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Smoothing Income against Crop Flood Losses in Amazonia: Rain Forest or Rivers as a Safety Net?

Abstract

This article examines the role of *ex post* labor supply in smoothing income in response to crop losses caused by large floods among riverine households in the Peruvian Amazon, where rich environmental endowments permit a variety of resource extractive activities and coping responses. The paper finds that households respond to crop losses primarily by intensifying fishing effort not by relying on gathering of non-timber forest products, hunting, or asset liquidation. This *ex post* labor adjustment helps to smooth total income against small crop losses but less well against large crop losses. Both relatively non-poor households with better fishing capital and poor young households with a physical labor advantage employ this natural insurance in rivers.

1. Introduction

Critical economic and environmental outcomes in developing countries depend on the capacity of the rural poor to cope with episodic shocks. Under extreme conditions – as during major droughts in semi-arid areas of Asia and Africa – poor rural households may choose to smooth assets (e.g., maintain livestock holdings) rather than to smooth food consumption (Lybbert et al., 2004; McPeak, 2004; Zimmerman and Carter, 2003), seeking to avoid future chronic poverty that might accompany sale of livestock to pay for normal food consumption levels (Rosenzweig and Wolpin, 1993). Such stark risk coping responses as partial starvation result, in part, from the lack of options that poor households might use in other instances, such as *ex post* labor adjustments (Cameron and Worswick, 2003; Kochar, 1999; Rose, 2001), loans or gifts from family or friends (Fafchamps and Lund, 2003; Udry, 1994), or non-productive asset disposition (Udry, 1995). Whereas heterogeneity of risk coping strategies locally and globally reflect distinctive asset-activity portfolios (Dercon, 1998; Hoddinott, 2006), differential access to factor markets and social networks, and disparate family demographics, coping responses are also shaped by options afforded by surrounding environmental resources.

Relatively little is known as yet of how the rural poor living in tropical rain forests cope with major shocks though forest and non-forest products are increasingly recognized as ‘safety nets’ for the forest peoples (Angelsen and Wunder, 2003). Indeed, even though hurricanes, floods, and forest fires are significant episodic shocks in tropical rain forest, they are not as commonly studied for their effects on poor people as in other regions of the world. This dearth of studies could be related to the perception that rain forest residents are less subject to harsh seasonal variations, have better potential access to multiple resources (land, non-timber forest products, timber, and often aquatic resources), and/or open access to forests and other natural resources, all of which might allow *ex post* labor adjustments (and hence more mutual insurance from social networks, too) to play a larger role in risk coping. An incipient literature is emerging on the role of the rain forest as "natural insurance" in which recent studies explore how access to multiple forest resources substitutes for or complements other forms of risk management for negative and positive income shocks (Delacote, 2007; Fisher and Shively, 2005; McSweeney, 2004; Pattanayak and Sills, 2001). Several important questions though remain largely unanswered, specifically:

- What types of *ex post* labor adjustment strategies are pursued following episodic shocks? How are they combined with asset liquidation and other forms of risk coping?
- How do these strategies vary with wealth and other household factors?
- How effective are tropical forest households in coping with major shocks?
- What types of impacts might their risk coping strategies have on future economic and environmental outcomes in areas of high biodiversity?

This paper seeks to explore the first three questions and to reflect on the fourth by focusing on the role of forest and riverine resources in the risk coping strategies of Amazonian peasant households living on the edge of the Pacaya Samiria National Reserve in Peru. The paper exploits household data from a year when the region was hit by an early major flood that devastated agricultural floodplain crops. Particular attention in the paper is given to the role of *ex post* labor adjustments to a major covariate shock, to integrated analysis of other risk coping approaches (especially asset disposition), and to key endogeneity issues that arise when linking shock outcomes to crop losses and subsequent responses.

After a summary description in Section 2 of livelihood strategies of the respondent households, we focus in Section 3 on exploring how *ex post* transitory labor income contributes to the smoothing of total income, using the direct measure of crop losses caused by floods. Because land type is so closely tied with crop choice, we seek to control for the potential endogeneity of cropping strategies and shocks. Other endogeneity issues are considered and attended to via key control variables in the income regression. We find a level of compensation for negative income shocks offered by *ex post* non-farm income that is comparable with previous findings elsewhere, and specifically that total income is relatively smoothed against small crop losses but not against large crop losses. Distinct from rural households in more arid regions, poor households in this tropical rain forest environment do earn significant levels of permanent non-farm income – both before and after the shock – through participation in a variety of resource extractive activities, such as fishing and to a lesser extent gathering of non-timber forest products (NTFPs).

Section 4 explores sources of heterogeneity in households' coping strategies. The analysis of *ex post* labor supply of Section 3 is extended to incorporate dissavings behavior and to examine households' decisions to adopt these coping strategies independently and jointly, using separate and joint Probit estimations. Among our key findings – in contrast to previous studies – is that fishing rather than forest product gathering is employed as the main *ex post* coping strategy by two types of households – by households with greater fishing capital as well as by poor young households with a physical labor advantage. Natural insurance, however, proves to be insufficient to compensate for major crop losses; differences in the capacity of households to use this coping strategy is strongly shaped by their asset endowments and demographic characteristics. The conclusion discusses the implications for poverty alleviation and environmental conservation in tropical forests.

2. Livelihood Activities in Amazonian Lowland

This study is based on household survey data gathered from traditional mestizo peasants (known locally as *ribereños*) in four villages located on the Marañón River, one of the primary Andean tributaries of the Amazon River in Peru. All four villages are located in or around the Pacaya-Samiria National Reserve, one of the largest protected areas in the Amazon. The Reserve encompasses over two million hectares of wetland and is dominated by seasonally or permanently inundated forest (Bayley et al., 1991; Rodríguez et al., 1995). Each year the river rises and falls over a range of 8-10 metres, demarcating the seasons and shaping household livelihood activities. The loss of crops due to occasional early, high and long-duration floods represents one of the biggest production shocks among rural households in the region and downstream in Brazil. Our study focuses on a destructive flood that occurred in 1993.

