Rural Households, Natural Resources and Poverty: Three Essays on the Economics of Extraction in the Lacandona Rainforest, México

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This thesis is dedicated to my wife.
Chiconita, this would have not been possible without you.

It is also dedicated to our families for their support, encouragement and patience.

Abstract

There is renewed international attention to the links between rural poverty and the use of natural resources. This dissertation analyses these links combining the tools of environmental and development economics. The three essays examine, theoretically and empirically, key aspects of non-timber forest products (NTFPs) extraction using an original data set collected in México.

Essay I explores whether income from natural resource extraction affects poverty and inequality in México and in the community that serves as case study (Frontera Corozal). Then, with information from this community, the short-run poverty effects of changes in the price of a specific NTFP (the *xate* palm) are evaluated. Results show that increases in the price of *xate* fronds are associated with a decrease in the number of poor individuals.

Essay II analyses the decision of how much labor to allocate to NTFP extraction. The approach followed is to include the opportunity cost of time as an explanatory variable in an econometric model of labor allocation to *xate* extraction. The results show, among other things, that the opportunity cost of time is negatively related to participation in NTFP extraction. Policies that increase off-forest employment, and thus the opportunity cost of time, are likely to result in a decrease in labor allocated to xate extraction.

Essay III presents a theoretical model that analyzes allocation of labor to NTFP extraction over space, with a view towards obtaining a deeper understanding of the role of extraction in poverty alleviation. The spatial dimension is included in the analysis to highlight the challenge that extraction across space implies in terms of managing the resource. Results show that under unmanaged common property an increase in the price of the natural resource, say due to a ‘green product’ price premium, does not necessarily help alleviate poverty. On the other hand, in the presence of local labor constraints, price increases can raise extraction income above the opportunity cost of time and help alleviate poverty even under local open access.

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Introduction

I.1. Background and Motivation

Tropical forests are home to more plant and animal species than any other terrestrial ecosystem; the genetic material found in them is irreplaceable (UNEP, 1995). Nevertheless, these forests are under threat in developing countries. It is estimated that the deforestation of tropical forests will be the single greatest cause of species extinction in the next half-century (WRI, 2004). In developing countries forests and severe rural poverty tend to share an overlapping space (Sunderlin et al., 2005). The potential importance of natural resources for the livelihood of rural households has long been recognized as these forests provide a wide array of goods for these households to use directly or to obtain cash income (Cavendish, 1999; Sunderlin et al., 2003).

At the end of the last century, development-oriented organizations became more concerned about the environment. Meanwhile, conservation organizations realized that in order to achieve their objectives they needed to look beyond plants and animals and incorporate the claims of rural poor communities into their agendas (Ruiz-Perez and Byron, 1999). As a result, both types of organizations began to work with communities to achieve conservation while increasing the income of their populations (Barham et al., 1999). Around the same period of time, extraction of non-timber forest products (NTFPs) as a way to conserve tropical forests gained the attention of these organizations.

The attention given to the commercial extraction of NTFPs as a conservation strategy comes from two implicit assumptions: a) Harvesting of NTFPs is less destructive, in terms of biodiversity, than timber harvesting, and, b) Increasing the returns from NTFPs for locals provides incentives to conserve forests. If, in addition, those who extract the resource are poor, then it is argued that an increase in the value of NTFPs could alleviate poverty while promoting conservation (Neumann and Hirsch, 2000; Belcher et al., 2005). This market-based conservation and development approach assumes that the link between the income of local populations and conservation is positive and that there will be no unintended negative consequences (e.g., an increase in income leading the poor to buy more cattle and thus increase deforestation for pastureland).

During the 1980's some argued that sustainable exploitation of this 'subsidy from nature' was the most profitable and immediate way of promoting conservation and that governments and NGOs were not paying enough attention to the NTFP alternative (Hecht et al., 1988; Peters et al., 1989). Early studies suggested that NTFP values were similar to timber values from the same forests, but less optimistic assessments giving lower net present value estimates followed (Belcher et al., 2005).

Browder (1990 and 1992) responded to these claims by questioning the financial viability of extractive reserves as well as their limited capacity to protect large forest areas.[1] There is a growing body of literature questioning the potential of NTFP commercialization to achieve the objectives of poverty alleviation and conservation (Belcher et al., 2005). Wunder (2001), for example, stated that there might only be a few synergies between development and forest conservation that lead to a win-win situation. He argues that, from a conservation point of view, it might be more effective to concentrate on the establishment and expansion of protected areas and conservation

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[1] Roughly speaking, extractive reserves are forested areas from which inhabitants that have usufruct rights but not the right to sell or deforest the land, extract forest resources collectively managed.

contracts than on sustainable development. Lybbert et al. (2002) tested whether the creation of new markets for a particular NTFP, argan oil in Morocco, had resulted in gains for locals, and specifically whether it helped to reduce poverty. Their results show that most of the gains have gone to those able to overcome capital and infrastructural constraints, mainly non-locals; the benefits to locals have gone to middle-wealth households and not to the poor.

Currently there is renewed international attention to the links between rural poverty and natural resource use.[2] At the same time national and local governments are paying more attention to the role that NTFPs play in rural household livelihoods (Belcher et al., 2005). The three papers in this dissertation address the links between NTFP extraction and poverty; conservation outcomes are left aside as a topic of future research.

I.2. Data and Setting

This dissertation is composed of three essays that examine key aspects of NTFP extraction theoretically and empirically, using an original data set collected in Frontera Corozal, México, in 2001 and 2004.[3] Frontera Corozal is a village in the *Selva Lacandona* (Lacandona Rainforest) in the Mexican state of Chiapas. The Lacandona Rainforest is a tropical forest characterized by its importance in terms of biodiversity (it

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[2] The two special issues ("Institutional Arrangements for Rural Poverty Reduction and Resource Conservation", and "Livelihoods, Forests and Conservation") published in 2005 by the journal World Development illustrate this. The recent series of international meetings on natural resources and poverty, including "The Role of Forestry on Poverty Alleviation", Italy, 2001; "Forests in Poverty Reduction Strategies", Finland, 2002; "International Conference on Rural Livelihoods, Forests and Biodiversity", Germany, 2003; and, "Economics of Poverty, Environment and Natural Resource Use", The Netherlands, 2006, is another indication of this renewed interest.

[3] The information collected refers to the periods September 2000-August 2001 and September 2003-August 2004. For ease of exposition we will refer to the first twelve-month period as 2001 and the second as 2004.

encompasses the Montes Azules UNESCO Biosphere Reserve) as well as by its archeological and cultural richness (SEMARNAP, 1996). It sits right at the center of the Mesoamerican Biological Corridor, arguably one of the most ambitious conservation and sustainable development projects in Mesoamerica (Conabio, 2003).

In 2001 a household survey was applied to 100 randomly selected households (approximately 10% of the village population). I visited these households again in the summer of 2004. During the second round of the survey 13 households were lost from the sample, six due to migration and seven because they refused to be re-interviewed. Table I.1 shows that, according to the information collected in 2001, these households are not statistically different from those that remained in the sample in terms of some of the main observable household variables. The exception is the age of the household head; on average the households that migrated from Frontera Corozal had younger household heads. Landholdings of the households that remained in the sample are on average larger; the difference is just statistically significant at the 10% level.

The natural resource on which the dissertation is focused is the *xate* palm (*Chamaedorea* spp.), a marketable NTFP that grows under the cover of the forests. *Xate* palm leaves are used by the floral industry as a backdrop for flowers in wedding and funeral displays. They are also in demand during Easter season, particularly on Palm Sunday.

Xate extraction is an important income generating activity for rural communities located in or around forests in México and Guatemala (CEC, 2002; Endress et al., 2004; Sánchez-Carrillo and Valtierra-Pacheco, 2003). *Xate* leaves extracted from these communities have been sold in national markets or exported to Canada, Europe and the

U.S.A. since the 1950s. México supplies 80% of the world's *xate*; Guatemala supplies 12% (Rainforest Alliance, 2005a). Recently, there have been some concerns about the sustainability of *xate* extraction from wild populations given the degree of extraction in both countries (CEC, 2002; Endress et al., 2004; Rainforest Alliance, 2005b). In the Lacandona Rainforest *xate* is the most important NTFP in terms of its contribution to cash income for households (Vásquez-Sánchez et al., 1992). In Frontera Corozal the sale of *xate* leaves can account for up to 68% of an individual household's income.

Table I.1. Attrition

	Households that remained in the sample	Households that did not remained in the sample	Difference in Means
Variable	Mean (μ_1)	Mean (μ_0)	(μ_1-μ_0)
Household Size (Number of members)	6.1	6.08	0.02
Education of the Head (years)	2.86	3.42	-0.56
Age of the Head (years)	40.76	33.69	7.07**
Land (Hectares)	39.97	28.46	11.51*
Pasture (Hectares)	3.26	3.08	0.18
Cattle Holdings (Number of Heads)	2.67	2.38	0.29
Work in *Xate* Extraction (Days per year)	27.22	26.46	0.76
	N = 86	N = 13	

Notes: One household was lost from the first round of the survey due to missing information.
* significant at 10%; ** significant at 5%

In México the process of transporting *xate* fronds from forests to markets can be summarized as follows: extractors gather palm leaves and deliver them to local collectors; a regional buyer then picks up the leaves and transports them to a regional collection center; then the leaves are sent to wholesale markets in México and abroad. There are only a few regional buyers in México; they are the ones who set the purchase price that will be paid to local extractors.

Xate has attracted the attention of national and international organizations as a possible means to simultaneously promote development and conservation. Recently, the North American Commission for Environmental Cooperation began to evaluate the possibility of establishing a green market for *xate* under the assumption that it will lead to the conservation of forests and at the same time to the improvement of local economic conditions (CEC, 2002; Bowman, 2003). A pilot project to purchase *xate* fronds harvested in México and Guatemala took place during March 2005 and April 2006 as part of this effort (CEC, 2005; Dean Current, personal communication, 2006).[4] The efforts of USAID, the Rainforest Alliance, other NGOs, and the national government to promote sustainable *xate* extraction in the Petén Region of Guatemala are another example of the interest in *xate* as a conservation and development tool (Heinzman and Reining, 1990; Rainforest Alliance 2005a).

In an effort to evaluate its implications for biological sustainability, *xate* has also been the focus of research on the impact that extraction has on the dynamics of palm populations; this has seldom been done with other NTFPs (Ackerly et al., 2003; Endress

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[4] During the first year of the pilot project Lutheran, Episcopalian and Unitarian churches in the U.S.A. bought 5,000 palm fronds to be used during Palm Sunday. In 2006 the amount of sales increased to 80,000. The plan for 2007 is to include Canadian churches and to sell as many as 1 million fronds (Dean Current, personal communication, 2006). During a normal Palm Sunday 30 million palm fronds, including *xate*, are used in the U.S.A. and Canada (CEC, 2005).

et al., 2004). Unlike most NTFP research, these studies could eventually provide the necessary information to incorporate biological aspects of *xate* explicitly into an economic model of extraction.

Community members have exclusive rights to extract natural resources from the contiguous rainforest; nevertheless, there are no community rules on how these resources, including *xate*, should be managed (Sánchez-Carrillo and Valtierra- Pacheco, 2003; Tejeda, 2004). *Xate* can therefore be considered as an unmanaged common property resource.[5] In spite of this, not everybody in the community participates in *xate* extraction. The determinants of household participation in the extraction of this common property resource are the subject of Essay 2.

The wild population of *xate* in Frontera Corozal has been characterized as being in a state of deterioration (Sánchez-Carrilo and Valtierra Pacheco, 2003; Tejeda, 2004). Sánchez-Carrilo and Valtierra Pachecho (2003) found that hours of work per day in *xate* extraction increased between 1996 and 2001 while productivity per day decreased. This is consistent with the perceptions of those interviewed in the 2004 survey: 68% of respondents who extracted *xate* thought that *xate* was harder to find than in previous years.

Unfortunately, there is no systematic information about how the stock and quality of wild *xate* around Frontera Corozal have truly changed over time. It is important to clarify that the information required to do this includes the change over time in the availability of marketable *xate* leaves and not only the change in the stock of *xate* palms. This distinction is crucial, because the extractor's situation is affected by changes in the

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[5] The term common property resource, as employed here, refers to a resource that is owned by a well-defined group whose members have the right to use the resource and exclude non-members from using it (Ciriacy-Wantrup and Bishop, 1975; Ostrom, 1990).

amount of marketable leaves available and not necessarily by changes in the stock of *xate* palms. As has been shown by Endress et al. (2004), it is possible that over-extraction of *xate* will lead to a situation in which the leaves produced by the palms shrink in size, thus losing their market value. If this occurs, it might be difficult for extractors to find marketable leaves even if the stock of palms is not decreasing, or at least not decreasing in an important way.

