
Median Asset Growth (%) (pre-Mitch to 2001)	-2.6	-5.0	-4.9	-2.1	-2.1
Households without Loss of Productive Assets					
Income Shock (US$)	93	101	70	95	121
Housing Loss (US$)	119	187	96	53	89
Aid received (US$)	141	88	134	161	261
Median Asset Growth (%) (pre-Mitch to 2001)	5.4	8.8	5.4	4.6	3.0

[a] Figures calculated only for those households that suffered asset losses.

percentage of their productive wealth (31%) than did wealthier households (8%). Across all wealth quartiles, losses were primarily comprised of lost plantations and land.

The second two panels of the table present additional descriptive data on households based on whether or not they experienced a loss of productive assets from Mitch. Not surprisingly, households that suffered asset losses also experienced greater income losses

(primarily crop income). For the lowest wealth quartile, these losses averaged 10% to 15% of annual household income.[15] Loss of housing stock was also substantial for many households. Aid (typically in the form of food and building materials) averaged between $50 and $600 across the quartile groups, but in no case averaged more than 10% of the value of lost productive assets.

Finally, Table 4 reports asset growth rates from mid-1998 (pre-Mitch) to early 2001.[16] These figures give can be used to get a sense of the empirical gap between $A_r^{"}$ and $A_r^{'}$ in Figure 1—*i.e.,* the asset gap between a household that experienced a shock and a household that did not. Across all pre-Mitch wealth quartiles, households without assets losses show substantially higher growth than those that suffered losses. The gap is 13.8% for the lowest quartile where poor households with losses had showed -5% net growth (loss) over the post-Mitch period, while poor households without losses had 8.8% growth. The gap is a smaller 5.1% for the wealthiest quartile (-2.1% versus 3% post-Mitch growth).

While these growth differences seem to signal that poor households are more sensitive to shocks (and less able to recover from them), among those households that did not suffer any asset losses, poor households tended to grow faster (8.8%) than did wealthier households (3.1%). We turn now to more thoroughly explore these patterns of vulnerability and resilience.

(b) Regression Analysis of Asset Loss and Recovery

For estimation purposes, we write the asset growth equation (1) as:

[15] The percentages are approximate as household income is measured only for the year 2000/01 and not for the year of the hurricane.

[16] Median growth rates are reported in the table. Mean growth rates are higher in all cases, but follow the same qualitative pattern. Many of the high growth rates appear to be the result of inheritances received post-Mitch.

$$A_{ri} = A_{bi} e^{r(\Theta_i, \varepsilon_i, x_i | A_{bi}, A_{si}, K_i, L_i) + \omega_i}, \tag{3}$$

where ω_i is a standard error term. Taking the logarithm of both sides and rearranging terms yields the following expression for the growth of assets from the pre-Mitch to the post-Mitch recovery period:

$$\ln(\frac{A_{ri}}{A_{bi}}) = x_i\beta + \sum_{j=1}^{4}(Q_{si}^j)\beta_A^j + \sum_{j=1}^{4}\left[(Q_{bi}^j\Theta_i)\beta_\Theta^j + (Q_{bi}^j\Theta_i L_i)\delta_L^j + (Q_{bi}^j\Theta_i K_i)\delta_K^j\right] + \varepsilon_i\beta_\varepsilon + F_i\delta_F + \omega_i \tag{3′}$$

where the growth rate *r(·)* has been replaced with the specification shown above. Similar to the specification employed to analyze the Ethiopian data in the prior section, equation (3′) indicates that growth from the pre-shock through the recovery period depends on basic household demographic characteristics (the x_i). Also paralleling the Ethiopian specification, the resilience of post-shock growth depends on the post-shock asset level, measured as the post-shock asset quartile of the household (Q_{si}^j, *j=1,..., 4*).

Unlike the Ethiopian data, the Honduras data contains direct household measures concerning the magnitude of asset shocks (Θ_i) and income shocks (ε_i). These measures were normalized by the pre-shock asset holdings of the household so that they entered the regression as the percentage of assets destroyed by the shock. In regression specification (3′), the sensitivity coefficients on the asset shock variable (but not the income shock variable) is permitted to differ by the pre-shock wealth quartile of the household (Q_{bi}^j, *j=1,..., 4* where *j=1* is the lowest quartile).[17]

[17] More general specifications of the influence of the income shock revealed no significant patterns.