Flood vulnerability varies across land types: upland is never flooded, high levee is flooded only by high floods in some years (e.g., 1993), low levee and backslope are flooded each year, and mudflats and sandbars appear only for a limited time during the low-water season.[1] Correspondingly, land types determine agricultural strategies and crop choices, especially given the very rudimentary technologies used by farmers in the region (no mechanized equipment or animal traction and very limited purchased inputs)

(Figure 1). In upland agroforestry, plantain and manioc (main food crops) are planted first, followed by tree crops; at any moment in the crop rotation the plot may be left in fallow. Lowland agroforestry sequences on the high and low levees depend on soil conditions determined by the annual flood; manioc (as well as maize to a lesser extent) is cropped annually, whereas plantain (a perennial) may be harvested over several seasons. On the levee backslope, farmers annually crop manioc (and maize and watermelon to a lesser extent), while on the mudflats and sandbars, they grow rice and cowpea, respectively, during the limited low-water period.

A typical household portfolio includes food crops on low levee and backslope – which are locally abundant – along with a combination of cash crops (especially rice) on fertile mudflats and/or food crops on secure upland and relatively secure high levee – both of which are locally scarce (sandbars which are also scarce are considered as a secondary land). Land clearing is a highly laborious task, undertaken only with machetes and axes, and is done by household and communal labor. Once cleared, land is held by usufruct (i.e., without title), privately used, and transferred principally along kin group lines (land markets are absent). As shown in Table 1, upland, high levee, low levee/backslope, mudflats, and sandbars constitute 25%, 30%, 20%, 21%, and 5% shares, respectively, of the mean land portfolio in our sample. Rice, plantain, and manioc are three major crops cultivated by households in our sample; they are produced by a one-half, two-thirds, and 84% of households and account for 42%, 23% and 13% of crop income, respectively. Our data do not allow us to distinguish between no participation and complete crop failure – it is possible that some apparent ‘non-producers’ factually experienced complete failure of one or more crops.

Local residents extract a variety of forest and aquatic products which are essentially open access resources near their community. Most households participate in subsistence fishing with rudimentary equipment (hook and line, small gillnets, spears, canoes, etc.), while more commercially-oriented fishers employ boats with engines and larger, more sophisticated fishing nets. All fishing capital is privately owned. As in other developing regions, shared labor arrangements are common with commercially-oriented fishermen. Households poor in fishing capital may work with owners of large nets, boats and/or engine in exchange for a share of the catch. Some households participate in NTFP gathering (e.g., palm fruit and heart of palm), hunting, and aquatic extraction (e.g., turtle, freshwater shrimp, aquarium fish), where labor is the only physical input required (hunting involves shotguns). Wage labor opportunities are scarce and quite seasonal, typically limited to floodplain rice harvesting. Overall, non-farm income from extractive activities is more significant than in many other developing rural areas; average household shares of income from agriculture, fishing, and other extractive activities are 52%, 32% and 16%, respectively (Table 1).[2]

3. Crop Losses and Income Smoothing

Survey respondents were asked to describe how they were affected by and responded to major floods in an open-ended question.[3] While floods are covariate shocks, household-level variations in land type, land quality, and hence crop choice make the resulting production shocks quite distinct across households. Careful interpretation of this qualitative information allows us to differentiate three levels of shocks household i experienced in the large flood year of 1993 – no crop loss, small crop loss, and large crop loss – captured by shock dummy variables, Z_{0i}, Z_{1i}, and Z_{2i}, respectively. In our sample, 18%, 60%, and 22% of households experienced no, small, and large crop losses, respectively (Table 1). As the magnitude of crop losses is also determined by the area of lowland that was flooded – all land types but upland denoted by L_i –, the shock dummy variables interacted with L_i serve as our measures for crop losses, $Z_i = (Z_{1i}*L_i, Z_{2i}*L_i)$ with no crop loss as a base case (Cameron and Worswick, 2003 use similar crop loss measures).

Even though flood shocks are exogenous, household-level crop losses caused by floods are usually not, as unobservable factors like *ex ante* crop choice, land quality, and farming skills, which determine crop losses, are potentially correlated with outcome variables – income and coping strategy – in our regression models. Lacking panel data and options for valid instruments, we control for these unobservable factors in the following manner. First, because major crop choice is tightly linked to the heterogeneity in land quality that occurs across land types, we use the size of each type of land owned (A_i) as a regressor to control for unobservable crop choice and land quality *across* land types. We use land owned rather than land operated to avoid additional potential endogeneity problems associated with fallowing decisions. Second, a dummy variable for high social status – leaders in kin groups or community groups (S_i) – is used as a proxy for unobservable skills as it captures the household's ability to mobilize communal labor for land clearing. Next, to control for unobservable land quality *within* each land type, an interaction term is added, i.e., of each of three scarce lands – upland, high levee, and mudflats – with the social status dummy (A_iS_i). Our implicit assumption is that socially well-positioned households are more likely to secure high quality land in each type. Minor crop choice variation *within* each land type is assumed to be mainly shaped by within-type land quality.