Although the dissertation focuses on the extraction of wild *xate* and cultivation of *xate* is still relatively small compared to extraction from the rainforest, it is important to mention that cultivation has been increasing in Frontera Corozal. From August 2001 to August 2004 the number of hectares of *xate* cultivated by the households in the survey sample rose from 24.75 to 44.25. In the same period the share of households that cultivated *xate* on their land increased from 9% to 12%. Finally, while the total number of days worked in wild *xate* extraction by the households in the sample decreased from 2,514 in 2001 to 1,707 in 2004, the number of days worked in cultivated *xate* extraction grew from 21 to 205.

I.3. Dissertation Overview

Essay I explores welfare implications of renewable resource extraction. The Frontera Corozal data set is combined with a data set representing all of rural México to examine distributional and poverty effects of natural resource extraction at the community, regional and national levels. First, I explore whether income from natural resource extraction affects poverty and inequality. The marginal impact of a change in the price of natural resources on inequality is then calculated. Then, using the information from

Frontera Corozal, the short-run poverty effects of changes in the price of *xate* are evaluated.

Results show that inequality and the number of poor individuals increases when natural resource income is not taken into consideration. In Frontera Corozal, a 10% increase in natural resource income reduces the Gini coefficient of per-capita income inequality by 0.11%. A doubling of the price of *xate* fronds in Frontera Corozal is associated with a 6% decrease in the number of poor individuals in the short run. The welfare analysis presented in this essay is partial in the sense that it assumes that labor allocation and the stock of *xate* does not change in response to marginal changes in natural resource income and prices. Essays II and III analyze labor allocation decisions and the long run equilibrium in the stock of *xate* under alternative price and management scenarios.

Essay II analyses the decision of how much labor to allocate to the extraction of the *xate* palm. At the optimum, some households decide to allocate labor of all or some of their members to NTFP extraction, while the optimal choice for other households is a corner solution in which the labor allocated to *xate* extraction is zero. This implies that labor allocated to resource extraction can assume the value of zero with positive probability, but it is continuous over positive values. In other words, when analyzing time allocation to NTFP extraction a censoring problem is faced.

The approach followed in this essay is to include the opportunity cost of time as an explanatory variable in a model of labor allocation to *xate* extraction. This allows the separation of the direct effects that exogenous variables have on labor allocation from the indirect effects that occur through the opportunity cost of time.

The results show that the opportunity cost of time is negatively related to participation in NTFP extraction. Policies that increase off-forest employment, and thus the opportunity cost of time, are likely to result in a decrease in labor allocated to xate extraction. Nevertheless, it is likely that individuals' and households' access to these new opportunities will not be homogenous. In particular, those with low levels of education might not be able to participate in other activities. New employment opportunities might indirectly benefit those who extract *xate* if they diminish pressure on the resource (by diverting labor to non-*xate* activities) and if this is reflected in increases in *xate* harvest rates.

Essay III presents a theoretical model that analyzes allocation of labor to NTFP extraction over space under managed and unmanaged regimes, with a view towards obtaining a deeper understanding of the role of extraction in poverty alleviation. The spatial dimension is included in the analysis to highlight the challenge that extraction across space implies in terms of managing the resource. In particular, cooperation among extractors is needed not only to limit the amount of total labor (total extraction) but also to allocate this labor optimally across space. The theoretical analysis is complemented by an empirical spatial analysis of *xate* extraction.

Results show that under unmanaged common property an increase in the price of the natural resource, say due to a 'green product' price premium, does not necessarily alleviate poverty. Irrespective of how much the price increases, the revenue per-day of work will always be equal to the opportunity cost of time. On the other hand, if there are constraints in the availability of local labor, price increases can raise extraction income above the opportunity cost of time and help alleviate poverty even under local open access. That is to say that if a relatively small group of people owns the resource, these individuals can earn from extraction more than their opportunity cost of time even if they do not have any internal rules to manage it, as long as they can exclude outsiders from extraction. These results highlight the importance of local management practices, in terms of both exclusion and coordination across time and space.

Essay 1: Natural Resource Extraction, Poverty and Inequality

1.1. Introduction

The potential importance of natural resources for the livelihood of rural households has long been recognized (Cavendish, 1999; Sunderlin et al., 2003). Households in natural resource rich environments often are poor, particularly in developing countries, and although natural resources may prevent or reduce poverty, dependence on these resources also can perpetuate poverty. The empirical evidence to date, mostly from studies of forest activities and poverty, is inconclusive (Wunder, 2001; Angelsen and Wunder, 2003).

This essay explores the impact of natural resource extraction on rural poverty and on the distribution of rural income, using Gini and poverty decomposition techniques, bootstrapping methods, and new data from a community survey implemented in the *Selva Lacandona* (Lacandona Rainforest) of México and a national rural household survey. The research has two objectives. The first is to analyze distributional and poverty effects of natural resource extraction at the community level and compare them to the effects at the regional and national levels. To estimate the impacts of natural resource extraction on rural income inequality, we use the Gini decomposition technique presented in Lerman and Yitzhaki (1985). The poverty index proposed by Foster et al. (1984) is used to analyze the poverty implications of resource extraction.

The second objective is to evaluate the short-run poverty effects of changes in the price of a non-timber forest product (NTFP) extracted from the *Selva Lacandona.* During the last twenty years, the commercialization of NTFPs has been advocated as a strategy that can lead to a win-win combination of poverty alleviation and forest conservation (Ros-Tonen, 2000; Angelsen and Wunder, 2003). The perceived promise of the commercial extraction of NTFPs as a conservation strategy springs from the hypothesis that, if the value of the resource increases, the incentives for conserving the forest will also increase. If those who extract the resource are poor, then an increase in the value of NTFPs could alleviate poverty while promoting conservation. Nevertheless, at present there is insufficient evidence to support this view. Findings from a number of studies suggest that the effects of extraction on forest conservation and poverty are ambiguous or even negative (Browder, 1992; Wunder, 2001; Lybbert et al., 2002; Angelsen and Wunder, 2003). This essay contributes to the literature by examining a case study in which the commercialization of a NTFP appears to have a positive impact on poverty alleviation, at least in the short run.

The remainder of the essay is organized as follows: In Section1.2 I provide a brief account of recent research on poverty, inequality and extraction of natural resources. The data and methods used to quantify and analyze poverty and inequality are described in section 1.3. In sections 1.4 and 1.5 I discuss the findings and present the conclusions.

1.2. Poverty, Inequality and Natural Resources

Quantitative studies of the relationship between natural resources, poverty and inequality are scarce. Using a data set from Zimbabwe, Cavendish (1999) shows the importance of including natural resources and environmental services when estimating poverty and inequality measures. By calculating these measures with and without considering the income derived from natural resources, he shows that rural poverty and inequality can be overstated using conventional household surveys (by as much as 98% for poverty and 44% for inequality, depending on the poverty line and the specific measure used).

For India, Reddy and Chakravarty (1999) find that if income from forestry were set to zero (under the scenario of restricting access to common property areas), poverty would increase by as much as 28%. They conclude that a 10% increase in other income sources would not be sufficient to neutralize the poverty effect of removing access to common property areas. The reduction in inequality due to forest-related income was found to be negligible (-0.1%). In southern Malawi, Fisher (2004) shows that forest income reduces income inequality (inequality increases 12% when forest income is not considered). Mahapatra et al. (2005) use an India data set to estimate the impacts of NTFP sales on cash income. They show that sales of NTFPs can decrease income inequality. Jodha (1986) finds that the Gini coefficient increases by as much as 36% in dry regions of India when income from common property resources is not considered.

Lybbert et al. (2002) test whether the creation of new markets for a particular NTFP, *argan* oil in Morocco, has resulted in gains for locals and a reduction in poverty. They find that new markets raise the price for *argan* fruit (the source of *argan* oil). However, most of the gains accrue to those who are able to overcome capital and infrastructural constraints, mainly non-locals. The benefits to locals flow primarily to middle-wealth households. Poor households tend to suffer, because they are usually net buyers of the fruit.

To my knowledge there has been no effort to estimate the impacts of natural resource income on poverty and inequality in México. This essay examines distributional and poverty effects of natural resource extraction at the community, regional and national levels. If income from natural resource extraction reduces poverty and inequality, then poverty and inequality estimates should increase when this income is not taken into account. I measure poverty with and without income from resource extraction using three variants of the Foster-Greer-Thorbecke poverty index. To explore the effect of natural resource income on inequality, I estimate Gini coefficients for household total income with and without this income source.

Comparing indexes with and without natural resource income provides insight into whether the elimination of this income would increase inequality and/or poverty. It also provides upper bounds on the *magnitudes* of these effects if households are able to compensate partially for the loss of resource-extraction income by switching into other activities. The magnitude of poverty and inequality effects can be explored using a marginal analysis, that is, by estimating the impact of a change in price (or income) associated with resource extraction on poverty and inequality, holding other income sources constant. In the case of inequality, this is accomplished using Gini decomposition techniques (Lerman and Yitzhaki, 1985). Using original household survey data from a community in the *Selva Lacandona*, the short-run poverty effect of an increase in the price of a specific non-timber forest product (the *xate* palm) is evaluated using simulation methods proposed by Reardon and Taylor (1996).

1.3. Data and Methods

1.3.1. Data

Data for this research are from the México National Rural Household Survey (Encuesta Nacional a Hogares Rurales de México, or ENHRUM) and from the 2001 round of a household survey conducted in a Lacandona rainforest community of the Mexican state of Chiapas.[6] Both surveys provide detailed data on assets, socio-demographic characteristics, production and incomes by source, including natural resource extraction.

The ENHRUM surveyed a nationally representative sample of rural households in January and February 2003. The sample includes 1,782 households from 80 communities in 14 states. INEGI, México's national information and census office, designed the sampling frame to provide a statistically reliable characterization of México's rural population. Reflecting INEGI's standard survey design criteria, the country was divided into five regions: Center, South-Southeast, West-Center, Northwest, and Northeast. To obtain information on household income generating activities as well as other variables, a community level survey was conducted in each community before applying the household survey.

The present research uses the full national rural household sample as well as the sub-sample for the South-Southeast region (372 households). I decided to focus on this region because of its importance in terms of natural resource availability and because it is where the community that serves as our case study is localized.

Data from these surveys make it possible to quantify natural resource extraction at the household level, as well as to test for influences of this activity on rural households' total income, income inequality and poverty for all of rural México, the South-Southeast region and Frontera Corozal. The Frontera Corozal data allows me to simulate the impacts that changes in the price of a specific NTFP could have on poverty in this forest community. Results from the analysis of Frontera Corozal provide valuable information not only to those currently involved in the creation of a green market for *xate*, which is

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[6] For more details on the survey and the community see the introduction to this dissertation.

also extracted in other threatened forest areas in México and Guatemala, but also to those interested in the use of price mechanisms as a poverty alleviation tool.

Total income is defined as the sum of net income from five sources: family production (crops, livestock, nonagricultural goods and services); natural resource extraction (firewood, wild fruits, wild animals, plants, etc.); wage labor (agricultural and nonagricultural); migrant remittances (both internal and international); and public transfers (PROCAMPO and PROGRESA/ Oportunidades).

Net income from household production activities, with the exception of livestock income, was estimated as the gross value of production minus purchased inputs.[7] Production includes not only commercial production but also output consumed at home and given to other households as gifts. In order to obtain the gross value of commercial production, households were asked the price at which they sold their product. For output consumed at home or given as gifts, households were asked the price they would have received by selling the product. Firewood and other goods produced for home consumption were valued by asking households what price they would have had to pay to purchase these goods.

Income from livestock production was estimated as the change in value of standing herds between the end and start of the survey year, plus (a) sales and gifts to other households of animals and animal products and (b) home consumption of home-produced animals and animal products, minus (c) livestock purchases and (d) livestock input costs (food, medicines, and other costs). Salary and wage income was aggregated

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[7] The inputs used by households vary not only across activities but also across communities. For example, fishing in some communities requires buying fuel and maintaining boats, while in other communities the only inputs are family labor and a fishing rod. The community surveys allowed me to capture these differences by adapting the household survey form to the specific characteristics of each community.

across all household members and jobs. Migrant remittances were aggregated across all remitters.

It is not clear how to value family inputs like labor, animals and equipment used in specific production activities. Because of this I did not try to impute values of family inputs. However, I did allow for the possibility of zero or negative net incomes in specific activities. The poverty line used in this analysis was established by the Mexican government as the monthly per capita income necessary to purchase a basic basket of food in rural areas, 495 pesos in 2002 (SEDESOL 2002).[8]

Table 1.1 presents some basic characteristics of the households included in the samples. Households are grouped into those that receive income from natural resources and those that do not. Data reveal lower levels of average schooling of heads of households that derive a portion of their income from natural resources. For example, in the community and national surveys, schooling averages 2.5 and 3.9 years, respectively, for heads of households with income from natural resource extraction, and 3.5 and 5 years in households without. This may reflect the low skill requirements for resource extraction activities, as well as the absence of more remunerative alternatives for uneducated households.

