DO TROPICAL FORESTS PROVIDE NATURAL INSURANCE?

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I. Introduction

The small farm households who live on forest frontiers throughout the tropics face myriad risks from weather, illness, crop pests and diseases, and prices. The literature on such households indicates that, given incomplete markets for credit and insurance, their primary strategy for mitigating risk is diversification, including varied cropping strategies to smooth their income and diverse means to maintain family consumption levels. The tropical forests themselves are highly diverse and the source of a wide range of products and services, some of which are considered famine foods or backstop resources in case of crises. These characteristics of tropical forests have been cast in a negative light: forest diversity means that any one economic species is widely scattered and collection costs are high, while use of the forest only as last resort may indicate that its products are inferior goods. We explore a different interpretation of tropical forests as natural insurance for local people. Our approach hinges on the fact that these forests are highly diverse, offering a wide range of products, some of which will be available to households when other income and subsistence sources fail.

The diversity and longevity of forest resources leads us to hypothesize that forest collection has lower mean output but also lower variance than agricultural production. We focus on the case of primarily agricultural households with access to publicly owned forests. In order to utilize the forest to mitigate negative shocks to agricultural production, households must have invested time in learning about the spatial and temporal distribution of forest products. The forest, measured by various qualitative and quantitative characteristics, is an essential input in this risk-reducing human capital formation. The labor time spent in the forest is weakly complementary to the forest itself in this process and is thus an indicator of the forest’s value as natural insurance. Our conceptual approach to households’ economic relation with forests draws on models from the averting behavior theory of environmental economics and the portfolio diversification theory of development economics. We plan to estimate the model with household survey data from the Tapajós National Forest in the Brazilian Amazon. In the analysis, we seek first to identify evidence that forests serve as insurance by mitigating risk, then to identify systematic differences in the importance of forests as insurance across income classes or other categories of households, and finally, as a long term objective, to estimate the value of the forests as insurance to local households.

After reviewing relevant literature on small holder risk management and on risk in rural economies of the Brazilian Amazon, we present a general theoretical framework based on household production and expected utility theory. We proceed to describe our case study area and present the empirical model. Finally, we present results and briefly summarize our study.

II. Literature Review

Risk has long been an issue of concern in development economics because of indications that such risk may slow adoption of technology and strategies of specialization which foster

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1 We follow convention in using the term risk to refer to general ambiguity about the future, including risk and uncertainty, both of which economic agents must evaluate to develop their own subjective beliefs about risk.
economic development, and may increase inequity, perpetuating poverty of some even as regional economic development occurs (Carter 1995). Many believe that the methods small holders use for managing risk “entail efficiency costs and adverse-equity impacts” (Walker and Jodha, 1986, p.31). Another strand of the literature has evaluated government policies to mitigate agricultural risk through crop insurance and improved access to credit; the common finding is that such policies have not improved efficiency or equity.

The literature is divided over how best to measure risk. One approach is to query households directly, eliciting their subjective evaluation of risk; studies of risk aversion have often relied on this approach. Other studies have sought objective measures, most notably from precipitation records (e.g., Carter 1997). A third measure is “effective risk,” which accounts for households’ ability to mitigate risk through income or consumption smoothing, in addition the root causes of the risk (e.g., Morduch 1995).

Households can respond to risk either before a shock (risk prevention, income smoothing) or after (loss management, consumption smoothing). The purchase of insurance, for example, could be a means to smooth income, pursued before the occurrence of a shock. The most commonly cited income smoothing strategy is diversification of the portfolio of economic activities by cultivating different fields, growing a variety of crops, varying fallow times and crop sequences, and possibly by investing in forest as well as agricultural land. Diversification may occur across environments that receive different shocks (changing distribution of shocks) or across activities which respond differently to shocks (changing magnitude of shocks). According to portfolio diversification theory, households trade-off the variability and mean profitability of the different activities. The degree to which households are willing to invest in assets or activities with lower variance and lower mean profit depends on their subjective risk evaluation (a function of objective risk and risk aversion) and their consumption smoothing opportunities. The mechanisms available for consumption smoothing depend on whether a shock is covariant (with neighbors) or idiosyncratic. Idiosyncratic shocks are thought to be largely insurable with reciprocal arrangements, whereas covariant shocks require vertical reciprocity or more likely, self insurance, such as liquidation of assets, pursuit of off-farm income, or remittances from off-farm family members. The idea that households employ accumulated assets to smooth consumption has also been linked to the permanent income hypothesis (Udry, 1994).