The analysis begins with an examination of how well our shock measure Z_i captures crop losses caused by floods. The following equation estimates the determinants of crop income y_i:

$$y_i = Z_i\alpha + A_i\beta_1 + S_i\beta_2 + A_iS_i\beta_3 + X_i\beta_4 + \varepsilon_i\,, \qquad (1)$$

where X_i represents other household characteristics than those in A_i, S_i, and A_iS_i that determine the level and variance of household permanent income. Specifically, X_i consists of a dummy variable for large fishing nets owned (a major productive asset for non-farm activities), age and squared age of the household head (which capture lifecycle effects) – almost all heads are male in our sample – and numbers of adults and children. The regressors also include village dummy variables that capture covariate shocks and all village characteristics that shape a household's permanent income.[4] It is hypothesized that crop income negatively responds to transitory idiosyncratic shocks Z_i. If the two crop loss variables adversely affect crop income in different magnitudes, then we expect that $|\alpha_1| < |\alpha_2|$, where α_j is the estimated coefficient of Z_jL.

Ordinary least-squares estimates (OLS) of (1) are presented in column (1) of Table 2. The coefficients on small and large shocks are negative and statistically significant; the latter is significantly larger than the former in magnitude (1.75 times). An additional hectare of lowland with small and large shocks, respectively, gives rise to a loss of 11% and 19% of predicted crop income with no shocks ($Z_1L = Z_2L = 0$) evaluated at mean values for the other explanatory variables. All estimated coefficients of land variables are positive, and those of high levee, low levee/backslope, and mudflats are statistically significant. Insignificant results for upland and sandbars are probably due to their limited holdings among our sample households (only one village is located on upland and sandbars are a minor land type). The marginal returns of upland and mudflats are positively affected by social status (neither of these interaction terms is statistically significant though). Within-land heterogeneity on upland and mudflats is economically important for the following reasons. Clearing upland forests is more demanding than lowland forests due to longer fallow and greater distances to clearing sites with larger fallow lands in upland agroforestry. The quality of mudflats varies significantly as soil conditions are determined by annual sediment deposition, and the acquisition of new mudflats involves coordination among villagers. In contrast, our results indicate that within-land heterogeneity is not significant on high levees.

The marginal returns of different land types are consistent with common views as discussed above. In particular, mudflats – especially high-quality mudflats held by those with a high social status – are the most fertile, followed by sandbars (another alluvium land), high levee, and low levee/backslope. Upland with considerable fallow lands – especially low-quality upland held by those without a high social status – is the least fertile. The dummy for large fishing nets has a positive and statistically significant impact on crop income. This reflects the fact that large fishing net holdings are positively correlated with holdings of boats and/or engines which are used to transport agricultural produce to local markets.

To further explore the performance of the shock measure, a similar estimation is done for each of the three major crops – rice, plantain, and manioc – as distinct cropping practices can beget differential vulnerability to large floods. Rice is cultivated on fertile mudflats which appear only for a limited time during the low-water season. Depending on the timing and speed of the rise in water-levels, rice plants can be seriously destroyed before the harvest even when the magnitude of flooding is not large (Chibnik, 1994). Although plantain (a perennial) tends to be cultivated on higher land than manioc in order to survive normal annual flooding, periodic high and long-duration floods can inundate the plant stem of the plantain over an extended period, causing massive destruction of the plants (Bergman, 1980). Manioc, a root crop, by contrast, is more resistant to flooding, and can also be harvested as flood waters rise or after they fall. Thus, 'unexpected' crop loss due to a severe flood is anticipated to be greater for rice and plantain than for manioc.

Because the dependent variable – income from each crop – is censored at zero, a Tobit model is employed. Two marginal effects of the adverse shocks holding all explanatory variables at mean levels are calculated: one based on the expected values of the dependent variable conditional on being uncensored, and the other based on the unconditional expected values of the dependent variable. As the former applies when no-production means non-participation and the latter applies when no-production means complete crop failure, the two measures serve as lower and upper bounds of true marginal effects in magnitude, respectively.

The conjecture about differential vulnerability of the three major crops is confirmed by the results presented in Table 2, columns (2)-(4). The overall fitness of the model for food crop – plantain and manioc, especially the latter – is weak. Yet, all of the estimated coefficients of small and large shocks are negative in each crop equation. Both small and large shocks significantly affect rice income (the marginal effects, respectively, are 11%-16% and 16%-22% of rice at means relative to no adverse shocks). Only large shocks negatively affect plantain and manioc income in a statistically significant manner (a loss of 18%-25% of plantain and 11%-15% of manioc at means relative to no adverse shocks). Together these three crops account for 63%-100% and 61%-86%, respectively, of total crop loss caused by small and large shocks. These findings suggest that our shock variables effectively identify crop losses caused by floods.

Following Rose (2001), our next step is to examine how these production shocks affect total household income. A standard dynamic labor supply model (see Cameron and Worswick, 2003) suggests that we can directly apply equation (1) to total income. The OLS results are shown in column (5) of Table 2. The estimated coefficients of small and large shocks are negative, but only the latter is statistically significant (the marginal effects are 4% and 11% of income at means relative to no adverse shocks, respectively). Their marginal effects are 57% and 85% of those in the crop income equation, respectively; that is, the overall effects of crop loss on total income are about 43% and 15% less than it would have been had households not earned non-farm income in response to small and large shocks. Therefore, income is better smoothed against the small shock than the large shock.

We also consider an alternative aggregate shock index (Z_{ai}) which is defined, by using the estimated marginal effects of the shock variables in the crop equation, as follows: $Z_{ai} = 0$ if $Z_{0i} = 1$ (no shock), $Z_{1i}L_i$ if $Z_{1i} = 1$ (small shock), and $1.75Z_{2i}L_i$ if $Z_{2i} = 1$ (large shock). The OLS estimates of the crop equation and the Tobit estimates of the rice, plantain, and manioc equations using this shock index variable are presented in columns (1)-(4) of Table 3, respectively. The estimated coefficients of the shock index variable are all negative and statistically significant. Other values for the weighting of the large shock (between 1 and 3) were tried and all results are very similar to what is presented here. As shown in the OLS estimates of the total income equation in column (5), non-farm income buffers 11% of income against crop losses measured by Z_{ai} on the margin. While these estimates are comparable to those found by Rose (2001, 10-36% depending on rainfall shock measures), the degree of income smoothing attained after small shocks is higher than she found in rural India. This difference is sensible given that in our sample non-farm income accounts for 48% of total income whereas the comparable figure in Rose (2001, p386) is only 12-16%.