Finally, aid received (F_i) and labor (L_i) and capital market (K_i) access variables are permitted in (3′) to moderate the influence of asset shocks on asset growth.[18] The aid variable is simply the amount of external assistance received by the household (normalized by the household's pre-shock stock of assets). The labor market indicator for a household is defined as the average off-farm labor market earnings within its community (there are a total of 31 separate communities within the sample). The variable was scaled to lie between zero and one by dividing it by the highest community average earnings level within the sample. The capital access measure was derived from a set of questions designed to probe whether or not a household was on its demand curve for credit (and hence price rationed in that market) or whether it had excess demand for credit and hence was subject to some form of quantity rationing (see Boucher *et al.* 2005 for details). Unfortunately, this measure reflects a household's status in 2001, well after the immediate post-shock period.

Table 5 presents ordinary least squares estimates of the parameters in (3′) for both restricted and unrestricted versions of the model. As before, we will concentrate on the restricted estimates that eliminate statistically insignificant interactions. The demographic variables are again sensible and statistically significant. The resilience patterns are, however, quite different from the Ethiopian results. Whereas the Ethiopian data showed higher growth for households that emerged from the shock with more assets, the Honduras estimates show more resilient growth for poorer households, although none of the estimated resilience coefficients are statistically different from zero. To be clear,

[18] In principal, these factors might also mitigate the impact of income shocks. However, in no instance did these interactions prove even remotely statistically significant. In addition, interactions between the aid variable and the shock variables were insignificant.

Table 5: Ordinary Least Squares Estimates of Asset Recovery and Growth
Dependent Variable, log(A_{ri} /A_{bi})

Explanatory Variables	*Full Model*	*Restricted Model*
Demographic Factors		
Age of Household Head	0.016**	0.016**
Squared Age of Head	-0.0003**	-0.0002**
Received Inheritance (dummy)	0.065**	0.65**
Department Dummies	included	included
Resilience		
Asset Quartile 1, Q_s^1	0.16	0.16
Asset Quartile 2, Q_s^2	-0.09	-0.09
Asset Quartile 3, Q_s^3	-0.11	-0.11
Asset Quartile 4, Q_s^4	-0.12	-0.13
Sensitivity to Shocks		
Asset Shock, Θ		
$Q_b^1 \; x \; \Theta$	-2.84**	-2.85**
$Q_b^2 \; x \; \Theta$	-3.23**	-3.24**
$Q_b^3 \; x \; \Theta$	-1.55**	-1.56**
$Q_b^4 \; x \; \Theta$	-0.68	-1.1*
Income Shock, ε	0.21**	0.21**
Housing Loss (Equals 1 if housing loss)	-0.10**	-0.10**
Mediating Factors		
Labor Market Access, M		
$Q_b^1 \; x \; \Theta x \; M$	0.82**	0.82**
$Q_b^2 \; x \; \Theta x \; M$	0.41	0.41
$Q_b^2 \; x \; \Theta x \; M$	-0.10	--
$Q_b^2 \; x \; \Theta x \; M$	0.14	--
$M \; x \; \varepsilon$	-0.05	0.05
Capital Market Access, K		
$\Theta x \; K$	--	0.26
$Q_b^2 x \; \Theta x \; K$	0.18	--
$Q_b^2 x \; \Theta x \; K$	1.33**	1.09*
$Q_b^2 x \; \Theta x \; K$	0.63	--
$Q_b^2 x \; \Theta x \; K$	-0.56	--
Aid Received, F	-0.01	-0.01
R^2	0.31	0.31

this finding does not mean that growth is zero, simply that it does not vary much that predicted with the core demographic factors.

Again contrasting with Ethiopia, all wealth quartiles in Honduras exhibit sensitivity to asset shocks. A coefficient of -1 would indicate that (other things equal) no recovery has taken place. A coefficient less than -1 indicates further deterioration of the asset position of the household through secondary coping strategies. As can be seen, for the wealthy quartiles, the coefficients are near -1. Apparently these households had little need to draw down further on their assets to smooth consumption in the wake of the shock. In contrast, the lower initial wealth quartiles show sharply greater sensitivity to shocks for the lower quartiles as the relevant coefficients are less than -1. Table 6, discussed below, draws out the full economic implications of these estimates.