Risk is commonly found to have differential impacts across households. Households of different income classes or family life cycle stages (related to dependency ratio) may exhibit different attitudes and responses to risk because of different levels of risk aversion, different exposures to risk, or different abilities to consumption smooth. A typical approach is to regress a measure of the extent of a risky production activity on household characteristics and on the sample variance of the risky activity; assuming there are no consumption smoothing opportunities, the coefficient is a measure of attitudes toward risk (Morduch 1993). In fact, consumption smoothing opportunities do often vary across households.

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2 Dillon and Scandizzo (1978) found that most farmers in their study in northeastern Brazil are risk averse; the requested risk premium was higher if they had an ethical belief against gambling, were older, and had larger households. When the scenarios placed subsistence at risk, income and requested risk premium were inversely related. Binswanger and Sillers (1983), on the other hand, also found that most farmers are slightly risk averse, but could identify no relation with wealth in several studies across several developing countries.
Other studies therefore have regressed measures of plot/crop diversification or allocation of wealth to risky assets on measures of consumption smoothing possibilities, such as total wealth or assets (e.g., Morduch 1993; Rosenzweig and Binswanger, 1993).

Small farmers in the Amazon face risk from weather, seasonal flooding patterns, unpredictable and variable soil quality, pests and crop diseases, illnesses, transportation, changing game and fish populations, uncertainty over public policies and land tenure, and prices. The literature on the Amazon often cites this risky environment as a cause of farm failures, conservative farming strategies, and diversification. For example, Scatena et al. (1996) and Walker and Homma (1996) assume that the diversity of crop and fallow sequences that they observe on colonist farms is a response to risk. Although these authors note that collection of forest products and agroforestry are also options for diversification, they do not find them in common use by colonists. In contrast, communities of Native Americans and of third or fourth generation immigrants do utilize a wide array of products from the forest. This “extractivist” population of the Brazilian Amazon has been estimated at 800,000.

Most of these traditional communities were established by people who originally came to the Amazon to exploit specific forest products, such as rubber and Brazil nuts. While many such commercialized species have suffered a decline in market value (e.g., rubber) or have been economically exhausted (e.g., rosewood oil), people continue to market and consume a wide variety of forest products. They may enrich the forest by planting economic species, transplant species from the forest to household gardens, and establish plantations of useful trees in areas to which they have established their own private use rights, but nevertheless they continue to collect some products from the publicly owned, native forest. Grimes et al. (1993) emphasize the non-timber commercial potential of the Amazonian forest, noting that the multiplicity of forest products in season at different times mean that they contribute to overall income stability, even though markets for individual products are highly variable. Arnold (1995:16), on the other hand, draws attention to the “role of forest-based activities, as a source of income that people can fall back on in times of crop failure or shortfall, or in order to cope with some other form of emergency.”

III. Theoretical Framework

Provision of natural insurance by tropical forests can be studied in a framework of expected utility maximization and household production. We assume that households are primarily engaged in agriculture (a), with forest collection (f) as a secondary, but potentially risk-mitigating, activity. Agricultural production is affected by various risks, and hence has a range of possible outcomes in any given year. We simplify this distribution to a two moment distribution represented by the mean (µa) and standard deviation (σa). Agricultural production is a function of household labor in agricultural, l_a, acquired expertise with agricultural production or the household endowment of agricultural human capital, HK_a, and weather variability, σw (Equation [1]).
Likewise, forest collection is summarized by a two-moment distribution (\( \mu_f \) and \( \sigma_f \)), and forest collection is a function of household labor in forest collection (\( l_f \)) and acquired expertise with forest collection or the household endowment of human capital of forest collection, \( HK_f \). Forest collection is also influenced by bio-physical quality of the forests, \( BIO \) and weather variability, \( \sigma_w \) (Equation [2]).

Equation [3] summarizes the key difference in the two economic activities: forest collection is the low return-low risk activity (\( \mu_f - \sigma_f \)) and agriculture is the high return-high risk activity (\( \mu_a - \sigma_a \)).