4. Coping Strategies

Qualitative information on the coping strategies of respondents following the 1993 flood provides a direct measure of *ex post* labor *adjustment*. Such information is different from *ex post* labor *participation*. For example, even though most households fish for subsistence throughout the year, only certain households reported fishing as a coping strategy; this means that these households reported coping with the flood shock by increasing their labor allocation to fishing. About half of the respondents adopted *ex post* labor adjustments, among which fishing and NTFP gathering were two common and non-exclusive activities with adoption rates of 35% and 19%, respectively (Table 1).

Although hunting and aquatic extraction are rewarding and critical extractive activities for some respondent households, virtually none reported using them as coping strategies. This is probably explained by their specific skill requirements and yield risk, while fishing and NTFP gathering are more accessible to the broader population and less risky because of the abundant fish stocks in the region and the non-mobility of NTFPs.

Distinct from other developing areas, very limited labor markets make wage labor a relatively uncommon coping strategy, with an adoption rate of only 8%. In Table 1 *ex post* non-fishing labor adjustment combines NTFP gathering, wage labor, and hunting, which are almost mutually exclusive responses with a cumulative adoption rate of 28%.

About a quarter of respondents reported disposing of assets in response to flood shocks, principally small livestock (e.g., chickens) (13% adoption rate), food stock (especially manioc flour) (9%), and cash savings (4%), which were disposed of almost mutually exclusively. No households reported disposing of large livestock such as cattle, buffalo and pigs or productive assets such as land and fishing capital. These findings are consistent with those of many extant studies in other developing regions (e.g., Fafchamps et al., 1998; Udry, 1995). Due to the relatively low propensity to dissave in each of the three forms of assets, we focus on aggregate dissaving behavior.[5]

Standard dynamic labor supply and savings model suggests that we can use the same determinants as in equation (1) to estimate two separate regressions, one related to household *i*'s adoption of *ex post* labor and the other to its dissaving response (P_i):

$$P_i^* = Z_i\gamma + A_i\delta_1 + S_i\delta_2 + A_iS_i\delta_3 + X_i\delta_4 + \nu_i \,, \qquad (2)$$

where P^*_i is the continuous latent variable associated with the outcome that household *i* increases *ex post* labor supply or dissavings ($P_i = 1$). The coefficient γ is the product of the effect of adverse transitory shocks on transitory income (examined in the preceding section) and the effect of transitory income on *ex post* labor supply or dissavings. If labor supply or dissavings is augmented in response to adverse shocks, then the coefficient estimate γ for that response should be positive. δ_j is the product of the effect of all other explanatory variables on permanent income and the effect of permanent income on *ex post* labor supply or dissavings.

The Probit estimates of the adoption of overall *ex post* labor adjustments, including the marginal effect of the adverse shock index Z_{ai} holding all explanatory variables at mean levels, are presented in column (1) of Table 4.[6] The estimated coefficient of the adverse shock is positive and statistically significant; its marginal effect is 12%. Thus, an increase of one standard deviation in the adverse shock index (4.4) augments the probability of adjusting *ex post* labor supply by over 50%. Households in our sample substantially augmented labor supply in response to crop losses.

To examine how distinctive non-farming activities respond to crop losses, we estimate *ex post* fishing, non-fishing, and gathering labor adjustments (wage labor is too uncommon to conduct this analysis), and the results are shown, respectively, in columns (2)-(4) of Table 4. In the fishing equation, the estimated coefficient of the crop loss variable is positive and statistically significant, and its marginal effect is 6%. In the non-fishing equation, the estimated coefficient of the crop loss is also positive but statistically insignificant with a small marginal effect (3%). The estimation results of the gathering equation are similar to those of the non-fishing equation with an almost zero marginal effect of the adverse shock index. Thus, while *ex post* gathering labor does not respond to crop losses, *ex post* fishing labor does in a significant manner. As shown in column (5), dissavings behavior does not respond to crop losses, either.

Why was gathering labor (a major component of non-fishing labor) unresponsive to crop losses even though gathering was a common coping strategy reported by respondents? Our interpretation is that gathering is generally intensified during the high water season – in both normal and unusually large flood years – because remote palm stands become more accessible by canoe and hence collection is more productive. Thus, some households may have augmented gathering in response to the flooding itself but not specifically to crop losses. This hypothesis, however, cannot be tested with our data with limited variations in the magnitude of floods. Contrarily, during the high-water season, fishing becomes less productive due to the dispersal of the fish stock in the floodplain forest.[7] Our finding that the fishing response to crop losses is common even under unfavorable conditions raises a question that is to be explored shortly: who could intensify *ex post* fishing? The disposition of small livestock and food stock is also a common practice during the high-water season, and for that reason dissavings may not have responded specifically to crop losses.

In the *ex post* fishing equation, the estimated coefficients of some of other explanatory variables are statistically significant in sensible ways. The negative coefficients of all land variables and the social status dummy indicates the substitution between the two major livelihood activities, farming and fishing. Large fishing net holdings have a positive impact as expected. The effect of the age of household head takes an inverted-U shape and its marginal effect peaks at around 38 years of age (which is notably smaller than the mean, 46 years). Fishing is preferred by young families with physical capacity for the labor involved. On the other hand, we find very limited significant results on other explanatory variables in the non-fishing, gathering, and dissavings equations.