On average, at the community and national level households without income from natural resources have higher endowments of land; however, the opposite is true in the resource rich South-Southeast region (the differences in unconditional means are not statistically different from zero in any case). Frontera Corozal was created in the late 1970s as a result of a policy of the Mexican government to relocate and congregate eight

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[8] Two other poverty lines are available from SEDESOL. The first includes income necessary to purchase a basic basket of food plus health and education services (587 pesos). The second also includes clothing, shelter, utilities and transportation (947 pesos).

Table 1.1. Descriptive Statistics

	Households That Extract Natural Resources		Households That Do Not Extract Natural Resources		Difference in Means
Variable	Mean (μ_1)	SD	Mean (μ_0)	SD	(μ_1-μ_0)
Frontera Corozal					
Household size	5.73	2.85	5.67	2.20	0.06
Age of the household head	36.90	10.59	42.89	12.40	-5.99***
Schooling of household head (years)	2.49	2.41	3.48	3.51	-0.99*
Landholdings (hectares)	36.38	23.31	40.54	18.63	-4.16
Livestock (2002 pesos)	2118.75	8103.49	15265.86	36078.31	-13147.11***
Livestock (number of animals)	0.87	3.11	5.67	13.44	-4.8***
Total per capita net income (2002 pesos)	4860.00	3377.36	4638.46	3271.27	221.54
	N = 52		N = 46		
South-Southeast Region					
Household size	4.23	1.96	3.95	1.77	0.28*
Age of the household head	48.20	15.25	49.17	15.81	-0.97
Schooling of household head (years)	3.99	2.88	4.55	4.05	-0.56*
Landholdings (hectares)	5.28	8.35	5.08	11.94	0.2
Livestock (2002 pesos)	4011.37	8254.51	3402.87	8699.56	608.5
Livestock (number of animals)	1.29	4.25	0.74	2.28	0.55*
Total per capita net income (2002 pesos)	5821.14	5788.98	11388.77	31395.83	-5567.63**
	N = 251		N = 121		
México					
Household size	4.29	2.09	3.88	1.88	0.41***
Age of the household head	49.56	15.59	47.77	16.53	1.79***
Schooling of household head (years)	3.87	3.18	5.01	4.11	-1.14***
Landholdings (hectares)	4.56	19.95	5.03	28.96	-0.47
Livestock (2002 pesos)	9786.50	37169.39	7162.86	38184.43	2623.64*
Livestock (number of animals)	3.27	14.34	2.30	12.80	0.97*
Total per capita net income (2002 pesos)	12411.92	20835.06	17374.70	35359.36	-4962.78***
	N = 846		N = 936		

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 1.2. Composition of the Per Capita Net Income
(2002 pesos)

	Households That Extract Natural Resources		Households That Do Not Extract Natural Resources		Difference in Means
Income Source	Mean (μ_1)	SD	Mean (μ_0)	SD	(μ_1-μ_0)
Frontera Corozal					
Government Transfers	1252.80	651.29	1103.92	740.65	148.88
Remittances	60.39	435.49	39.44	213.53	20.95
Natural Resources	820.37	1086.24	0.00	0.00	
Family production	1554.82	1845.21	1795.38	2153.31	-240.56
Wages	1171.61	1552.54	1699.72	2744.04	-528.11
Total Income	4860.00	3377.36	4638.46	3271.27	221.54
	N = 52		N = 46		
South-Southeast Region					
Government Transfers	761.35	1010.19	561.60	646.66	114.69***
Remittances	760.74	3566.92	979.31	4251.10	-218.57
Natural Resources	706.54	1039.57	0.00	0.00	
Family production	1210.22	3139.04	4987.26	27976.78	-3777.04*
Wages	2382.29	3444.32	4860.60	15214.77	-2478.31**
Total Income	5821.14	5788.98	11388.77	31395.83	-5567.63**
	N = 251		N = 121		
México					
Government Transfers	852.94	1724.80	546.01	1798.32	306.93***
Remittances	2914.84	15082.87	1944.66	12742.61	970.18*
Natural Resources	759.91	1250.74	0.00	0.00	
Family production	2528.03	9791.37	5139.58	30929.85	-2611.55***
Wages	5356.20	10824.70	9744.46	17112.89	-4388.26***
Total Income	12411.92	20835.06	17374.70	35359.36	-4962.78***
	N = 846		N = 936		

* significant at 10%; ** significant at 5%; *** significant at 1%

indigenous (Chol) communities into a new settlement. The household heads were allocated 50 hectares each. Because of this, there is a wide difference between average landholdings in Frontera Corozal and the rest of the region and country. Households with income from natural resources in Frontera Corozal own less livestock (oxen, horses and cattle), both in quantity and value, than those that do not extract natural resources. At the national and regional levels the opposite is the case. These disparities could be explained by the different roles that livestock plays in different settings. In Frontera Corozal, for example, livestock are raised predominantly by relatively rich households that are less likely to participate in resource extraction.

Table 1.2 shows that, on average, wage income and income from family production activities are lower in households that extract natural resources than in those that do not. Total per capita net income is lower for non-extractors in the national and regional samples but not in Frontera Corozal (none of the differences in unconditional means is statistically different from zero). From these basic descriptive statistics we can expect the impact of income from natural resources on poverty and inequality to be different at each level of data aggregation.

1.3.2. Poverty Measures

To measure poverty three variants of the Foster-Greer-Thorbecke (FGT) poverty index are used. The FGT index is calculated using the formula:

$$FGT(\alpha) = \frac{1}{N}\sum_{i=1}^{N} I_i \left(1 - \frac{y_i}{z}\right)^{\alpha} \tag{1.1}$$

where $I_i = 1$ if $y_i \leq z$ and zero otherwise. Per capita income is represented by y_i, z is the poverty line, N is the population size and α is a weighting parameter that can be viewed as a measure of poverty aversion. When $\alpha = 0$ the formula collapses to the incidence or headcount index of poverty, that is, the percentage of poor in the population.

The headcount index, while intuitive and easy to interpret, has some drawbacks. Among other things, it treats poverty as a discrete rather than continuous characteristic.

The headcount measure of poverty does not change if the incomes of very poor individuals increase but not enough to put them above the poverty line. Similarly, the headcount measure does not increase if only those below the poverty line face a negative shock that decreases their income, no matter how severe this shock might be.

To provide a more complete picture of how poverty changes under different scenarios, the poverty gap and sensitivity (poverty gap-squared) measures are commonly used in addition to the headcount measure. The poverty gap measure corresponds to $\alpha = 1$. It reflects how far below the poverty line the average poor household's income falls (i.e., the depth of poverty). If the income of a poor household increases but not enough to nudge it above the poverty line, total poverty as measured by this index will decrease (even though the headcount measure does not change.[9]

When $\alpha = 2$ we obtain the poverty severity index. Like the poverty gap measure, it is sensitive both to the headcount and to changes in incomes of households that remain in poverty. However, it accords a greater weight to poor individuals who are further away from the poverty line. Poverty measured by this variant of the FGT index will decrease more if the individual receiving the income is extremely poor.

Foster, et al. (1984) present a decomposition of the poverty index by population subgroup while Reardon and Taylor (1996) propose a simulation method to decompose the FGT poverty coefficient by income source. This second method is used in the simulations of the impacts of natural resource extraction income on poverty in Frontera Corozal.

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[9] In addition, one can recover the minimum cost to eliminate poverty with perfect targeting by multiplying the depth of poverty by Nz.

1.3.3. Inequality Measures

Of the various inequality indices that satisfy the five basic properties mentioned by Ray (1998), I opt for the Gini coefficient, which is arguably the most intuitive, with its neat correspondence to the Lorenz curve, and lends itself to easy-to-interpret decompositions of income effects.

Following Lerman and Yitzhaki (1985), the Gini coefficient for total income inequality, G, can be represented as:

$$G = \sum_{k=1}^{K} S_k G_k R_k \tag{1.2}$$

where S_k represents the share of component k in total income, G_k is the source Gini, corresponding to the distribution of income from source k, and R_k is the Gini correlation between income from source k and the distribution of total income.

Equation (1.2) allows the decomposition of the influence of any income component, in this case natural resources, upon total income inequality, as the product of three easily interpreted terms:

a) How important the income source is in total income (S_k);

b) How equally or unequally distributed the income source is (G_k); and

c) How the income source and the distribution of total income are correlated (R_k), that is, the extent to which the income source does or does not favor the poor.

For example, if resource extraction income represents a large share of total income, it may potentially have a large impact on inequality. However, if it is perfectly equally distributed ($G_k = 0$), it cannot influence inequality even if its magnitude is large. If it is large and unequally distributed (S_k and G_k are large), it may either increase or decrease inequality, depending upon which households, at which points in the income distribution, receive income from this activity. If income from natural resources is unequally distributed and flows disproportionately towards households at the top of the income distribution (R_k is positive and large), its contribution to inequality will be positive. However, if it is unequally distributed but flows disproportionately to poor households, it may have an equalizing effect on the rural income distribution, and the Gini coefficient may be lower when natural resource income is included.

Using the Gini decomposition proposed by Lerman and Yitzhaki (1985) the effect of changes in natural resource income on inequality, holding income from all other sources constant, is estimated. Consider a percentage change in income from source k equal to e_k. It can be shown (see Stark et al., 1986) that the percentage effect on the Gini coefficient (that is, the Gini elasticity) is equal to:

$$\frac{\partial G / \partial e_k}{G} = \frac{S_k R_k G_k}{G} - S_k \qquad (1.3)$$

where G denotes the Gini coefficient of total income inequality prior to the income change. The percentage change in inequality resulting from a small percentage change in income from source k equals the initial share of the income source in inequality minus the initial share in total income.

1.4. Empirical Analysis

If income from natural resource extraction reduces poverty, then measured poverty will be higher when income from this source is taken into consideration than when it is not. I begin by calculating each of the three FGT poverty measures with and without income from natural resources. These calculations are performed for Frontera Corozal, the South-Southeast region and México. I then concentrate on the case study of Frontera Corozal, analyzing the impacts that changes in the price of the *xate* palm have on poverty at the community level.

The role that income from natural resource extraction plays in income inequality is analyzed using two strategies. The first is to calculate the Gini coefficient with and without income from natural resources. The second is to decompose inequality by income sources to obtain the percentage change in inequality due to a percentage change in each source of income. This analysis is done using the data at the national, regional and community levels. Other researchers have used similar approaches to analyze the impacts of natural resource income on poverty and/or inequality; however, I do not know of any study that has applied this method to México or simulated the impacts of price changes of a particular NTFP.

Finally, to test the statistical significance of the poverty and inequality measures, I obtain confidence intervals using bootstrapping techniques. Davidson and Flachaire (2004) have shown that the bootstrapped standard errors of the FGT poverty measures perform very well and give accurate inference in finite samples. The bootstrapped standard errors of the Gini coefficient, according to Mills and Zandvakili (1997), are expected to perform better than asymptotic standard errors in small samples.

1.4.1. Natural Resources and Poverty

Table 1.3 presents results for the poverty experiments using the community, regional and national samples. When income from natural resources is ignored, poverty increases in all three cases, and the poverty increases are all significantly different from zero. Nevertheless, the effect on poverty is substantially lower for all of rural México than for the other two samples. For example, for México the FGT index with $\alpha = 2$ increases by 10.8% as a result of not considering natural resources, compared with increases of 17.1% and 18.4% for the region and community, respectively. Using the headcount measure, the incidence of poverty increases 4.2 percentage points at the national level and 4.5 percentage points in both Frontera Corozal and the South-Southeast region. The poverty gap measure reveals a similar pattern of greater sensitivity of poverty at the regional and community levels than at the national level.

Table 1.3. FGT Index With and Without Income from Natural Resources

Index	Frontera Corozal	South-Southeast Regior	México
FGT ($\alpha = 0$)			
Without NR	0.810	0.717	0.446
With NR	0.775	0.686	0.428
Difference	0.035	0.031	0.018
	(0.020, 0.054)	(0.023, 0.040)	(0.015, 0.022)
FGT ($\alpha = 1$)			
Without NR	0.389	0.406	0.257
With NR	0.350	0.364	0.235
Difference	0.039	0.042	0.022
	(0.034, 0.046)	(0.037, 0.046)	(0.020, 0.023)
FGT ($\alpha = 2$)			
Without NR	0.219	0.288	0.205
With NR	0.185	0.246	0.185
Difference	0.034	0.042	0.020
	(0.028, 0.040)	(0.037, 0.046)	(0.019, 0.022)
N =	559	1515	7047

Notes: All measures use household per capita income attributed to individuals and are calculated on an individual basis.
95% bootstrapped percentile confidence intervals in parentheses.

These differences are explained by the fact that in the national sample a smaller proportion of household income derives from natural resource extraction than in the South-Southeast region and in Frontera Corozal. This is not surprising when one considers that households in this region and community have access to a greater abundance of natural resources than rural households in México as a whole.