The relatively low variance of forest collection is due to the diversity of forest products, and is associated with the entire range of forest products, not any individual forest product. As described in the literature review, agricultural households will therefore engage in forest collection to diversify their portfolio and smooth their income. Moreover, collection of forest products requires less up-front investment than agriculture (clearing, planting, and weeding), and households can choose to collect more from the forest after the realization of a shock. In this regard, forests may also be thought of as offering consumption smoothing possibilities, and hence reducing the adversity of ‘bad’ outcomes.\(^3\) Since purchase of insurance is an example of \textit{ex ante} income smoothing activities, in this study we focus on the opportunities to smooth income through forest collection activities. However, since consumption smoothing can modify households’ effective risk exposure and thereby influence household insurance investment decisions, we work with the notion of effective risk. Equation [4] presents our description of effective risk, where risk is described in terms of standard deviation of household income. The parameter \( k \) measures the impact of risk on consumption and is a function of consumption smoothing opportunities (CSO). In our simple model, household income is the sum of income from agricultural production and forest product collection.

\[ \sigma^e_\pi = k (CSO) \sigma_\pi \]

\(^3\) See Morduch (1995) for further discussion of the distinction between \textit{ex ante} income smoothing and \textit{ex post} consumption smoothing behavior, and examples of both.
When opportunities exist to completely smooth away production risks (k = 0), e.g. perfect futures markets exist, effective risk is zero.

Given the absence of credit or insurance markets, household utility is a function of the expected current year economic production, and idiosyncratic household characteristics, such as stage in life-cycle (HH), that affect risk aversion. We adopt the empirically tractable mean-variance utility form, in which utility depends primarily on those two moments of the distribution of economic production (Equation [5]).

\[ U = V (\mu, \sigma, HH) \]

Rosenzweig and Binswanger (1993) discuss the conditions under which this more restrictive form of utility is an adequate approximation of agricultural household preferences in risky environments. Since household utility is maximized by low risk (\( \sigma \)) and high return (\( \mu \)) activities, and forest collection and agricultural production are low return-low risk and high return-high risk activities respectively, households will engage in a combination of the two. In the language of portfolio diversification theory, the typical household trades higher returns for lower risk and holds a portfolio comprised of a combination of lower and higher risk activities such that expected utility is maximized (Equation [6]).

\[ V_{\mu}m_{HK_j} = V_\sigma n_{HK_j} \sigma_w \cdot k \]

where \( m_{HK_j} = m_{HK_a} - m_{HK_f} \)

and \( n_{HK_j} = n_{HK_a} - n_{HK_f} \)

Given convex preferences, and uncorrelated agricultural and forest collection yields, Figure [1] describes a situation in which the combination of forest product collection and agricultural production (\( \theta \)) results in a higher level of utility than corner solutions associated with exclusive agricultural production or forest product collection.

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\[ ^4 \text{A second possible form of household utility gives paramount importance to the possibility of disaster: households want to ensure their survival and thus focus on the minimum possible return (or the minimum return that occurs above some threshold of probability). Because the households in our study area are clearly above minimum thresholds, this option is not further considered in this study (see Pattanayak and Sills (1997) for further details).} \]
Households’ use of the forest as insurance is directly related to the utility maximizing resource allocation represented in Equation [6]. These allocations depend on returns and risk of economic production in agriculture and in forest collection which in turn depend on households’ endowment of human capital associated with each of these activities. Because of the limited opportunities to hold conventional capital assets in subsistence economies, accumulation of human capital is the one of the few *ex ante* investment choices made by households. Our representation of insurance is, thus, one interpretation of why households invest in human capital for forest collection. In fact, we develop a particular application of the household production framework, in which the $z$ good is the knowledge and experience (human capital) necessary to utilize the forest. By adding this human capital in forests to their economic portfolio, households which have access to the forest can mitigate risk. There is an opportunity cost to the time invested in building human capital, and that cost, interpreted as an insurance premium, provides a clue as to the value of forests as natural insurance. Households accumulate knowledge and skills, or human capital, about forests and agriculture by spending time in those activities, conditional on the quality of the resources. Thus, human capital in forest collection is a $Z$ good, which provides insurance, or a lowering of risk, to households.

This $Z$ good is not actually observed, but its production requires observable inputs. To produce the $Z$ good, the household must use the forest, a public good, and private goods such as its own labor time and tools (Figure [2]). Household use of the forest is a joint production activity, resulting in the $z$ good (preparedness to use the forest) and actual collection of forest products. We are only concerned with the forests’ contribution to utility by way of the $Z$ good. We assume that at least one of the private goods (e.g., labor) is
essential for producing the Z good. The private good required to utilize the forest could be defined as trips to forest, distance to forest, ownership of forest, or time spent in forest.