To examine who intensified fishing in response to crop losses, we allow the marginal effects of the adverse shock to vary across households:

$$P_i^* = Z_i\gamma + Z_i B_i \gamma_1 + A_i\delta_1 + S_i\delta_2 + A_i S_i \delta_3 + X_i\delta_4 + \nu_i\,, \qquad (3)$$

where B_i is factors which alter households' response to adverse shocks in the form of labor supply or dissavings. Based on our findings in the previous regressions, we include the fishing net dummy and the age of household head in B_i (the squared age of household head is dropped here as no significant non-linear relationship is found when it is added).

The Probit estimates of equation (3) for the five coping strategies examined in Table 4 are presented in Table 5. Most results are very similar to what is reported in Table 4, and the adverse shock index is jointly statistically significant only in the fishing equation. A new key finding though is that households with large fishing nets and young households are more likely to adopt fishing in response to crop losses. The marginal effects of the adverse shock index are estimated for young, middle, and old households with and without large fishing nets, where their ages are mean age minus one standard deviation, mean age, and mean age plus one standard deviation (33, 46, and 59 years), respectively. The most critical factor that significantly alters the responsiveness of *ex post* fishing is fishing net holdings. With large fishing nets, the marginal effects are in the range of 27% for households with age at means. As such, an increase of one standard deviation in the adverse shock index augments the probability of the adoption of *ex post* fishing by almost 120%. For young households, the marginal effects become even larger. Meanwhile, the marginal effects among those without large fishing nets are small and statistically insignificant except for young households (12%). Hence, both relatively non-poor households with better fishing capital and poor young households with a physical advantage intensified fishing as a coping strategy, but poor older households did not. No significant results are found for non-fishing, gathering, and dissavings responses.

So far, we have implicitly assumed that coping strategies are independent of each other. To see whether relaxing this assumption alters our findings, we jointly estimate the adoption of three coping strategies using the trivariate Probit model. Two sets of three coping strategies are examined: fishing, non-fishing, and dissavings in the first set, and fishing, NTFP gathering, and dissavings in the second set. The estimation results of equations (2) and (3) for the first and second sets are presented in columns (1)-(4) in Table 6, respectively. The independence of the three coping equations is not rejected in any of these four models.[8] Indeed, all the estimated coefficients are very similar to what we found when we treat coping strategies as independent, which buttresses the robustness of our earlier findings.

5. Conclusion

Our main findings are that riverine households in the Peruvian Amazon respond to crop losses due to floods primarily by intensifying fishing effort and this *ex post* labor adjustment helps smooth total income against small crop losses but does not fully smooth income against large crop losses. Both relatively non-poor households with better fishing capital and poor young households with a physical advantage in doing hard labor are more likely to employ this form of natural insurance.

The significant role of natural insurance found in this study underscores the importance of environmental conservation as a means to protect the poor against risk. Yet, different extractive activities can play quite distinctive roles as insurance. In the Pacaya Samiria National Reserve, fishing is a major form of insurance against crop losses even though other extractive options, such as NTFP gathering, are also significant livelihood activities. Unlike many other locales in the tropical rain forests, the primary environmental concerns in the Reserve are not deforestation and pasture formation, but species degradation and biodiversity loss caused by local resource extraction, especially hunting, aquatic extraction, and NTFP gathering. Our findings suggest that the river, not the forest, matters most as the poor's safety net in the Reserve, and that the natural insurance role of fishing does not significantly conflict with the major forest and wildlife conservation concerns. However, households' capacity to use the river's resources as insurance depends on their endowments (fishing capital) and characteristics (age). By subsidising fishing capital accumulation, for example, conservation groups could reduce both the vulnerability of poor households to adverse shocks and future reliance on fragile forest resources; clearly though attention to fishery management would be needed (see Bayley and Petrere, 1989).

In tropical forests where aquatic options are nil or limited, households must rely more on terrestrial resources to cope with risk, which may exacerbate the downward spiral of poverty and environmental degradation, and their *ex post* behaviors may be quite heterogeneous. In such a case, supporting alternative insurance options like savings and sustainable labor activities (e.g., wage labor out of forest or contingent employment opportunities) designed to reflect across-households heterogeneity may be called for to prevent vicious cycles of poverty and degradation. Detailed empirical work is needed to investigate further the distinct roles and impacts of natural insurance of resource-reliant people in environmentally heterogeneous locales.

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Notes

[1] In Amazonia, 'lowland' refers generally to lands that are susceptible to flooding whereas 'upland' refers to *terra firme* (i.e., land that is never flooded). Lowland soils along the Amazon and its Andean tributaries tend to be younger and significantly more fertile than upland soils. Despite the development promise of the lowlands (Barrow, 1985; Norgaard, 1981), economic research on lowland agriculture is surprisingly scant.

[2] The number of observations of income variables (n = 77) is smaller than that of other variables (n = 95) due to missing observations. All income analyses are performed on the former sub-sample, and other analyses not requiring income data are conducted with the whole sample to increase the accuracy of estimation.

[3] In the case of rainfall shocks, the focus of many extant works in the literature, it is difficult to distinguish *ex ante* and *ex post* behaviors because low rainfall regimes are often experienced as cumulative effects. Contrarily, we focus on floods, which occur in a specific identifiable period, allowing respondents and observers to identify *ex post* responses as well as shock magnitude.

[4] One village is located on upland in our sample. While most households earned only *ex ante* crop income, some households in this upland village that could farm the plots which were not flooded earned *ex post* crop income after the shock. Most of the *ex post* crop income can be considered as permanent income as all they could do is to harvest what was available on their plots.

[5] No households reported using credit or remittances, and the use of transfer as mutual insurance was very rare. It seems that natural resource extraction options in the region

allow households to rely less on those insurance options than are common in other rural areas. The low frequency of mutual insurance in response to flood shocks is also consistent with the widely held notion that mutual insurance under covariate shocks is much less feasible than under idiosyncratic shocks. Indeed, mutual insurance was a common coping strategy in response to idiosyncratic health shocks among households in our sample.