1.4.2. Simulation of Poverty and NTFP Price Changes in Frontera Corozal

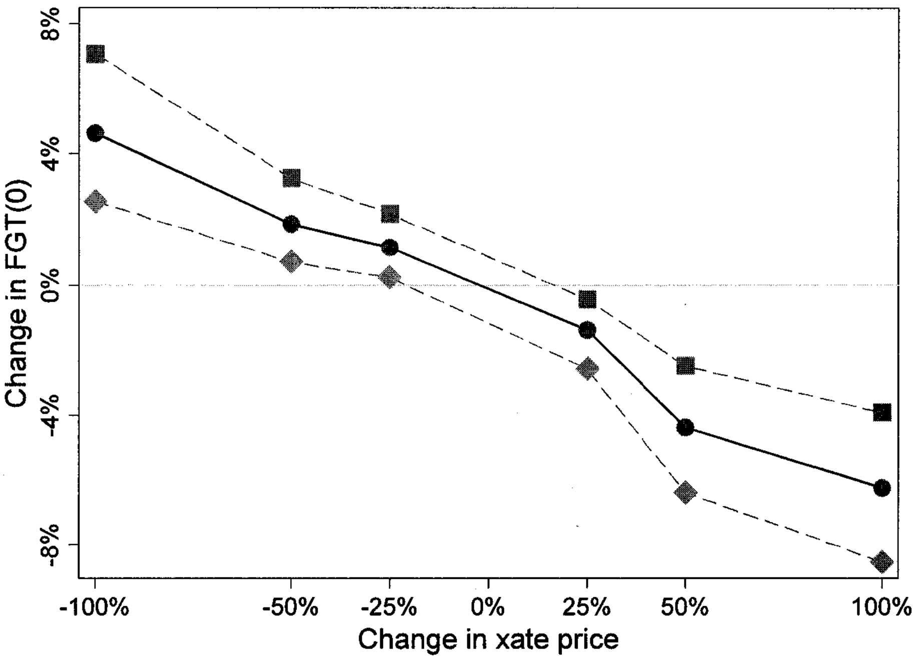
The data from Frontera Corozal make it possible to simulate the short-term impacts of changes in the price of a non-timber forest product on poverty at the community level. The leaves of the *xate* palm (*Chamaedorea* spp.) are used by the floral industry as a backdrop for flowers in wedding and funeral displays and during the Easter season, particularly on Palm Sunday.

Recently, the Commission for Environmental Cooperation of North America (CEC) began to evaluate the possibility of establishing a green market for *xate* under the presumption that it will lead to the conservation of forests and at the same time improve local economic conditions (CEC, 2002; Bowman, 2003). A pilot project to purchase *xate* fronds harvested in México and Guatemala from communities interested in achieving sustainable production took place during March 2005 and April 2006 as part of this effort (CEC, 2005; Dean Current personal communication, 2006).

The difference between the price paid by the consumer and what the *xate* extractor receives is substantial; according to CEC (2002) the price paid to *xate* extractors is less than 7% of the final price. In this analysis I concentrate on changes in the price received by extractors instead of on changes in the price paid by the consumer of the product.

To evaluate the potential poverty effects of changes in the price received by *xate* extractors, I calculate the three FGT measures for a variety of simulated price changes. Three price decreases (25%, 50% and 100%) simulate a hypothetical situation in which the demand for *xate* decreases, including an extreme scenario in which no *xate* is demanded at all. The simulation of price increases (25%, 50% and 100%) represents a first approach toward understanding the potential impacts that the creation of a green market for *xate* could have on terms of poverty alleviation.

Figure 1.1. Change in Incidence of Poverty (Headcount)



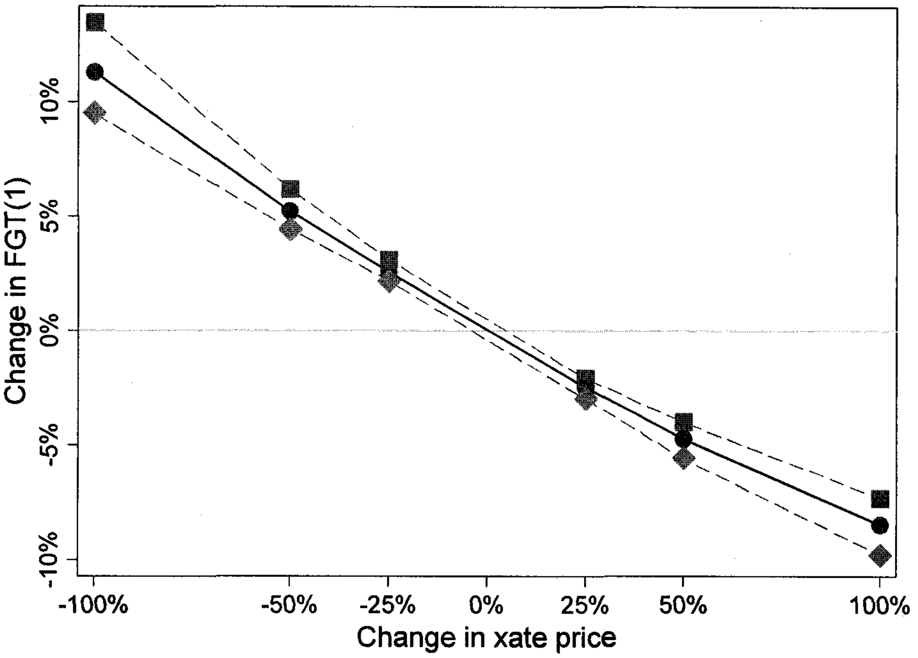
Note:Dashed lines represent 95% bootstrapped percentile confidence bounds

Considering that *xate* is not used or consumed in any form by households in Frontera Corozal, the price changes have no direct negative effect on household expenditures. In addition, *xate* extraction does not require any capital investments or infrastructure that could prevent the poor from participating in this activity. This contrasts with the case of the *argan* oil analyzed by Lybbert et al. (2002), in which most of the local poor were excluded from the benefits of new markets (because of capital and infrastructure constraints) or even negatively affected (because of the higher prices they had to pay as consumers of the *argan* fruit).

In principle it can be argued that price increases provide incentives to substitute extraction of *xate* from the rainforest to a more reliable system like local plantations. My simulations are based on the assumption that price increases do not change the system of *xate* production. In particular, I assume the price premium to be available only for *xate* that is extracted from wild populations in a biologically sustainable way. I concentrate on this scenario to avoid the complications that a change in the production system has on our analysis, but more importantly, because this is the scenario on which plans for certification and eco-labeling for *xate* palm are based.

As can be seen in Figure 1.1 the extreme case of no *xate* market implies an increase of almost 5% in the poverty headcount measure. This means that the percentage of persons below the poverty line would rise from 77% to 81%. Figures 1.2 and 1.3 show that a zero demand for *xate* would increase the poverty gap by 11% and the severity of poverty by 18%. The greater sensitivity of the poverty gap and severity measures is an indication that *xate* price changes have a large impact on the poorest of the poor compared with those close to the poverty line.

Figure 1.2. Change in Depth of Poverty (Poverty Gap)



Note:Dashed lines represent 95% bootstrapped percentile confidence bounds

Figure 1.1 shows that a 100% price increase implies a 6% decrease in the headcount measure (i.e., the percentage of the population below the poverty line changes from 77 to 72).[10] Figures 1.2 and 1.3 show an 8% and 11% decrease in the poverty gap and severity measures when the price of *xate* doubles. The changes in these two measures reveal that the price increases have a significant impact on the welfare of some of the poorest members of the community, even when it is not enough to bring them

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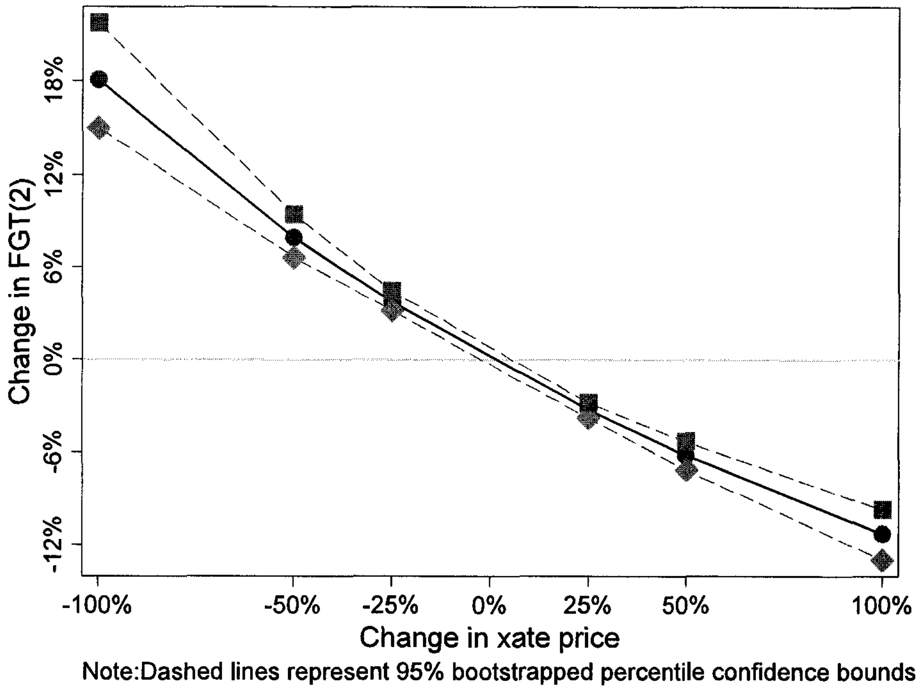
[10] A 100% price increase is not too extreme considering the results of a survey that shows that Christian congregations in the US would be willing to double the price they pay for palms harvested in a sustainable way (CEC, 2005). Furthermore, the 'eco-palm' project, the pilot project that took place in March 2005 and April 2006 resulted in extractors receiving a price premium well above 100% (Dean Current, personal communication, 2006). A project in the Peten region of Guatemala that is based on direct exportation (i.e., on bypassing the intermediaries) of leaves from the extractors to a U.S. wholesaler resulted in a doubling of the price paid to extractors (Rainforest Alliance, 2005c).

above the poverty line. The confidence bounds for the three figures show that all these changes are statistically different from zero.

Figure 1.3. Change in Severity of Poverty (Poverty Gap-Squared)



Note:Dashed lines represent 95% bootstrapped percentile confidence bounds

It is important to recognize that these results assume that households do not change their allocation of labor in response to *xate* price changes. That is, during the simulation exercise the intensity of *xate* extraction (and other activities) is held constant.[11] Even though the assumption of no labor reallocation is a strong assumption, the resulting changes in poverty measures due to a price decrease can be seen as short-run upper bounds, and the changes due to price increases as short-run lower bounds, on poverty reductions. Another implicit assumption in this analysis is that in the short-run *xate* availability remains unchanged. In order to obtain long-run conclusions I would

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[11] In Essay 2 labor allocation to xate extraction is analyzed using an econometric approach.

need to simulate the impacts that changes in prices have not only on labor allocation and intensity of extraction but also on the stock of *xate* available. This requires biological data and will be the subject of future research.

1.4.3. Natural Resources and Inequality

Table 1.4 presents a decomposition of the contributions of resource extraction and other income activities to per capita total net income and income inequality. The first column, labeled S_k, presents the share of each income source in the per capita total income for each of the three samples. In Frontera Corozal the primary income source is family production activities (34%), while wages are the principal source of income for rural households in the South-Southeast region and in México (44% and 54%, respectively). The contribution of income from natural resources ranges from 2.3% (for all of rural México) to 7.3% (for the community sample). Government transfers are an important income source in Frontera Corozal, accounting for 27% of income. Meanwhile, remittances represent 13% of per capita income at the national level and 10% in the South-Southeast region.

The second column of Table 1.4, G_k, presents the Gini coefficient for each income source. Inequality in the distribution of natural resource income is relatively high; G_k for natural resource income is 0.77, 0.71, and 0.80 in the community, regional and national samples, respectively. These high values for the source specific Gini coefficients can be explained partially by the fact that many households do not participate in extraction; thus, there are many zero incomes from this activity in the source Gini calculations (the same is true for other income sources, e.g., remittances).

At the community level the income source that is most unequally distributed is remittances from internal and international migrants; few households in Frontera Corozal had migrants in 2001. Meanwhile, the national and regional data suggest that the most unequally distributed income source is family production. This is in part due to the presence of negative net-income from agriculture for some households in the sample.[12]

As indicated earlier, a high income source Gini (G_k) does not necessarily imply that an income source has an unequalizing effect on total income inequality. An income source may be unequally distributed yet favor the poor. This is the case for natural resources in all of our samples. The Gini correlation between natural resources and the distribution of total per capita income (R_k) ranges from 0.11 (national sample) to 0.34 (community sample), and it is the lowest of all income sources in the national sample. At the national level, because of the low Gini correlation between natural resources and total-income rankings, the percentage contribution of this income source to inequality (0.3%) is smaller than the percentage contribution to income (2.3%). Thus, natural resources have an equalizing effect on the distribution of total rural income. A 10% increase in income from natural resources, other things being equal, reduces the Gini coefficient of total income inequality by 0.2%, and this change is statistically significant.