**Fig 2**

![Diagram of Household Production of Human Capital for Forest Collection](image)

We model human capital as a function of time spent in an activity. Households also spend time in the forest or in agriculture in order to collect or grow products. We combine the effort in production and in human capital accumulation, because all learning is assumed to occur “on the job,” either in forest collection or in agriculture. As discussed earlier, the joint inputs, \( HK_a \) and \( HK_f \), are essential for production and affect the mean and variance of economic production. We expect to find that while the average contribution of HK in forest collection towards average profits is lower than for HK in agriculture, its contribution to the variance is also lower (Equation [3]). The first order conditions from utility maximization show that households balance the time spent in forests and in agriculture in order to achieve the best feasible distribution of economic production, taking into account the relative contribution of \( HK_f \) and \( HK_a \) to risk as well as to the average level of economic production (Equation [6]). Associated with these utility maximizing choices, is a derived demand function for human capital in forest collection \( HK_f \). Equation [7] describes the reduced form version of \( HK_f \) as a function of weather variability, household specific characteristics, consumption smoothing opportunities, forest quality and all other exogenous factors.

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If the household does not have any of the private good (if its cost is too high), then the marginal utility of forest is zero. This description fulfills Bockstael and McConnell’s (1983) conditions for recovering the value of a public environmental good that serves as an input in household production.
Equation 7

\[ HK_f = h(\sigma_w, CSO, BIO, HH) \]

Household production of HK\(_f\) is unlikely to be observed. Instead, we observe the private inputs, and primarily the labor input, l\(_f\), in forest collection (Figure [3]).

This labor input is essential for production of HK\(_f\), which occurs simultaneously with collection of forest products. The reduced form labor demand function will be a function of the same set of exogenous variables (Equation [8]) as determine HK\(_f\). Empirical estimation of the labor input demand function provides an adequate first approximation of household investment in insurance in the face of risk and uncertainty. This input demand function will eventually allow us to estimate the value of the forest as an input into human capital and consequently insurance.

Equation 8

\[ l_f = l(\sigma_w, CSO, BIO, HH) \]
IV. The Study Area

The Tapajós National Forest is a 600,000 hectare multiple use forest in the middle Amazon, owned and managed by the Brazilian federal environmental agency. Along the National Forest border on the Tapajós River, there are 18 traditional communities, which were in place before the declaration of the National Forest, and who have continued their agricultural and forest collection activities, despite sporadic opposition from the environmental agency. The total population is about 3000 people, with average family size of 5 people. A participatory census in 1993 found that the main economic activities were shifting agriculture (principally manioc), house gardens, small livestock, forest collection, hunting, and fishing. Although the ancestors of the current residents came to the region to collect forest products such as rubber and Brazil nuts for commercial sale and studies have found that the forest is rich in economic species (Oliveira, 1993), the current population sells only limited amounts of forest products. They have fought hard to maintain access to the forest, however, and insist that it is important to their livelihood and the future of their communities. Their use of the forest is in direct contrast to the more recent colonists on the road that borders the National Forest on the other side; although the colonists have equal access to the forest, studies have found that they do not use it extensively (Walker and Homma, 1996; Scatena, et al., 1996).

In March of 1997, a random stratified sample of 325 households was surveyed, and additional in-depth, open-ended interviews were conducted. The survey confirmed the 1993 results about the relative importance of different income sources. Most (80%) of the households listed agriculture as one of their primary sources of income, and 93% of households reported planting some crops in the survey year. Manioc was planted in 95% of plots. The communities are quite isolated, with 75% of households reporting that they travel to the nearest market only once a month or less frequently. Transportation is by irregular boat service, and there is no public communication (postal or phone). Most communities have small stores, but in general are subsistence oriented. Households said that the main sources of risk (for agricultural production) include variable soil quality (unpredictable when choosing a plot to clear), variation in precipitation patterns, and leaf cutter ants. Variability in weather can affect production through several mechanisms. Farmers can save time and ensure greater productivity if they burn their field immediately before the first rains; in an unusual weather year, they are more likely to guess incorrectly. Second, while the crops are growing, the amount of precipitation and the temperature affect the outcome. They indicated that production of many individual forest products, such as specific fruits, was also variable, but was not correlated with agricultural production or even with other forest products. In years of poor agricultural production, most households said that they depend primarily on assistance from friends, family, and the community. They may turn to the forest for food or medicine, when they have not produced or cannot purchase it; alternatively, they may collect forest products such as honey and Brazil nuts to sell in market. Across all of the communities, households said that they did not have access to insurance or credit, and specifically did not have access to government subsidized credit because they do not officially own their land and hence cannot use it as collateral. The

6 We have not been able to obtain the original data from this 1993 survey, but do have community level summary statistics.
study area is statistically summarized in Table [1].