While unmediated shocks are estimated to have this devastating impact on productive assets, more robust local labor markets help offset these impacts, especially for the lowest wealth quartile households. Access to capital markets has a similar effect for second quartile households, though it has little effect for other households in the sample.

Income shocks (measured as income lost due to the hurricane normalized by household pre-Mitch assets) are counter-intuitively estimated to have a positive impact on growth. While it is possible that households that suffered large income losses took reactive steps that ultimately enabled them to more quickly build up productive assets (*e.g.*, income shortfalls may have forced households into bearing the fixed costs of migration to secure wage earnings), it also seems possible that high income losses occurred when households were involved in high value market opportunities and thus had

better access to market-based coping mechanisms. In any event, efforts to further decompose this effect by looking at quartile-specific effects caused the variable to melt away into insignificance. Similarly, interactions between income losses and measured market access failed to detect any significant patterns. As an addition control for other losses suffered in the hurricane, a dummy variable was included in the regression, taking a value of one for households experiencing loss of housing. More intuitively, when households did experience housing loss, recovery of productive assets was significantly slowed by approximately 10%.

In summary, patterns of sensitivity and resilience in Honduras appear quite different from those in Ethiopia. Unlike Ethiopia, there is no sign of asset smoothing in the wake of shocks. Indeed, the asset growth of less well-off households appears to be extremely sensitive to shocks received. When labor and capital market access are stronger, this sensitivity is reduced. However absent that access, poorer Honduran households appear to struggle economically in the wake of a shock.

In order to draw out the implications of the regression coefficients more clearly, we again calculate predicted asset levels for a variety of stylized low and high wealth households that experienced different shocks in different market environments. Table 6 presents the results of these calculations. Initial asset levels are taken to be the mean for each quartile. For each asset level, the table contrasts the experience of a household that had no asset shock with the experience of a household that suffered a 31% asset loss (which was the mean loss level for the lower wealth quartile households that experienced losses). Other shocks were set to zero and all other household characteristics are set to mean levels for the sample.

For the no shock case, the low wealth household shows higher growth than the high wealth household, though this result is driven entirely by the quartile-specific resilience coefficients of dubious significance. However, in the high shock scenario, the excess sensitivity of poor households to asset shocks completely overturns this modest convergent process. Absent good market access, a low wealth household that experienced an immediate 31% asset loss is estimated to experience further declines and a net asset growth rate of -48% from its pre-Mitch position to the time of the study 30 months later. A wealthier household that experienced an identical 31% loss is estimated to have recovered partially from the loss and exhibit a net growth rate of -14%. Were we to further take into account that wealthier households on average only lost 7.5% of their assets (not 31%), then the unequalizing effect of the shock would be further magnified. When poor households are compared to where they counterfactually would have been without a shock, the impacts of the shocks stand out even more sharply.

Table 6: Sensitivity to and Resilience from Shocks in Honduras

	Lowest Wealth Quartile			*Highest Wealth Quartile*		
	No Shock	31% Asset Loss		No Shock	31% Asset Loss	
		Poor Market Access	Good Market Access		Poor Market Access	Good Market Access
Pre-Shock Assets	$650	$650	$650	$76,821	$76,821	$76,821
Post-Recovery Assets	$1,040	$439	$584	$91,779	$65,445	$70,875
30 Month Growth Rate	60%	-48%	-10%	19%	-14%	-7.7%

Finally, Table 6 shows that more buoyant labor and capital market access serves to offset the unequalizing effect of asset shocks. Under these circumstances, lower wealth households would be able to offset much of the 31% asset loss (climbing back to a

net asset change of -10%). Wealthier households are also estimated to benefit slightly from better market access, but the final recovery gap between poor and rich households is almost eliminated. These results are especially interesting in the context of a related study by Carter and Castillo (forthcoming). In that study, Carter and Castillo find that recovery from Mitch was more rapid in communities characterized by high levels of pro-social norms of trust and altruism. Interestingly, further analysis by Carter and Castillo suggests that only a subset of households seems to actually benefit from the pro-social environment, suggesting that there may be processes of exclusion that prevent all households from benefiting from socially mediated access to insurance and capital. If correct, when merged with the results presented here, we seem to see a situation in which local social mechanisms leave poor Honduran households quite vulnerable to asset shocks. In this environment, access to supporting capital and especially labor markets seem to be especially important.