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[12] In Table 1.4, the income-source Gini coefficient for family production is higher than 1.0. This does not imply perfect income inequality, but rather reflects the presence of some negative income values. Income-source Gini coefficients greater than 1.0 have been reported elsewhere in the literature (e.g., Lerman and Yitzhaki, 1985). The Gini coefficient is a measure of dispersion, similar to a coefficient of variation; it is equal to the expected difference between two randomly drawn observations divided by the mean. One can view the mean as the expected difference between each observation and zero. If all observations are positive, zero is outside the range of observations, so the ratio is lower than one. However, if some observations are negative, zero is not outside the range of the group, and the ratio depends on the location of zero in the range. Wodon and Yitzhaki (2002) argue that the ability to handle negative incomes is an advantage of the Gini coefficient over Atkinson's index.

Income from natural resources is also equalizing in the South-Southeast region and in Frontera Corozal; a 10% increase in natural resource income reduces the Gini coefficient by 0.36% and 0.11%, respectively, in these two samples. The change is statistically significant at the regional level but it is not statistically different from zero in Frontera Corozal.

Table 1.4. Gini Decomposition by Income Source

Income Source	Share in Total Income (S_k)	Income Source Gini (G_k)	Gini Correlation with Total Income Rankings (R_k)	Share in Total-Income Inequality	% Change in Gini from a 10% Change in Income Source
México					
Family production	0.343	0.552	0.769	0.479	1.36 (0.48, 2.79)
Wages	0.296	0.628	0.585	0.359	0.63 (-0.80, 1.55)
Natural resources	0.073	0.772	0.335	0.062	-0.11(-0.55, 0.32)
Government Transfers	0.273	0.295	0.377	0.100	-1.73 (-2.21, -1.03)
Remittances	0.015	0.971	-0.014	-0.001	-0.15 (-0.60, 0.31)
Total income		0.304			
N = 559 individuals					
South-Southeast Region					
Family production	0.293	0.992	0.799	0.418	1.26 (0.62, 2.02)
Wages	0.442	0.672	0.766	0.411	-0.32 (-0.99,0.44)
Natural resources	0.062	0.711	0.326	0.026	-0.36 (-0.45, -0.28)
Government Transfers	0.099	0.587	0.178	0.019	-0.80 (-0.98, -0.62)
Remittances	0.104	0.937	0.722	0.127	0.23 (-0.06, 0.57)
Total income		0.555			
N = 1515 individuals					
Frontera Corozal					
Family production	0.265	1.015	0.786	0.357	0.92 (0.70, 1.21)
Wages	0.541	0.667	0.804	0.491	-0.51 (-0.75, -0.23)
Natural resources	0.023	0.803	0.109	0.003	-0.20 (-0.23, -0.18)
Government Transfers	0.044	0.766	0.236	0.013	-0.30 (-0.35, -0.26)
Remittances	0.127	0.927	0.681	0.135	0.08 (-0.05, 0.24)
Total income		0.592			
N = 7047 individuals					

Notes: All measures use household per capita income attributed to individuals and are calculated on an individual basis. Gini decomposition and bootstrapping was done using the Stata command descogini, which is described in López-Feldman (2006). 95% bootstrapped percentile confidence intervals in parentheses.

In the three samples income from family production has a high Gini coefficient and a high Gini correlation with total income rankings ($R_k = 0.77$, 0.80 and 0.79 in the community, regional and national samples, respectively). This income source accounts for more than 25% of total income in all the cases. Income from family production is associated positively with inequality; a 10% increase in this source increases the Gini coefficient by 1.4, 1.3 and 0.9 percentage points at the community, regional and national levels. All impacts are statistically different from zero.

In the national sample, government transfers are unequally distributed ($G_k = 0.77$). However, the Gini correlation between transfers and total income is low ($R_k = 0.24$), indicating that transfers favor households at the bottom of the income distribution. Other things being equal, a 10% increase in government transfers is associated with a 0.3% decrease in the Gini coefficient of total income. At the regional level, government transfers are less unequally distributed ($G_k = 0.59$) and the correlation between this income source and total income ($R_k = 0.18$) is lower than at the national level. A 10% increase in this income source has an equalizing effect; the Gini coefficient decreases by 0.8%. Government transfers have the highest equalizing impact at the community level; a 10% increase in transfers reduces the Gini coefficient by 1.7%. All of these impacts are highly significant. Wages have an equalizing effect on the rural income distribution at the national level, but their effect is not significantly different from zero at the regional and community levels.

Table 1.5 presents the Gini coefficients resulting from the simulation exercise of excluding income from natural resources. This exercise points out the importance of natural resource extraction in reducing rural income disparities. At the national level, the

Gini coefficient increases by 2.4% when natural resource income is ignored. The effect is higher in the South-Southeast region, where the Gini increases 5%. In Frontera Corozal the Gini increases by 4.3%. All of these effects are statistically different from zero.

Table 1.5. Gini Coefficients With and Without Income from Natural Resources

Index	**Frontera Corozal**	**South-Southeast Regioı**	**México**
Gini without NR	0.317	0.583	0.606
Gini with NR	0.304	0.555	0.592
Difference	0.013	0.028	0.014
	(0.007, 0.021)	(0.025, 0.031)	(0.013, 0.015)
N =	559	1515	7047

Notes: All measures use household per capita income attributed to individuals and are calculated on an individual basis.
95% bootstrapped percentile confidence intervals in parentheses.

1.5. Conclusions

The findings highlight the importance of income from natural resource extraction for the alleviation of poverty and income inequalities in the Lacandona Rainforest community of Frontera Corozal as well as in the resource-rich South-Southeast region and in México. Natural resource extraction is an important source of income for many rural households. Without it, many households' ability to satisfy their basic needs would be jeopardized.

Price simulations reveal that poverty in Frontera Corozal can be reduced in the short-run by programs that raise the price that households receive for *xate*. In the long run, however, sustained price increases could lead to overexploitation of the resource, leaving everyone worse off. The biological relationship between extraction and the resource base, the incentives and disincentives that this creates for future extraction, and the institutional setting surrounding price increases will jointly determine whether this seemingly perverse outcome occurs. Both long and short-run considerations should be weighed carefully when assessing the potential to promote the green marketing of *xate* or other natural resources as a poverty alleviation and forest conservation tool.

Essay 2: Labor Allocation to Non-Timber Forest Products Extraction

2.1. Introduction

During the last twenty years the commercialization of non-timber forest products (NTFPs) has been considered as a strategy that could lead to a win-win situation in which poverty alleviation and forest conservation are simultaneously achieved (Ros-Tonen, 2000; Angelsen and Wunder, 2003). The attention given to the commercial extraction of NTFPs as a conservation strategy comes from the hypothesis that if the value of the resource increases the incentives for conserving the forest will increase too. If, in addition, those who extract the resource are poor, then it is argued that the increase in value could alleviate poverty while promoting conservation. Nevertheless, there is not enough sound evidence to support this view. In fact, a number of studies suggest that the effects of extraction on forest conservation and poverty reduction are ambiguous or even negative (Browder, 1992; Wunder, 2001; Lybbert et al., 2002; Angelsen and Wunder, 2003).

As these studies point out, the role that NTFP extraction could actually play in promoting conservation and poverty alleviation is case specific. As a result it has been argued that the effective implementation of conservation and development programs in rainforest areas requires an understanding of the microeconomic logic behind activity choice and resource use decisions among heterogeneous households (Coomes and Barham, 1997).

By explaining the economic logic behind rural households' decisions of time allocated to the extraction of a particular NTFP this essay attempts to shed some light on this debate. The case study in which the essay is based on shows that, even in a single village, heterogeneity across households can lead to very different natural resource use decisions. In this work I focus on the links between extraction and poverty and leave conservation considerations aside.

The main objective of this essay is to understand the determinants behind households' decisions regarding their allocation of labor to natural resource extraction. In particular I address the following questions: When all individuals in a village have access to a natural resource and extraction requires no physical capital, why do some individuals and households participate in extraction and others do not? Is there a negative relationship between the opportunity cost of a day of work and the allocation of labor to NTFP extraction? Do lower levels of capital (both human and physical) imply a low opportunity cost of time?

The next section presents the theoretical and empirical models for labor allocation. Econometric results are presented and discussed in section 2.3. Section 2.4 concludes.

2.2. Labor Allocation and NTFP Extraction

2.2.1. Literature Review

The empirical literature on the microeconomics of NTFP extraction is relatively scarce. The studies can be divided in two groups: those that refer to firewood (e.g., Bluffstone, 1995; Amacher et al., 1996; Kölin and Parks, 2001) or include NTFP extraction as part of an aggregate measure of extraction (e.g. Takasaki et. al., 2000; Fisher et al., 2005), and those that look at a particular NTFP (Lybbert et al., 2002; Escobal and Aldana, 2003) or group of NTFPs (e.g., Coomes et al., 2004). This essay builds on both types of studies.

I draw from the first group of studies to design my basic methodology. Labor allocation decisions are assumed to take place at the level of the farm household. I extend the model by allowing household members to have different productivities or access to employment opportunities. By doing this the effects that individuals' characteristics (like age and education) play in the allocation of labor to NTFP extraction can be studied.

The second group of studies focuses on NTFPs that are commercialized outside of the extractor's village and analyzes the role of NTFPs in terms of poverty alleviation or resource conservation. The present essay focuses on a commercial NTFP and on the effect that physical and human capital have on households' extraction decisions. Contrary to past NTFP studies, but similar to firewood studies, I explicitly include the opportunity cost of time as one of the determinants of labor allocation.

An additional strength of this essay is the level of detail in terms of the calculation of marginal effects. The marginal effects that changes in the dependent variables have on the expected value of labor supplied to NTFP extraction are painstakingly calculated, contrary to other studies that present only the coefficient estimates. This gives us a solid basis to understand the potential impacts that different policies (e.g., promotion of off-farm employment) might have on extraction practices and poverty. Furthermore, inasmuch as the data set used for the empirical analysis includes information on both extractors and non-extractors (contrary to some previous studies, e.g., Escobal and

Aldana, 2003), the marginal effects for the whole population and for extractors in particular are calculated.

2.2.2. Theoretical Model

The economic analysis of NTFP extraction followed here is based on a household farm model. Each household i is formed by J_i working members and K_i non-working members. Households maximize utility (over leisure and consumption) subject to an endogenous budget constraint that depends on their decision of how to allocate the labor of their working members across different activities. To simplify notation the household subscript (i) is omitted whenever possible.

The model is set up as a multi-period problem in which households maximize utility over time. This allows us to take into account the fact that households' NTFP extraction decisions are affected by the resource stock available at time t, which in turn is affected by aggregate extraction at $t-1$. The details of the model are as follows:

1. Households derive utility from consumption of a composite good (C_t) and leisure of working members (l_{jt}), given a vector $\boldsymbol{F}_t$ of household and individual characteristics that are treated as exogenous. The number of non-working members of the household is included in this vector. The utility function, $U(C_t, l_{1t}, \ldots, l_{jt}; \boldsymbol{F}_t)$, is assumed to be quasiconcave and strictly increasing in consumption and leisure. Utility is discounted over time by a discount factor r.
2. Each working member of the households has a time endowment of T days per period of time. To maximize utility households allocate their total time

endowments (JT) across three alternatives: leisure (l_{jt}), NTFP extraction work (L_{jt}^{NT}) and work in other productive activities (L_{jt}^{O}).

3. The model allows members of the same household to have different productivities depending on their individual characteristics (e.g., age, sex or education). Access to a given activity may vary across members of the same household. Hired labor and family labor are not assumed to be perfect substitutes.
4. The amount of NTFP that an individual can extract at a given point in time is given by $q_{jt}^{NT} = q_{jt}^{NT}\left(L_{jt}^{NT}; S_t, \boldsymbol{\theta}_{jt}\right)$ where S_t is the stock of the resource available at time t and $\boldsymbol{\theta}_{jt}$ is a vector of household and individual characteristics that can affect the individuals' ability in extraction. The only cost of extraction is the time involved, no inputs or assets are needed. The price of the NTFP is p_t^{NT} and it is set by the international market.
5. The growth function of the resource is $S_{t+1} - S_t = g(S_t) - H_t$ where $g(S_t)$ is the density dependent natural rate of growth of the resource population under no extraction, and $H_t = \sum_{i=1}^{N}\sum_{j=1}^{J} q_{jit}^{NT}$ is the amount of NTFP extracted by <u>all</u> the households at time t.
6. The composite production function of the other activities is $q_t^O = q^O\left(L_{1t}^O, \ldots, L_{jt}^O, L^H; \mathbf{A}_t\right)$, where $\mathbf{A}_t$ is a vector of physical capital (e.g., land) and other individual and household specific characteristics that affect farm

productivity and are taken as given by the household. L_t^H is the amount of labor hired. $q^O(\cdot)$ is concave and non-decreasing in its arguments.