[6] The small and large shock variables cannot be used to estimate equation (2) because all households who experienced no shocks ($Z_{0i} = 1$) neither adjusted *ex post* labor supply nor employed dissaving (i.e., perfect prediction of $P_i = 0$).

[7] The infrequency of hunting as a coping strategy even though its productivity is improved during the high-water season, when wildlife is concentrated on the reduced non-inundated lands and the access to hunting sites is improved, suggests the significantly high risk entailed in hunting.

[8] These insignificant results are mainly due to the limited degrees of freedom of our trivariate Probit model, which also makes its overall significance weak. It is still noted that the estimated correlations of error terms between fishing and NTFP gathering in both equations (2) and (3) and those between fishing and dissavings in equation (3), which are positive and negative, respectively, have considerable magnitudes, while all other estimated correlations are very small. Hence, unobservable factors like skills which affect *ex post* fishing is positively and negatively correlated with those which shape NTFP gathering and dissavings, respectively. In particular, households with high fishing skills are more and less likely to intensify NTFP gathering and dissave, respectively.

Table 1. Descriptive Statistics.

	Whole sample (n = 95)	With complete income data (n = 77)
Land holdings (ha):		
Upland	1.1 (1.9)	1.1 (1.7)
High levee	1.3 (2.1)	1.5 (2.3)
Low levee/backslope	0.9 (1.6)	0.9 (1.7)
Mudflat	0.9 (1.6)	1.1 (1.7)
Sandbar	0.2 (0.7)	0.2 (0.8)
Total lowland (L_i)	3.3 (3.4)	3.7 (3.6)
All land	4.4 (4.2)	4.8 (4.2)
Participation (0/1):		
Crop		0.92 (0.27)
Rice		0.49 (0.50)
Plantain		0.66 (0.48)
Manioc		0.84 (0.37)
Fishing		0.99 (0.11)
Other extraction		0.48 (0.50)
Income (Sole):		
Crop		2602 (2722)
Rice		1081 (1550)
Plantain		586 (958)
Manioc		328 (305)
Fishing		1585 (2254)
Other extraction		797 (1658)
Total		4984 (4006)
Household characteristics:		
Social status (0/1)	0.34 (0.48)	0.34 (0.48)
Large fishing nets owned (0/1)	0.31 (0.46)	0.29 (0.45)
Age of household head	46.1 (13.2)	45.3 (13.4)
Number of adults	3.5 (1.9)	3.5 (1.9)
Number of children	3.2 (2.1)	3.4 (2.1)
Adverse idiosyncratic shocks:		
No shocks (0/1) (Z_{0i})	0.18 (0.39)	0.19 (0.40)
Small shocks (0/1) (Z_{1i})	0.60 (0.49)	0.60 (0.49)
Large shocks (0/1) (Z_{2i})	0.22 (0.42)	0.21 (0.41)
Small shocks*Lowland ($Z_{1i}L_i$)	2.0 (3.3)	2.3 (3.6)
Large shocks*Lowland ($Z_{2i}L_i$)	0.8 (2.1)	0.8 (2.3)
Adverse shock index (Z_{ai})	3.4 (4.4)	3.7 (4.8)
Overall *ex post* labor adjustment (0/1)	0.52 (0.50)	0.49 (0.50)
Fishing	0.35 (0.48)	0.31 (0.47)
Non-fishing	0.28 (0.45)	0.26 (0.44)
NTFP gathering	0.18 (0.39)	0.14 (0.35)
Wage labor	0.08 (0.28)	0.09 (0.29)
Hunting	0.03 (0.18)	0.04 (0.19)
Overall dissaving (0/1)	0.24 (0.43)	0.25 (0.43)
Livestock	0.13 (0.33)	0.14 (0.35)
Food stock	0.09 (0.29)	0.08 (0.27)
Cash	0.04 (0.20)	0.04 (0.19)

Notes: These are sample means with standard deviations in parentheses.

Table 2. The Determinants of Income - Small and Large Shocks.

(n=77)	Total crop (1)	Rice (2)	Plantain (3)	Manioc (4)	Total income (5)
Small shocks	-420 *	-392 ***	-136	-32	-240
	(232)	(144)	(94)	(27)	(292)
Large shocks	-730 ***	-562 ***	-319 ***	-69 **	-620 **
	(242)	(161)	(113)	(32)	(310)
Upland (ha)	14	-247	98	3.9	41
	(185)	(186)	(116)	(31)	(274)
High levee (ha)	582 **	435 **	129	74 *	450
	(278)	(203)	(141)	(38)	(374)
Low levee/backslope (ha)	449 *	163	265 **	51	348
	(249)	(183)	(126)	(35)	(316)
Mudflat (ha)	664 **	764 ***	286 **	-1.2	602
	(289)	(207)	(136)	(39)	(361)
Sandbar (ha)	622	-128	36	162 *	755
	(483)	(481)	(351)	(95)	(793)
Social status (0/1)	-140	-715	-64	107	1000
	(725)	(776)	(455)	(126)	(1600)
Upland*Social status	290	318	37	-0.2	-78
	(466)	(458)	(284)	(81)	(772)
High levee*Social status	-98	279	62	-67	-220
	(214)	(239)	(172)	(47)	(378)
Mudflat*Social status	295	239	102	14	-450
	(273)	(251)	(180)	(51)	(473)
Large fishing nets owned (0/1)	1600 **	146	525	28	1900 *
	(638)	(580)	(364)	(99)	(997)
Age of household head (years)	-30	-0.8	-19	1.1	-59
	(106)	(132)	(89)	(24)	(189)
Squared age of household head (years^2)	0.35	-0.06	0.29	0.05	0.69
	(1.2)	(1.4)	(1.0)	(0.3)	(1.9)
Number of adults	18	87	-43	25	25
	(154)	(124)	(90)	(25)	(207)
Number of children	141	158	74	29	388 *
	(132)	(143)	(98)	(28)	(217)
Sigma		1385 ***	1059 ***	308 ***	
		(168)	(110)	(28)	
F (p-value)	0.00				0.00
Chi-squared (p-value)		0.00	0.16	0.48	
R squared	0.60				0.33
Log-likelihood		-341.9	-445.0	-475.5	
$\alpha_1 = \alpha_2 = 0$ (p-value)	0.00	0.00	0.02	0.02	0.09
$\alpha_1 = \alpha_2$ (p-value)	0.01	0.14	0.02	0.02	0.08
Marginal effects at means:					
Small shock (conditional means)		-186 ***	-58	-20	
		(66)	(40)	(17)	
Small shock (unconditional means)		-265 ***	-82	-26	
		(94)	(57)	(22)	
Large shock (conditional means)		-266 ***	-135 ***	-43 **	
		(75)	(48)	(20)	
Large shock (unconditional means)		-380 ***	-193 ***	-58 **	
		(106)	(69)	(27)	
Predicted income at means with no shocks	3826	1691	769	431	5739
	(715)	(415)	(284)	(81)	(850)