V. Implementation of Framework: The Empirical Model

Implementation and testing of the theoretical framework require evidence on the impact of forests on the effective risk faced by households (adversity or variation) and on households’ valuation of that risk. This implies looking at risk-money tradeoffs that households make. Both forests’ impact on risk and valuation of risk can be deduced from their behavior, reflected in the labor inputs into forest collection and agriculture. Empirical implementation of the model requires estimation of Equation [8].

We take a particular set of assumptions and approach to calculating the insurance value of forests in the empirical case, some of which is supported by the empirical evidence presented in the previous section and some of which is axiomatic. Our theoretical approach applies to households that are primarily agricultural and that face agricultural risk due mainly to covariant weather risk. We assume that households can also collect products from the forest if they invest the time in learning the spatial and temporal distribution of those products; this effective access to the forest can potentially mitigate the adversity of a poor agricultural outcome. Thus, our model applies to long term residents of the Amazon, as opposed to indigenous groups or recent colonists. We assume that households maximize expected utility and that mean-variance preferences approximate their utility functions. We further assume the absence of formal credit and insurance markets. To implement the model, we assume that households’ report of the distribution of agricultural yields are a reasonable measure of the relative risk faced by the households. We focus on yield, rather than price variation, because variability in yield is likely to be the greatest risk in subsistence-oriented economies. The assumptions of the household production framework, with human capital in forests as the Z good, forests as the essential input, and labor time in the forest as the weakly complementary private good, all hold. We develop a model of households with individual agricultural production subject to weather risk and access to public forest lands. Use of the forest is considered as a diversification and risk mitigation strategy.

Table [2] lists three potential empirical models for econometric implementation of the theory discussed in the previous sections. In each case, the dependent variable is a measure of input into human capital for forest product collection. The key independent variables are the measures of agricultural yield risk over the past ten years and perception of agricultural production in the survey year relative to other years. As discussed previously, household and bio-physical characteristics are included as controls in these models, which attempt to econometrically establish patterns of household use of the forest as natural insurance. The rest of this section discusses, with examples, the four categories of variables employed in the empirical model.

Since we do not have time series data, we assume that the reported average time in forest collection over recent weeks is actually a good proxy for the average time over recent years, because respondents are likely to have recalled historical averages at least as easily as current levels. Because human capital in this environment depends on experience rather than
formal education, we have chosen this proxy.\textsuperscript{7} The fraction of household time spent in the forest, or a measure of labor diversification accounting for time in various activities, will be our dependent variable in the estimated equation. Number of forest product collection trips in survey year, or the average over the last ten years are other candidates for labor input in forest collection.

Variation of total profits will be our measure of risk, because no objective physical measures are available.\textsuperscript{8} Moreover, we do not have information on consumption; hence we assume that changes in profit cause equivalent changes in utility resulting from changes in risk; i.e., the willingness to pay for the change in utility resulting from the change in profit is just that change in profit.\textsuperscript{9} Since manioc is the mainstay of agriculture in this region, we use the coefficient of variation of total manioc production as a reasonable approximation of risky profits. The unit-less index of spread is used instead of the spread itself in order to account for riskiness relative to mean manioc productivity.

Although we must combine time in production and in human capital accumulation since all learning is assumed to occur “on the job,” we hope to tease out household \textit{ex ante} behavior in the face of anticipated risks by controlling for consumption smoothing responses. By separately including household perceptions of relative agricultural productivity in the survey year (measured on a Likert scale of good - normal - bad), which should be related to households’ use of forest collection to smooth consumption, we have a starting point for empirically separating income and consumption smoothing behavior. Therefore, the coefficient on the risk variable captures household production of human capital in forest collection (\textit{ex ante} income smoothing), separate from the time spent in the forest to actually collect products, which is conditioned by their perception of agricultural productivity in that particular year (\textit{ex post} consumption smoothing). We use subjective measures of risk, based on responses to questions about perceived effects of risk, because those data were most feasible to collect. We expect that the sign on the coefficient of the risk variable will be negative.