7. A budget constraint ensures that expenditure in consumption will be equal to the sum of NTFP income, income from other productive activities and exogenous income (E_t).

To maximize utility households solve the following problem:

$$\underset{C_t, L_{jt}^X, L_{jt}^F, L_{jt}^{Of}, L_t^H, l_{jt}}{Max} \quad \sum_{t=0}^{\infty}\left[r^t * U\left(C_t, l_{1t}, \ldots, l_{jt}; \boldsymbol{F}_t\right)\right] \tag{a}$$

$$\begin{aligned} s.t \qquad p_t C_t &= p_t^{NT}\left(\sum_{j=1}^{J} q_{jt}^{NT}\right) + p_t^O q_t^O - wL_t^H + E_t \\ T_j &= L_{jt}^{NT} + L_{jt}^O + l_{jt} \\ \sum_{j=1}^{J} T_j &= JT \\ q_{jt}^{NT} &= q_{jt}^{NT}\left(L_{jt}^{NT}; S_t, \boldsymbol{\theta}_{jt}\right) \\ q_t^{Of} &= q_t^O\left(L_{1t}^O, \ldots, L_{jt}^O; \boldsymbol{R}_t\right) \end{aligned}$$

The NTFP that households extract is located in a common property forest and there are no rules that control extraction by community members. In this setting of unmanaged common property, households have limited incentives to incorporate in their maximization process the effects that their current extraction decisions have in the future. The result is the same as in a situation of open-access: at each period households solve static maximization problems, considering the time path of the stock of the NTFP as well as the time path of all the exogenous variables as given and out of their control (Bluffstone, 1995; Damania et al., 2003). As a result, problem (a) simplifies to maximization of utility on a period-by-period basis. Implicitly I am also assuming that there are no savings possibilities and that physical capital is taken as given by the household; otherwise this simplification is not possible.[13]

Given this framework, labor allocation has two important characteristics. The first is that production and consumption decisions are not separable, which implies that household characteristics like size and land endowments could affect production decisions. The second is that labor allocation can vary across individuals belonging to the same household. By solving the F.O.C. of the period-by-period version of problem (a) I can obtain individual labor allocation as summarized by the following set of reduced form equations:

$$L_{jit}^{NT} = L_{jit}^{NT}\left(\boldsymbol{p}_t, S_t, \boldsymbol{F}_{jit}, \boldsymbol{A}_{jit}, \boldsymbol{\theta}_{jit}\right)$$

$$L_{jit}^{O} = L_{jit}^{O}\left(\boldsymbol{p}_t, S_t, \boldsymbol{F}_{jit}, \boldsymbol{A}_{jit}, \boldsymbol{\theta}_{jit}\right)$$

where $\boldsymbol{p}_t' = \left[p_t^{NT}, p_t^{O}, w_t\right]$. The first equation is the one estimated here; that is, I estimate labor allocation to NTFP extraction at the individual level. In this model, household i decides how much labor from individual j, if any, will be allocated to NTFP extraction at time t.

2.2.3. *Empirical Strategy*

As a result of the maximization of utility, some households decide to allocate labor from all or some of their members to NTFP extraction, while the optimal choice for other households is a corner solution where nobody works in extraction $\left(L_{jit}^{NT} = 0 \ \forall j\right)$. This implies that labor allocated to resource extraction can assume the value zero with positive

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[13] These assumptions are not unrealistic in poor regions of developing countries where saving mechanisms are not readily available and where access to credit is highly dependent upon endowments.

probability, but it is continuous over positive values. In other words, when analyzing allocation to NTFP extraction, there is a censoring problem.

The approach followed in this essay to study the determinants of labor allocation to NTFP extraction is to estimate a model that includes the opportunity cost of time $\left(w_{jit}\right)$ as an explanatory variable. This allows me to disentangle the direct effects that exogenous variables have on labor allocation from the indirect effects that occur trough the opportunity cost of time. The choice of whether or not to allocate labor to the alternative activity, which is simultaneous with the allocation of labor to NTFP extraction, affects the returns that a given individual can obtain from a day of work in non-NTFP activities. Thus, w_{jit} is endogenous (i.e., u_{jit} and v_{jit}, as defined below, are correlated). To correct for the inconsistency of the estimators implied by the endogeneity of w_{jit} the following instrumental variables tobit model is estimated:

$$\begin{aligned} L_{jit}^{NT} &= \max\left(0, L_{jit}^{NT*}\right) \\ L_{jit}^{NT*} &= \alpha_1 + \rho w_{jit} + \pi_{jit}^{'}\boldsymbol{\beta}_{\pi} + \beta_{\tau}\tau_t + u_{jit} \end{aligned} \tag{2.1}$$

$$w_{jit} = \alpha_2 + z_{jit}^{'}\gamma_z + \gamma_{\tau}\tau_t + v_{jit} \tag{2.2}$$

where L_{jit}^{NT} measures the number of days allocated to NTFP extraction by individual j from household i at the time period t. L_{jit}^{NT*} is a latent variable, and the vector z_{jit} includes the household and individual information contained in $\boldsymbol{A}_{jit}, \boldsymbol{F}_{jit}$ and $\boldsymbol{\theta}_{jit}$. More specifically, $z_{jit}^{'} = \left(\boldsymbol{\pi}_{jit}^{'}, \boldsymbol{\eta}_{jit}^{'}\right)$, where $\pi_{jit}^{'}$ is a vector of exogenous variables and $\boldsymbol{\eta}_{jit}^{'}$ is a vector of instruments. This model is estimated using maximum likelihood under the assumption that $\left(u_{jit}, v_{jit}\right)$ are multivariate normal.

Prices (p_t) and the stock of NTFP (S_t) are omitted from the equations to be estimated, although they were part of the reduced form equations derived above. The data available (see next section) come from a single village, and prices do not vary across individuals at a given point in time. The same is true for the stock of NTFP that is available from common property. A year dummy (τ) is included in the estimation to indirectly account for changes in prices and NTFP stock over time. Unfortunately, this procedure does not allow one to disentangle the effects of changes in prices from changes in stock or other variables that are constant across individuals but change over time (e.g., weather).

The normality assumption is critical. If normality is not satisfied then by using the tobit estimator we have not only inconsistency but also a problem of incorrect functional form for the expected values of the dependent variables. Nevertheless, there is no statistic available to test the null of multivariate normality of the errors in the instrumental variables tobit model. I test the normality assumption of a regular reduced form tobit model that includes the instruments and excludes the opportunity cost of time, using the conditional moment test with bootstrapped critical values proposed by Drukker (2002). This bootstrap method corrects for a size problem that arises when relying on asymptotic critical values.

2.3. Labor Allocation Results

2.3.1. Descriptive Statistics and Expected Signs

The data used here come from two household surveys applied in Frontera Corozal, México, during the years 2001 and 2004.[14] Frontera Corozal is a village in the Lacandona Rainforest (*Selva Lacandona*) in the Mexican state of Chiapas. The resource on which I focus in this analysis is the *xate* palm (*Chamaedorea* spp.), a marketable NTFP. *Xate* is the most important NTFP in the Lacandona Rainforest in terms of its contribution to cash income for households (Vásquez-Sánchez et al., 1992).[15]

Table 2.1 summarizes the variables that are included in the econometric model. The sample consists of 332 individual observations for 2001 and 351 individual observations for 2004 from 86 households. All individuals included in the sample are 13 years of age or older.

Education is expected to positively affect individuals' opportunity cost of time.[16] Schooling could also decrease individuals' willingness to participate in risky physical activities like *xate* extraction. The number of individuals in the household who have completed elementary school or who have more than 9 years of education is expected to positively affect the opportunity cost of time, due to human capital complementarities. Households with higher levels of education are expected to have higher returns in activities that potentially involve more than one family member (e.g., agriculture and family businesses).

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[14] The information collected refers to the periods September 2000-August 2001 and September 2003-August 2004. For ease of exposition we will refer to the first twelve-month period as 2001 and the second as 2004.

[15] For more details on the survey and the community see the introduction to this dissertation.

[16] See the appendix for a brief explanation of how the opportunity cost was estimated.

Table 2.1. Descriptive Statistics

Variable		Description	Mean	(s.e.)
Dependent Variable	Xatewk	Days of work in *xate* extraction	5.912	(20.064)
Individual Characteristics	Head	1= Individual is head of household	0.252	
	Male	1= Male	0.534	
	Age	Age in years	30.180	(14.876)
	Educ	Years of education	4.857	(3.659)
Household Characteristics	HH-elem	Number of household members (except individual) with elementary school completed (6 years)	1.568	(1.491)
	HH-sec	Number of household members (except individual) with at least 9 years of education	1.117	(1.236)
	Adults	Number of adults in the household [13, 59] years old	5.100	(2.490)
	Dependent	Number of children and elderly in the household	2.368	(1.430)
	Land	Hectares of land (at beginning of the period)	46.138	(20.374)
	Capital	1= Owns a car or a boat (at beginning of the period)	0.119	
	Cattle	Number of animals owned (at beginning of the period)	3.811	(10.677)
	Assets	Household assets index (Principal Components Analysis)	0.649	(0.224)
	Tradition	1= Parents of household head and/or spouse have a history of non-timber forest products extraction	0.444	
	Year	1= 2004	0.514	
	N	Pooled observations	683	

Xate extraction in the rainforest is a physically demanding activity that involves walking long distances; we therefore expect to find an inverted U-shaped relationship between age and *xate* extraction. Although participation of women in *xate* is higher than in other activities (e.g., agricultural employment), it is still the case that extraction is an activity dominated by men. The effect that the number of adults and the number of dependents (children plus elderly) in the household have on *xate* extraction is not clear *ex-ante*.

Xate extraction also is a labor-intensive activity that does not require capital. However, wealth and physical capital affect the opportunity cost of time through other activities. Individuals in poorly endowed households are constrained from participating in the most remunerative activities requiring capital investments. When access to credit is limited and dependent on endowments or credit markets do not exist, households must self-finance production activities. Proxies for household wealth include the value of cattle holdings, land, a dummy variable for ownership of a car or boat, and an index of family assets. The wealth index is constructed from dwelling characteristics and ownership of durable goods using principal components analysis following Filmer and Pritchett (2001). The assets index and the other three variables are expected to have a positive effect on the opportunity cost of time but are not expected to have any direct effect on *xate* labor allocation.

A dummy variable, "Tradition", takes on the value of one if the parents of the household head and/or the parents of the spouse ever participated in the extraction of non-timber forest products. It is included as a proxy for the role of culture, tradition or familiarity with extractive activities in the estimation of the *xate* labor allocation equation. A time dummy ($\tau = 1$ for 2004, 0 for 2001) is also included in the econometric estimation.

2.3.2. Identification Strategy and Estimation Results

The first potential identification problem that I face is sample selection: not all individuals in the sample participate in *xate* extraction. The surveys provide information on the relevant explanatory variables for all individuals in the sample, regardless of whether or not they worked in *xate*. The best strategy to deal with a censored sample like this is to estimate a tobit model (Wooldridge, 2002).

A second identification concern comes from the inclusion of an endogenous variable, the opportunity cost of time, in the equation for time allocated to *xate* extraction. Controlling for the opportunity cost of time makes it possible to disentangle direct and indirect effects of changes in the other variables on *xate* labor allocation. The identification strategy that I use is to estimate an instrumental variables version of the tobit model. Similar to linear models, identification in the tobit requires that there is at least one variable in the equation for the endogenous explanatory variable (equation (2.2), the opportunity cost of time equation) that is not in the equation of interest (equation (2.1), *xate* labor allocation). I use as instruments the variables cattle, land, assets and capital. None of these variables have a direct impact on *xate* extraction. Extraction does not use any of these as inputs, and *xate* is not used to feed cattle. Therefore, these variables can affect labor allocation only trough the effect that they have on the opportunity cost of time, via other activities. They do not belong in the NTFP labor allocation equation once the opportunity cost of time is included.