Notes: Columns (1) and (5) are OLS estimates with robust standard errors in parentheses and columns (2)-(4) are tobit estimates with standard errors in parentheses. Other regressors which are not shown are village dummies and constant. Sigma is the estimated standard deviation of the error term in the tobit model. α_1 and α_2 are the estimated coefficients of small and large shocks, respectively.

*: significant at 10%, **: significant at 5%, ***: significant at 1%.

Table 3. The Determinants of Income - Shock Index.

(n=77)	Total crop (1)	Rice (2)	Plantain (3)	Manioc (4)	Total income (5)
Adverse shock index (Z_{ai})	-420 ***	-314 ***	-185 ***	-40 **	-370 **
	(129)	(91)	(64)	(18)	(175)
F (p-value)	0.00				0.00
Chi-squared (p-value)		0.00	0.13	0.43	
R squared	0.60				0.33
Log-likelihood		-342.2	-445.3	-475.6	
Marginal effects of adverse shock at means:					
Conditional means		-150 ***	-79 ***	-25 **	
		(43)	(27)	(11)	
Unconditional means		-213 ***	-112 ***	-34 **	
		(61)	(39)	(15)	
Predicted income at means with no shocks	3826	1532	874	420	6026
	(544)	(353)	(241)	(69)	(734)

Notes: Columns (1) and (5) are OLS estimates with robust standard errors in parentheses and columns (2)-(4) are tobit estimates with standard errors in parentheses. Other regressors which are not shown are the same as those in Table 2.

*: significant at 10%, **: significant at 5%, ***: significant at 1%.

Table 4. The Determinants of the Adoption of *Ex Post* Labor Supply and Dissavings - No Interactions with Shock.

	Overall labor	Fishing	Non-fishing	NTFP gathering	Dissavings
(n=95)	(1)	(2)	(3)	(4)	(5)
Adverse shock index (Z_{ai})	0.30 **	0.23 *	0.12	0.05	-0.05
	(0.14)	(0.12)	(0.10)	(0.14)	(0.08)
Upland (ha)	0.08	-0.28	0.22	0.12	0.01
	(0.12)	(0.17)	(0.15)	(0.29)	(0.15)
High levee (ha)	-0.37	-0.30	-0.13	0.09	0.05
	(0.23)	(0.21)	(0.21)	(0.35)	(0.17)
Low levee/backslope (ha)	-0.34	-0.41 *	-0.14	0.04	0.21
	(0.23)	(0.22)	(0.20)	(0.24)	(0.17)
Mudflat (ha)	-0.44 *	-0.42	-0.21	-0.74	0.36 **
	(0.25)	(0.26)	(0.24)	(0.53)	(0.18)
Sandbar (ha)	-0.15	-0.94	0.29	0.35	-0.16
	(0.57)	(0.58)	(0.49)	(0.73)	(0.42)
Social status (0/1)	-0.83	-0.71	-0.52	-0.89	0.69
	(0.60)	(0.52)	(0.58)	(0.67)	(0.48)
Upland*Social status	-0.24	0.11	0.09	0.73 *	0.32
	(0.32)	(0.31)	(0.29)	(0.39)	(0.27)
High levee*Social status	0.45	0.36	0.03	-0.18	-0.03
	(0.39)	(0.25)	(0.23)	(0.31)	(0.24)
Mudflat*Social status	0.57	-0.01	0.15	0.65	-0.27
	(0.44)	(0.31)	(0.25)	(0.50)	(0.21)
Large fishing nets owned (0/1)	0.83 *	0.84 *	-0.12	0.36	-0.12
	(0.49)	(0.46)	(0.49)	(0.59)	(0.44)
Age of household head (years)	0.26 *	0.25 *	0.20	0.21	0.03
	(0.14)	(0.13)	(0.15)	(0.15)	(0.11)
Squared age of household head (years^2)	-0.004 **	-0.003 **	-0.003	-0.003	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Number of adults	-0.06	-0.06	-0.01	0.07	-0.02
	(0.14)	(0.14)	(0.13)	(0.15)	(0.12)
Number of children	0.04	0.02	-0.03	-0.11	0.10
	(0.12)	(0.12)	(0.11)	(0.13)	(0.11)
Chi-squared (p-value)	0.00	0.00	0.00	0.01	0.24
Pseud R squared	0.47	0.35	0.36	0.38	0.21
Log-likelihood	-35.1	-40.1	-36.4	-27.7	-41.7
Marginal effects of adverse shock at means	0.30 **	0.23 *	0.12	0.05	-0.05
	(0.14)	(0.12)	(0.10)	(0.14)	(0.08)

Notes: These are probit estimates with standard errors in parentheses. Other regressors which are not shown are village dummies and constant.