Biophysical factors serve as proxy for the forest quality which conditions human capital accumulation and are assumed to be exogenous. Forest quality proxies include a community level index of forest diversity (the number of forest products collected), a biological index (from surveys of the Tapajos forests), and distances to forest. Our \textit{a priori} expectations are that better forest quality raises the return on forest collection relative to variation and, therefore, induces greater forest collection and human capital accumulation. Distances to nearest township and to the river are proxies for prices, \textit{i.e.} they are likely to capture most of the differences due to different input and output prices. Prices are

\textsuperscript{7} Rosenzweig and Binswanger find support for “hypothesis that in environment subject to risk but characterized by stationarity in weather and slow technical change, experience - but not formal schooling - has real payoffs.”

\textsuperscript{8} Observed variation in agricultural profitability (which we take as our measure of risk) may be endogenous (effect and cause of) diversification, because households which spend more time in other activities will have less human capital in agriculture, and hence may have less predictable returns; we cannot avoid this problem because do not have physical measures of environmental risk.

\textsuperscript{9} See Pattanayak (1997) for a theoretical discussion of the conditions under which incremental profits are adequate measures of welfare changes for agricultural households in tropical countries.
important exogenous variables in the labor allocations of the agricultural households. Theses proxies, along with community level labor and forest product prices, are therefore included as exogenous variables.

The value of forest as natural insurance also depends on the availability of credit and other consumption-smoothing options. Proxies for consumption smoothing opportunities include asset holdings (particularly livestock), number of households members living off-farm and sending remittances, availability of transport to markets, and off-farm labor opportunities. We expect the negative signs for coefficients of these variables. Household characteristics are likely sources of heterogeneity in responses to anticipated risks, and the value of forests may differ among classes of households, if they have different risk exposure and different valuation of risk, i.e. different levels of risk aversion. Relevant household characteristics include family life cycle stage (proxied as age of household head), education (number of years), origin (long term resident or migrant), and number of years in the community and in the Amazon.

VI. Estimation Results

This section summarizes the results of two estimated models from the options listed in Table [2]. ‘Number of forest collection trips’ and ‘Percent time spent in forest collection and hunting’ are the dependent variables in Models [1] and [2] presented in Tables [3] and [4] and are discussed in the same sequence.

Since ‘number of forest collection trips’ is an integer, a negative binomial distribution is used to estimate the equation in Model [1]. The statistical significance of the overdispersion parameter reveals that this general form count model is preferred to the more popular poisson model. For comparison’s sake ordinary least square (OLS) results are also presented in Table [3]. The statistically significant positive coefficient on the risk parameter, suggests that household’s facing greater risks are more likely to take forest collection trips, ceteris paribus. This result lends support to our central hypothesis that forests, and the diversity of products they contain, serve as natural insurance for agricultural households living in a risky and uncertain environment.

The overall model is also supported by statistically significant coefficients on other variables that have theoretically appropriate signs. Households having other income sources and living in the more affluent central sections of villages take fewer forest collection trips. Having greater consumption smoothing opportunities than households with fewer income alternatives and households living at village margins, these households have less interest in using the forest as insurance, and, therefore, in accumulating human capital for forest collection. The sign of count of possesions coefficient does not have an intuitively obvious explanation. The signs on the age and age squared variables indicate that while young and old households take fewer trips, middle aged households, who perhaps have the appropriate

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10 Dillon and Scandizzo (1978) found the poor tobe more risk averse, whereas Binswanger and Sillers (1983) found this to be not generally true.

11 The interviewer dummy identifies households in the affluent central section of villages because this interviewer surveyed very few households at the village margin.
combination of experience and youth, take more trips.

Estimated coefficients of Model [2], using ‘percent of time spent in forest product collection activities’ as the dependent variable, are presented in Table [4]. A Tobit model is used to estimate this equation because some households reported not spending any time in forest product collection (a substantial number of zeros). For comparison’s sake ordinary least square (OLS) results are also presented in Table [4]. In general, both models have a poor statistical performance. The risk coefficient is not statistically significant, as is the case for many of the explanatory variables used. The negative coefficient on the ‘inexpensive house’ dummy and the positive coefficient on the ‘interviewer’ dummy (corresponding to the affluent section of the village) both offer evidence that wealthy households with greater consumption smoothing opportunities are less inclined to rely on forest product collection as means of natural insurance.

VII. Discussion

Despite their preliminary nature, the estimated equations provide support for the hypothesis that tropical forest diversity is an important source of natural insurance for agricultural households living at the forest margins. The positive and statistically significant coefficient on the risk variable shows that households are aware of this natural insurance property of their forested environment, and ‘buy’ insurance by investing time in learning about the forest products through collection trips. In contrast to this finding for income smoothing opportunities, the results offer no evidence for the argument that forests offer consumption smoothing opportunities, i.e. households who believe that agricultural production in a given year is poor spend no more time in the forest than households who believe that agricultural production is good. This may be because the survey year was not ‘bad enough’ in terms of agricultural production to force households to use their forest collection insurance.