Table 2.2. Opportunity Cost of *Xate* Labor

	First Stage (OLS)
	Coefficient
Head	0.23
	[2.02]
Male	-1.54
	[1.49]
Age	0.21
	[0.24]
Age^2	-0.00
	[0.00]
Educ	0.72***
	[0.26]
HH-elem	-0.78
	[0.64]
HH-sec	1.92**
	[0.78]
Adults	-0.83
	[0.61]
Dependent	0.47
	[0.43]
Tradition	-1.62
	[1.46]
Year	-9.72***
	[1.24]
Cattle	1.87***
	[0.06]
Land	-0.02
	[0.04]
Assets	22.36***
	[3.75]
Capital	42.43***
	[2.39]
Constant	31.04***
	[5.77]
R^2	0.79
N	683

* significant at 10%; ** significant at 5%; *** significant at 1%

The first-stage estimation results, for the opportunity cost equation, are presented in Table 2.2. Cattle, assets, and capital have a strong and significant positive effect on the opportunity cost of time, while the effect of land is not statistically different from zero. Both the education level of the individual and the number of household members with nine or more years of education have a positive effect on the opportunity cost. The variables included in the opportunity cost of time regression explain a considerable proportion of the variation in this variable, as illustrated by an R^2 of 0.79.[17]

Results of the instrumental variables tobit estimation of the *xate* labor allocation equation appear in Table 2.3. Three alternative measures of the estimated marginal effects of the explanatory variables on *xate* extraction are presented in the table. This is because, in the tobit model, the marginal effect of a change in a regressor on the conditional mean can be calculated in three different ways, depending upon one's interest. We can calculate the marginal effect on the latent variable mean $\left(E\left[L^{NT*} \mid X\right]\right)$, the marginal effect on the truncated mean $\left(E\left[L^{NT} \mid X, L^{NT} > 0\right]\right)$, or the marginal effect on the censored mean $\left(E\left[L^{NT} \mid X\right]\right)$, where X includes all of the observations for w, π and τ. It can be shown (see Wooldridge, 2002) that:

$$E\left[L^{NT*} \mid X\right] = X\boldsymbol{\beta}$$

$$E\left[L^{NT} \mid X, L^{NT} > 0\right] = X\boldsymbol{\beta} + \sigma_u\left(\frac{\phi\left(X\boldsymbol{\beta}/\sigma_u\right)}{\Phi\left(X\boldsymbol{\beta}/\sigma_u\right)}\right)$$

$$= X\boldsymbol{\beta} + \sigma_u\lambda\left(X\boldsymbol{\beta}/\sigma_u\right)$$

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[17] Notice that the estimates presented for the first stage correspond to ordinary least squares estimation although the instrumental variables model is estimated by maximum likelihood. The results of the 'true' first stage via maximum likelihood are almost identical to those from OLS but the latter allows us to calculate R^2.

$$E\left[L^{NT} \mid X\right] = P\left(L^{NT} > 0 \mid X\right) \cdot E\left[L^{NT} \mid X, L^{NT} > 0\right]$$

$$= \Phi\left(X\beta / \sigma_u\right) X\beta + \sigma_u \phi\left(X\beta / \sigma_u\right)$$

where $\lambda\left(X\beta / \sigma_u\right)$ is the inverse Mills ratio, and $\beta' = \left[\alpha_1, \rho, \beta_\pi', \beta_\tau\right]$. Consequently, the marginal effect of a change in variable k on the expected value of the latent, truncated and censored variables can be calculated by using, respectively,

$$\frac{\delta E\left[L^{NT*} \mid X\right]}{\delta x_k} = \beta_k \tag{2.3}$$

$$\frac{\delta E\left[L^{NT} \mid X, L^{NT} > 0\right]}{\delta x_k} = \beta_k \left\{1 - \lambda\left(X\beta / \sigma_u\right)\left[X\beta / \sigma_u + \lambda\left(X\beta / \sigma_u\right)\right]\right\} \tag{2.4}$$

$$\frac{\delta E\left[L^{NT} \mid X\right]}{\delta x_k} = \beta_k \Phi\left(X\beta / \sigma_u\right) \tag{2.5}$$

These results depend on the normality assumption. The test of normality shows that the conditional moment (5.79) is smaller than the 10% bootstrapped critical value (12.70), which implies that the null hypothesis of normality cannot be rejected. In this case, the results obtained will be consistent and the expected values will have the functional forms shown above.

An interpretation of these marginal effects is the following: the first marginal effect corresponds to the effect of a change in x_k on the *desired* days of *xate* work, the second to a change in the actual days of *xate* work for *xateros*, and the third to a change on the actual days of *xate* work for *xateros* and non-*xateros*. It is important to note that even though the magnitude of the three marginal effects can differ, the sign will always be determined by β_k, a characteristic that does not hold for other non-linear models (e.g., the Heckman model).[18]

Table 2.3. ***Xate*** **Work**

Instrumental Variables Tobit

	β_k	$\frac{\delta E\left[L^{NT} \mid X\right]}{\delta x_k}$	$\frac{\delta E\left[L^{NT} \mid X, L^{NT} > 0\right]}{\delta x_k}$
Opportunity Cost	-1.49***	-0.13***	-0.40***
	[0.41]	[0.03]	[0.10]
Head	3.78	0.34	1.01
	[18.31]	[1.70]	[4.87]
Male	56.44***	4.98***	13.19***
	[15.21]	[1.75]	[3.23]
Age	5.27**	0.08	0.20
	[2.48]	[0.06]	[0.19]
Age^2	-0.07**	-	-
	[0.03]		
Educ	-4.90**	-0.43**	-1.30**
	[2.03]	[0.19]	[0.53]
HH-elem	-15.34**	-1.34**	-4.08**
	[7.62]	[0.66]	[2.02]
HH-sec	-8.74	-0.76	-2.33
	[7.39]	[0.65]	[1.97]
Adults	5.34	0.46	1.42
	[5.99]	[0.51]	[1.59]
Dependent	0.11	0.01	0.03
	[3.77]	[0.33]	[1.00]
Tradition	28.61**	2.63*	7.39**
	[12.48]	[1.39]	[3.22]
Year	-30.18***	-2.70***	-7.74***
	[8.83]	[0.92]	[2.08]
Constant	-90.19*	-	-
	[46.53]		
Observations		683	
χ^2 (Exogeneity test)	17.74		

Cluster robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

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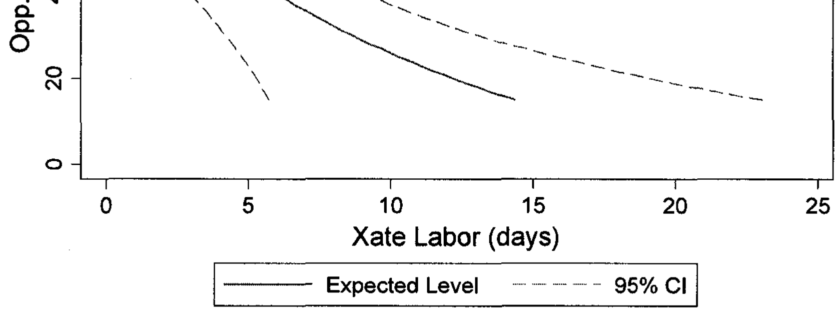
[18] These result holds because it can be shown that the adjustment factor in the marginal effects of the truncated and censored mean will always be non-negative (Wooldridge, 2002).

In many empirical applications only the marginal effects on the latent variable mean, equation (2.3), are reported. Nevertheless, as argued by Wooldridge (2002), in some situations the latent variable might not have any quantitative meaning. The latter is especially true when the model comes from a corner solution, as in our case when interest is centered on marginal effects on the censored and truncated means.

An additional complication is that the marginal effects in a tobit model, like other non-linear models, are not necessarily constant (as they are in an ordinary least squares model), and they can be different for each observation. Furthermore, the marginal effects need not be linear. This implies that the interpretation of marginal effects is not straightforward, and the information that a single number can convey is limited.

Figure 2.1. ***Xate*** **Labor Supply for** ***Xateros*** **and Non-*****xateros***

$\left(E\left[L^{NT}|X\right]\right)$

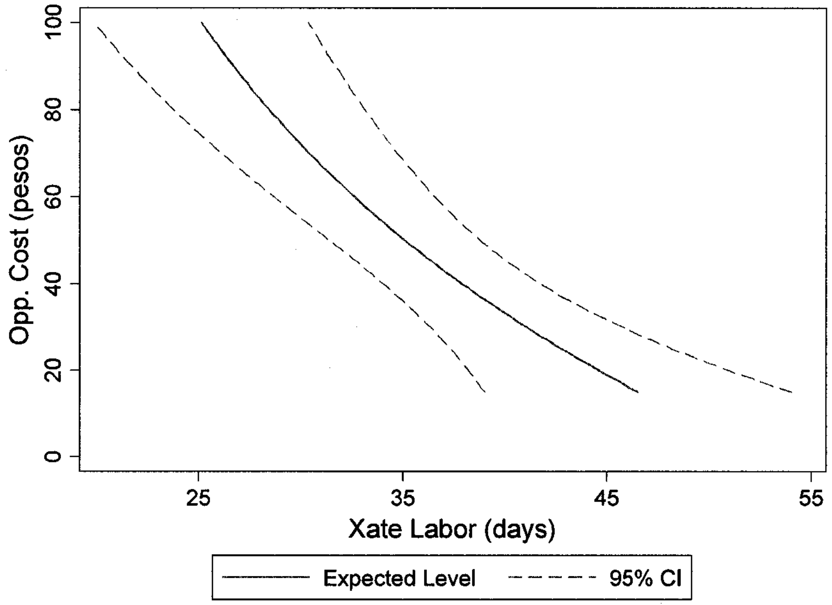


Note: All variables except opp. cost are set at mean values

The marginal values for the truncated and censored means can be calculated in at least three different ways: using average values of the explanatory variables; calculating the marginal effect for each observation and then obtaining the average; or calculating the marginal effects for some "typical" observations (Kennedy, 2003). To obtain the estimated effects presented in Table 2.3, in equation (2.5) I replace X with $\overline{X}$ (and $\boldsymbol{\beta}$ with $\widehat{\boldsymbol{\beta}}$), while in equation (2.4) I replace X with the average values of those individuals who participated in *xate* extraction.

Figure 2.2 ***Xate*** **Labor Supply for** ***Xateros***

$\left(E\left[L^{NT} | X, L^{NT} > 0\right]\right)$



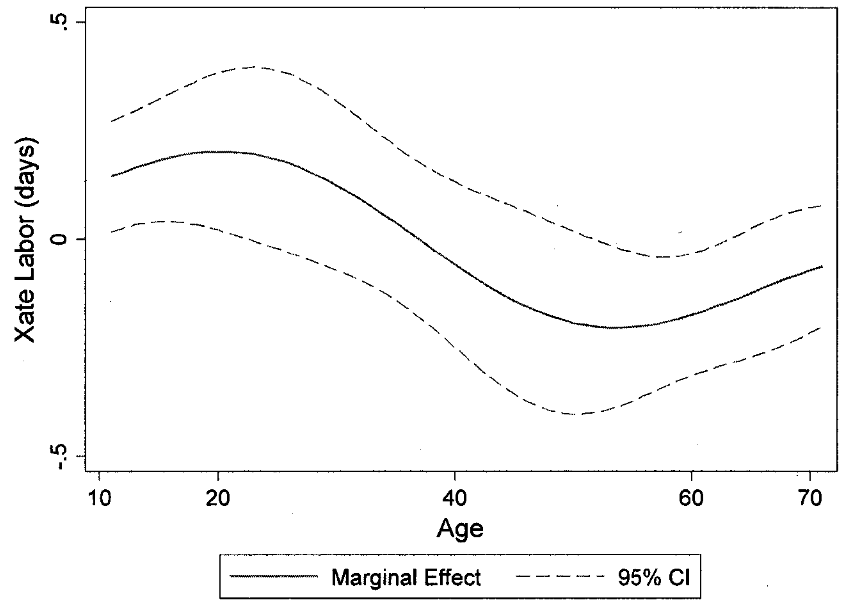
Note: All variables except opp. cost are set at mean values

Table 2.3 shows that the opportunity cost of time has a negative and significant effect on the allocation of labor to *xate* extraction. The higher the income that an individual can earn in a day of work in non-*xate* activities, the lower the number of days that he will allocate to *xate* extraction.

The relationship between opportunity cost and *xate* labor allocation is negative and nonlinear. This can be seen more clearly by looking at figures 2.1 and 2.2. These figures display the censored and truncated expected values of *xate* labor, $E\left[L^{NT} \mid X\right]$ and $E\left[L^{NT} \mid X, L^{NT} > 0\right]$, respectively, as a function of the opportunity cost of time. They allow us to differentiate the impact that a change in the opportunity cost will have on the whole population (combining a change in the probability of participation with a change in days of participation) from the impact that it will have on those participating in the activity before the change.