V. CONCLUDING REMARKS

In the fictive world of full and complete markets, poor households could draw on loan and insurance contracts to cope with the often disastrous asset and income losses brought by severe environmental shocks. Drawing on future earnings, households in this world could rebuild lost assets and sustain their level of current consumption without further depletion of their productive assets and future possibilities. The story of one Ethiopian household told at the beginning of this paper is a case study of how far the actually existing world can be from that fictive world. In the real world of Ato Mohammed, environmental shocks can decapitalize the poor, and trap them in impoverished position

from which they cannot escape. When this happens, a humanitarian problem of disaster relief becomes a long-term development problem.

In an effort to better understand the nature of environmental shocks, this paper has employed longitudinal data on assets to understand the longer term impacts of two environmental shocks, the three-year drought of the late 1990s in Ethiopia and the 1998 Hurricane Mitch in Honduras. Analysis of the Ethiopian data reveals a disturbing pattern of asset smoothing or protection among the lowest wealth households, meaning that the household tries to desperately hold on to its few assets even as income and consumption possibilities dwindle. The analysis also reveals a pattern of weak resilience amongst the poorest Ethiopian households, meaning that those who exit a shock with few assets experience difficulties in rebuilding their assets and livelihoods. Together these patterns at least hint at the generality of the experience of Ato Mohammed.

Analysis of the Honduran data reveals a different, but similarly provocative pattern. Relatively wealthy households seem to be able to protect their assets in the wake of a shock, while poorer households are apparently put on a downward trajectory of further asset depletion as they cope with a shock. While these households do not exhibit the asset protection strategies of the Ethiopian poor, they too appear to be quite distant from the world of full and complete markets. While there is weak evidence that poorer Honduran households can begin to rebuild their assets, absent buoyant factor markets for labor (and to a lesser extent capital), the rebuilding process is slow, and the net effect of shocks appears to be profoundly unequalizing, at least over a medium term.

The analysis here has of course fallen short of fully resolving all the puzzles and complexities of even the two disasters studied here. Further research may reveal other

important facets of wealth-differentiated asset recovery experiences by exploring the asset composition of varied wealth categories of households. For example, do the poor in Ethiopia hold most of the animal assets in small stock and chickens, while the better-off own more cattle and plow oxen? These types of assets differ in their "lumpiness", their functions in income and wealth generation, and in the extent to which they are protected in the face of shocks. Future studies should address the likelihood that different asset portfolios of the rich and poor may constrain or facilitate post-disaster recovery paths.

While future research to solve remaining puzzles is always desirable, given the importance of shocks, it seems worth speculating on the policy and development implications of our findings, especially since most disasters and their impacts are treated as humanitarian not development problems. An important first step would be to build social safety ('insurance') nets that keep vulnerable households from losing their assets and sinking further into poverty. For the chronically poor, a safety net of guaranteed food needs and, in some cases, minimal cash income, can allow them to divert efforts from survival-type (often destructive) coping strategies, to more remunerative activities that might build assets and 'pull' them out of poverty. Given that social networks and institutions play an important role in keeping households from falling into poverty, externally supported safety nets, as well as any form of development policy in general, need to be cognizant of the way in which such social networks operate so as to minimize any potential negative impact of programs on existing social institutions.

The estimated relevance of markets for households' ability to resort to livelihoods that do not lead to asset erosion suggests programs that go further than building safety nets. Policies that improve non-farm employment opportunities, rural market

infrastructure, and availability of credit—especially in the post-disaster period—are important ways that governments and development agencies can help limit long-term asset depletion. Our findings show that market conditions do make a difference in how shocks differentially affect certain communities and regions. Policies that make markets more accessible to the chronically poor and vulnerable will mitigate the kind of widespread human suffering now associated with natural disasters.

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