Both of the empirical models will undergo considerable modification. In particular, we hope to identify better measured variables that more adequately represent the empirical situation. In addition, we will explore alternative specifications from the modeling options listed in Table [2]. The literature suggests that the importance of risk mitigation may depend on households’ asset position and stage in family life cycle. In order to identify the differential importance of the forest as risk mitigation to these categories of households, future plans also include interacting the risk variable with dummy variables for these categories. Another objective of future analysis is to quantify the welfare change due to the availability of forests as natural insurance. One possibility may be to calculate areas under derived demand curves for labor time in forest, with some measure of forest availability or quality as the demand shifter. This measure could be risk itself, since the presence of forests presumably affects the coefficient of variation of household income, our measure of risk.\footnote{A simpler, but not necessarily alternative, measure is to calculate the opportunity cost of re-allocating labor from agricultural to forest collection activities with lower mean yield per unit of labor. This is the amount that households are willing to pay in order to reduce their risk exposure.}

This paper represents perhaps the first attempt to construct and estimate a model of the natural insurance provided by tropical forest biodiversity to people living on the forest
margins. It draws on microeconomic theory to inform development and conservation policy. We believe that this is an important topic because natural insurance from tropical forests can play a role in preventing malnutrition and rural-urban migration, in allowing experimentation with new techniques (Walker and Homma, 1996), and in mitigating inequity by providing an opportunity for self insurance accessible to all income classes. Evidence of this nature supports protected areas which preserve the forest but allow sustainable local use. Although government forest preservation is a type of public risk reduction, it is only effective if individuals engage in complementary private risk reduction by investing time in learning about the diversity of forest products and their seasonal and spatial availability. This paper has attempted to characterize conditions under which private investment in natural insurance is likely. Ultimately the results of this study can help reconcile two apparently contradictory objectives: conservation of rapidly disappearing tropical rain forests, and local economic development.

VIII. Bibliography


Table 1. **HOUSEHOLDS IN THE TAPAJÓS NATIONAL FOREST**

| Survey | • 320 out of 500 households  
|        | • 6 interviewers  
|        | • 3 weeks  
| Demographics | • 5 people per household  
|        | • 95% from the Amazon  
|        | • 80% have some education  
|        | • average = 3 years  
| Agriculture | • 80% listed as primary source of income  
|        | • 35% of household time  
|        | • 93% have fields  
|        | • average = 2 hectares  
|        | • corn (48%)  
|        | • rice (33%)  
|        | • beans (32%)  
| Manioc | • 75% harvested  
|        | • 56% sold in Santarém or community  
|        | • Yield (sacks / ha)  
|        | • min 36  
|        | • mode 60  
|        | • max 80  
| Variation | • Causes  
|        | • soils (36%)  
|        | • precipitation (24%)  
|        | • Response  
|        | • salary (16%)  
|        | • friends-family (22%)  
|        | • Last year  
|        | • bad (19%)  
|        | • good (48%)  
| NTFPs | • 84% collected products (average = 5)  
|        | • 27% sold products (average = 2)  
|        | • 7% of household time  
|        | • Collecting trips  
|        | • 9 last year  
|        | • 175 minutes  
|        | • Examples  
|        | • vines  
|        | • honey  
|        | • sucuba sap  
|        | • fruits  
| Other Income | • Fishing  
|        | • Rubber  
|        | • Retirement  
|        | • Remittances  
|        | • Employment: 33% worked ($5/day)  
| Wealth | • Household goods, e.g. 64% own radio  
|        | • Production inputs, e.g. 57% own gun  
|        | • House construction, e.g. 52% thatch  
|        | • Livestock, e.g. 88% own poultry (16 birds)  
| Expenditures | $1400/ year  