*: significant at 10%, **: significant at 5%, ***: significant at 1%.

Table 5. The Determinants of the Adoption of *Ex Post* Labor Supply and Dissavings - Interactions with Shock.

(n=95)	Overall labor (1)	Fishing (2)	Non-fishing (3)	NTFP gathering (4)	Dissavings (5)
Adverse shock index (Z_{ai})	0.46	1.20 **	-0.16	0.33	-0.31
	(0.41)	(0.53)	(0.36)	(0.48)	(0.32)
Z_{ai}*Large fishing nets owned (0/1)	0.18	0.41 *	-0.16	-0.01	0.27 **
	(0.17)	(0.22)	(0.15)	(0.17)	(0.13)
Z_{ai}*Age of household head (years)	-0.004	-0.020 *	0.006	-0.006	0.004
	(0.008)	(0.011)	(0.007)	(0.009)	(0.006)
Chi-squared (p-value)	0.00	0.00	0.00	0.02	0.11
Pseud R squared	0.48	0.41	0.37	0.38	0.27
Log-likelihood	-34.5	-36.0	-35.7	-27.5	-38.6
Joint significance test for adverse shock (p-value):	0.17	0.06	0.43	0.91	0.16
Marginal effects of adverse shock:					
Means	0.13 **	0.09 **	0.02	0.01	-0.01
	(0.06)	(0.04)	(0.03)	(0.01)	(0.02)
No large fishing nets; Young	0.12 *	0.12 **	0.02	0.03	-0.05
	(0.07)	(0.05)	(0.06)	(0.04)	(0.04)
No large fishing nets; Middle	0.10 **	0.03 *	0.03	0.00	-0.03
	(0.05)	(0.02)	(0.03)	(0.01)	(0.02)
No large fishing nets; Old	0.04	0.00	0.02	0.00	-0.01
	(0.03)	(0.01)	(0.01)	(0.00)	(0.02)
Large fishing nets; Young	0.06 *	0.32 ***	-0.05	0.04	0.03
	(0.03)	(0.12)	(0.09)	(0.08)	(0.05)
Large fishing nets; Middle	0.14 **	0.27 **	-0.01	0.01	0.04
	(0.07)	(0.11)	(0.04)	(0.03)	(0.04)
Large fishing nets; Old	0.16 **	0.16 *	0.00	0.00	0.05
	(0.08)	(0.09)	(0.01)	(0.01)	(0.03)

Notes: These are probit estimates with standard errors in parentheses. Other regressors which are not shown are the same as those in Table 4. The ages of young, middle, and old households, respectively, mean age minus one standard deviation, mean age, and mean age plus one standard deviation (33, 46, and 59 years). All other variables which are not specified are held at mean levels in the estimation of marginal effects.
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

Table 6. The Determinants of the Adoption of *Ex Post* Labor Supply and Dissavings - Trivariate Probit Model.

	Fishing, non-fishing, dissavings		Fishing, NTFP gathering, dissavings	
	No interactions with shock	Interactions with shock	No interactions with shock	Interactions with shock
(n=95)	(1)	(2)	(3)	(4)
Equation 1 - Fishing:				
Adverse shock index (Z_{ai})	0.22 *	1.25 **	0.23 *	1.18 **
	(0.12)	(0.54)	(0.12)	(0.49)
Z_{ai}*Large fishing nets owned		0.45 **		0.40 *
		(0.23)		(0.20)
Z_{ai}*Age of household head		-0.02 *		-0.02 **
		(0.01)		(0.01)
Equation 2 - Non-fishing/NTFP gathering:				
Adverse shock index (Z_{ai})	0.12	-0.17	0.05	0.40
	(0.10)	(0.37)	(0.14)	(0.50)
Z_{ai}*Large fishing nets owned		-0.17		-0.01
		(0.16)		(0.17)
Z_{ai}*Age of household head		0.01		-0.01
		(0.01)		(0.01)
Equation 3 - Dissavings:				
Adverse shock index (Z_{ai})	-0.05	-0.24	-0.05	-0.24
	(0.08)	(0.31)	(0.08)	(0.31)
Z_{ai}*Large fishing nets owned		0.28 **		0.28 **
		(0.13)		(0.13)
Z_{ai}*Age of household head		0.00		0.00
		(0.01)		(0.01)
Correlations of error terms (ρ_{kl}):				
ρ_{12}	0.09	0.15	0.49 *	0.41
	(0.23)	(0.24)	(0.26)	(0.26)
ρ_{23}	-0.12	0.05	-0.10	-0.03
	(0.22)	(0.25)	(0.24)	(0.26)
ρ_{31}	-0.14	-0.40	-0.11	-0.37
	(0.22)	(0.24)	(0.23)	(0.25)
$\rho_{12}=\rho_{23}=\rho_{31}=0$ (p-value)	0.84	0.44	0.27	0.21
Chi-squared (p-value)	0.16	0.28	0.38	0.55
Log-likelihood	-117.7	-109.0	-107.5	-99.9
Joint significance test for adverse shock (p-value):				
Equation 1		0.05		0.05
Equation 2		0.42		0.87
Equation 3		0.15		0.15

Notes: These are trivaraite probit estimates with standard errors in parentheses. Other regressors which are not shown are the same as those in Table 4. ρ_{kl} is the estimated correlation of error terms in equations *k* and *l*.

*: significant at 10%, **: significant at 5%, ***: significant at 1%.

Figure 1. Land Types and Crop Choice.