Table 2. Potential Empirical Models

<table>
<thead>
<tr>
<th>Labor in Forest ($L_f$)</th>
<th>Risk ($\sigma$)</th>
<th>Forest Quality ($F$)</th>
<th>Exogenous Prices ($P$)</th>
<th>Consumption Smoothing ($H_{cs}$)</th>
<th>Other Household Attributes ($H_o$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in Forest</td>
<td>Coeff. Variation Manioc</td>
<td>Forest Diversity</td>
<td>Labor</td>
<td>Assets/Wealth</td>
<td>Life Cycle</td>
</tr>
<tr>
<td>Trips Last Year</td>
<td>Agricultural Production Last Year</td>
<td>Physical Measure at Community Level</td>
<td>Transportation</td>
<td>Remittances</td>
<td>Experience</td>
</tr>
<tr>
<td>Average Trips</td>
<td>Distance to Forest</td>
<td>Outputs</td>
<td>Position in Community</td>
<td>Other activities</td>
<td>Health</td>
</tr>
<tr>
<td></td>
<td>Time to Collect</td>
<td></td>
<td></td>
<td>Outside Connections</td>
<td>Community</td>
</tr>
<tr>
<td>Model I: Number of Trips to Collect from Forest Last Year</td>
<td>OLS</td>
<td>Negative Binomial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-----</td>
<td>-------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manioc Production Coeff. of Variation (past 10 yrs)</td>
<td>8.61</td>
<td>1.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last year’s agricultural production (bad to good)</td>
<td>-0.28</td>
<td>-0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest Diversity Index</td>
<td>16.39</td>
<td>2.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes to High Forest</td>
<td>0.002</td>
<td>-0.0001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to Collect</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distant Communities (dummy)</td>
<td>-2.27</td>
<td>-0.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Communities (dummy)</td>
<td>3.60</td>
<td>0.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Income (dummy)</td>
<td>-3.85</td>
<td>-0.42</td>
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<td></td>
</tr>
<tr>
<td>Count of Possessions</td>
<td>0.34</td>
<td>0.76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interviewer (dummy)</td>
<td>-4.75</td>
<td>-0.76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (Average of Household Heads)</td>
<td>1.08</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age squared</td>
<td>-0.01</td>
<td>-0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α (overdispersion)</td>
<td>0.73</td>
<td>0.00</td>
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<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-21.19</td>
<td>-1.65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean Number of Trips: 8
N: 140
Adjusted R^2: 0.08
LR Statistic: 305
## Table 4. Model II: Percent Time Spent in Forest (Collecting and Hunting)

<table>
<thead>
<tr>
<th></th>
<th>OLS Coeff</th>
<th>P. Value</th>
<th>TOBIT Coeff</th>
<th>P. Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manioc Production Coeff. of Variation (past 10 yrs)</td>
<td>0.002</td>
<td>0.98</td>
<td>0.002</td>
<td>0.97</td>
</tr>
<tr>
<td>Last year’s agricultural production (bad to good)</td>
<td>-0.01</td>
<td>0.13</td>
<td>-0.02</td>
<td>0.18</td>
</tr>
<tr>
<td>Forest Diversity Index</td>
<td>-0.02</td>
<td>0.90</td>
<td>0.05</td>
<td>0.77</td>
</tr>
<tr>
<td>Minutes to High Forest</td>
<td>-0.00001</td>
<td>0.91</td>
<td>0.00002</td>
<td>0.88</td>
</tr>
<tr>
<td>Distant Communities (dummy)</td>
<td>0.02</td>
<td>0.27</td>
<td>0.04</td>
<td>0.13</td>
</tr>
<tr>
<td>Near Communities (dummy)</td>
<td>0.03</td>
<td>0.10</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>Inexpensive House</td>
<td>0.04</td>
<td>0.01</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Remittances</td>
<td>-0.004</td>
<td>0.81</td>
<td>-0.007</td>
<td>0.71</td>
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<tr>
<td>Other Income (dummy)</td>
<td>0.02</td>
<td>0.20</td>
<td>0.03</td>
<td>0.14</td>
</tr>
<tr>
<td>Interviewer (dummy)</td>
<td>-0.04</td>
<td>0.05</td>
<td>-0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Count of Possessions</td>
<td>0.003</td>
<td>0.28</td>
<td>0.003</td>
<td>0.33</td>
</tr>
<tr>
<td>Count of Older Children</td>
<td>-0.006</td>
<td>0.18</td>
<td>-0.009</td>
<td>0.13</td>
</tr>
<tr>
<td>$\sigma$ (variance)</td>
<td></td>
<td></td>
<td>0.11</td>
<td>0.00</td>
</tr>
<tr>
<td>Constant</td>
<td>0.05</td>
<td>0.19</td>
<td>0.01</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Mean Percent Time Spent: 0.08

N: 205

Adjusted $R^2$: 0.05

Log Likelihood: 76.91