Figure 2.3. Marginal Effect of Age on the Expected Level of *Xate* Work for *Xateros* and Non-*Xateros*

$\left(\delta E\left[L^{NT}|X\right] / \delta x_{age}\right)$



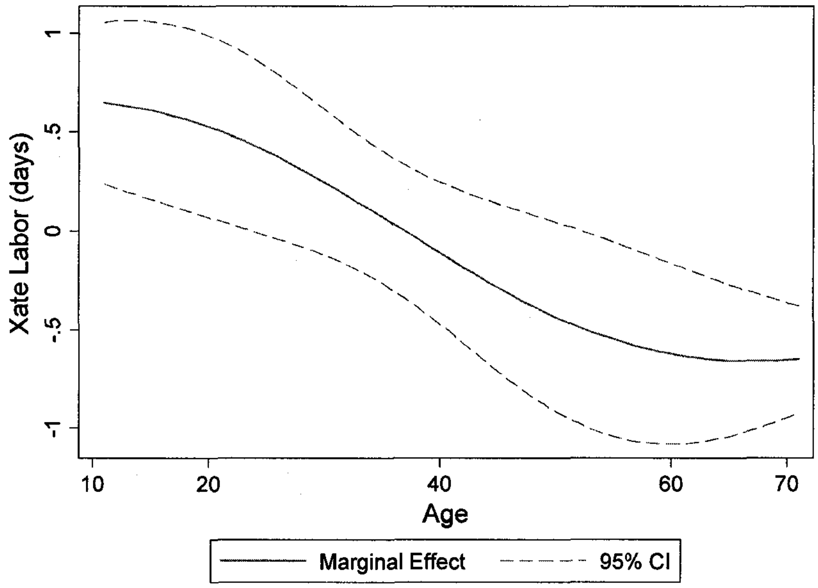
Note: All variables except Age are set at mean values

Figure 2.1 shows that if the opportunity cost is equal to 40 pesos (approximately US$4) per day, the expected *xate* labor supply of the average individual is 6 days. If the opportunity cost increases to 80 pesos the expected *xate* labor supply is less than one day. Figure 2.2 depicts the expected *xate* labor supply for those who participate in extraction. For this group, the expected *xate* labor supply is almost 30 days if the opportunity cost is equal to 40 pesos and more than 40 days if its equal to 80 pesos.

The indirect effect that the individual and household education variables have on *xate* labor allocation through their effects on income-generating capabilities in other activities is captured by the opportunity cost. The direct effect of the education variables is statistically significant (except for household secondary education). A negative effect of education is consistent with distaste for *xate* work for individuals from relatively educated households.

Figure 2.4. Marginal Effect of Age on the Expected Level of *Xate* Work for *Xateros*

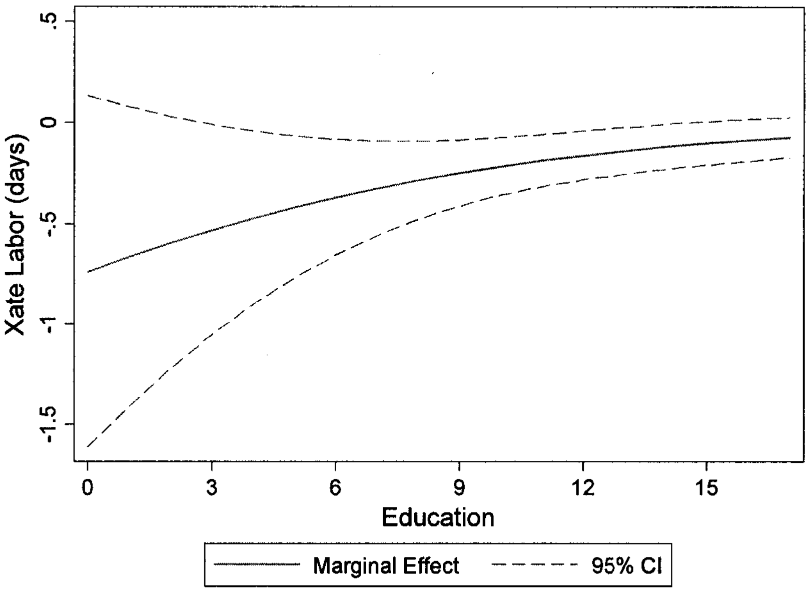
$\left(\delta E\left[L^{NT}|X,L^{NT}>0\right]/\delta x_{age}\right)$



Note: All variables except Age are set at mean values for xateros

Figure 2.5. Marginal Effect of Education on the Expected Level of *Xate* Work for *Xateros* and Non-*Xateros*

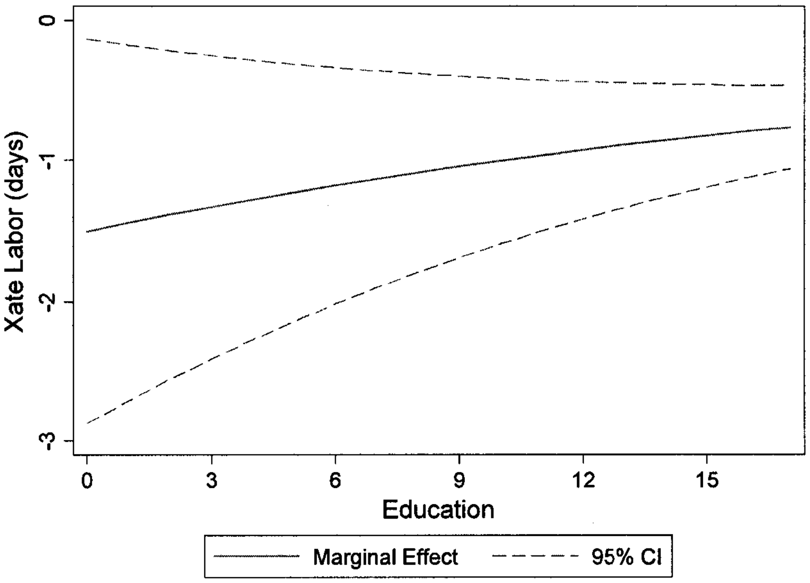
$\left(\delta E\left[L^{NT}|X\right]/\delta x_{educ}\right)$



Note: All variables except Education are set at mean values

Figure 2.6. Marginal Effect of Education on the Expected Level of *Xate* Work for *Xateros*

$\left(\delta E\left[L^{NT}|X,L^{NT}>0\right]/\delta x_{educ}\right)$



Note: All variables except Education are set at mean values for xateros

As anticipated, family history of participation in gathering and harvesting of natural resources has a positive impact on wild *xate* exploitation. This variable could be capturing a higher marginal productivity of labor allocated to *xate* extraction due to familiarity with extractive activities, a preference for working in the rainforest, or a combination of the two. The negative sign of the year-dummy coefficient could be the result of decreasing availability of the resource (as claimed by the inhabitants of the community). However, it also could be due to an increase in off-farm employment options, or to other time-varying village variables. The allocation of effort to *xate* extraction follows a concave pattern with respect to age, reminiscent of a Mincerian earnings equation. This and a positive sign of the coefficient on the male dummy variable are in part explained by the fact that extracting *xate* from the rainforest is a physically demanding activity. Nevertheless, it should be acknowledged that females and individuals at either end of the age distribution are less likely to participate in *any* activity.

The second and third columns of Table 2.3 report the marginal effects of a change in each explanatory variable on the number of days allocated to *xate* extraction for everybody and for *xateros*, respectively. Results show that the average male (*xatero* or not) works five days more per-year in *xate* extraction than the average female (column 2). An average *xatero* from an "extractive family" (i.e., Tradition=1) will work seven days more per-year in *xate* than an individual from a non-extractive family (column 3).

Although these results provide useful information, with the aid of graphical analysis we can gain a better understanding of how the marginal effects change depending on the values of the explanatory variables. In particular, the marginal effects might be statistically different from zero for some values of the dependent variables but not for others (see for example the marginal effects for age). Figures 2.3 to 2.6 illustrate how the marginal effect of a change in age and individual education changes depending on the original value of these variables. Similar figures could be presented for all variables in Table 2.3; however, for the sake of brevity I concentrate on only these two variables. Furthermore, the marginal effects implied by changes in opportunity cost can be inferred from the slopes of figures 2.1 and 2.2. In Figure 2.3, the marginal effect of a change in age is positive and increasing for individuals below 24 years of age but decreasing and even negative for those over 40 years. Figure 2.4 shows that the marginal effect is positive but decreasing for *xateros* younger than 38 years of age and negative thereafter. Figures 2.5 and 2.6 show that, although an additional year of education decreases *xate* labor supply, the direct effect of schooling decreases as education levels increase.

2.4. Conclusions

This essay identifies some of the basic factors shaping the allocation of labor to non-timber forest product extraction using data from a sample of village households in Chiapas, México. The opportunity cost of time, which is partially explained by human and physical capital, is negatively related to participation in NTFP extraction. In addition, even when accounting for the indirect effects of human capital on labor allocation to NTFP via the returns in other activities, individual and household education both have a negative effect on *xate* labor allocation. This suggests that individuals with high levels of education have a distaste for *xate* extraction work, and other things (including the wage) being equal, would prefer to work in alternative activities.

Policies that increase off-forest employment alternatives and thus the opportunity cost of time are likely to result in decreases in labor allocated to *xate* extraction. Nevertheless, it is likely that access to these new opportunities will not be homogenous. In particular, those with low levels of education might not be able to participate in other activities. New employment opportunities might still indirectly benefit those who extract NTFPs if they lower pressure on the resource (by diverting labor to non-*xate* activities) and if this is reflected in increases in NTFP harvest rates.

On the other hand, while an increase in the price of the NTFP will lead to a short-run improvement in the economic condition of extractors (see Essay 1), it might have a neutral or even negative effect on welfare in the long-run. An increase in price implies a reduction in the differential between the opportunity cost of time and the revenue from a day of work in extraction activities, increasing the optimal amount of labor that some households allocate to extraction. An increase in the supply of NTFP labor could then result in lower harvest rates per-unit of effort for each and every participant in the activity (see Essay 3).

In the long run the income effect of policies that increase off-forest employment or the price of the NTFP will depend upon interrelationships between the NTFP labor supply and the growth rate of the resource.

2.5. Appendix: Estimating the Opportunity Cost of Xate Labor

Jacoby (1993) and Skoufias (1994) developed a general methodology to estimate the supply of labor for agricultural households whose members do not work for wages. The methodology that they propose does not require the imputation of a value of time from a small group of wage laborers to a larger group of self-employed. The main steps of the procedure are as follows: 1) an agricultural production function for the household is estimated (Cobb-Douglas is the preferred production function in both papers); 2) based on the estimates of the agricultural production function the marginal product is estimated, and; 3) total labor supply at the individual level is estimated using shadow wages as one of the regressors.

A similar methodology is used in this essay as the basis to estimate the opportunity cost of a day of work in *xate*. In the theoretical model presented in section 2.2 households decide how to allocate labor between *xate* extraction and all other possible productive activities. This distinction is used when estimating the opportunity cost of a day of work in *xate*. The value of households' production in all the non-*xate* activities $\left(Q_{it}^{O} = p_{t}^{O} * q_{it}^{O}\right)$ is used to estimate a Cobb-Douglas production function. All of the households in the sample participate in non-*xate* activities; therefore, there is no selectivity problem when estimating this aggregate production function.

I account for the potential endogeneity of inputs resulting from correlation with time-invariant unobserved factors by using panel data methods. Using the balanced panel of households (86 observations for two periods) three models are estimated: OLS, fixed-effects and random-effects (Table 2.4). A Hausman test of the random versus fixed-effects specification fails to reject the random model. In practice, the parameter estimates under the three specifications are very similar and the results of estimating labor allocation are not sensitive to the choice of specification.

Table 2.4. Cobb-Douglas Non-*Xate* Production Function

OLS, Fixed Effects and Random Effects

Dependent Variable: ln non-*xate* production	OLS	FE	RE
Lnnonxwork	0.75***	0.75***	0.74***
	[0.06]	[0.09]	[0.06]
Lninpu	0.10***	0.09**	0.10***
	[0.02]	[0.03]	[0.02]
Lnarea	0.21**	0.24	0.21**
	[0.09]	[0.15]	[0.09]
Lncatt	0.15***	0.06	0.15**
	[0.06]	[0.12]	[0.06]
Lneduc	0.06	-0.15	0.06
	[0.07]	[0.35]	[0.07]
Lnhhprim	-0.05	-0.04	-0.05
	[0.10]	[0.25]	[0.10]
Lnhhsec	0.04	0.10	0.04
	[0.10]	[0.32]	[0.11]
Capital	0.58***	-0.39	0.54***
	[0.20]	[0.44]	[0.21]
Constant	4.42***	4.71***	4.43***
	[0.35]	[0.70]	[0.35]
Observations		172	
R^2	0.71	0.63	0.60
$\chi^2(8)$			7.66
Prob>χ^2			0.47

* significant at 10%; ** significant at 5%; *** significant at 1%

Based on the random-effects estimates, the household-level opportunity cost of a day of work was derived using the following expression:

$$\hat{w}_{it} = \frac{\hat{Q}^{O}_{it}}{L^{O}_{it}} \hat{\beta}_{L^{O}}$$

where $\widehat{Q}_{it}^{O}$ denotes the fitted value of non-*xate* production by household i in year t, L_{it}^{O} is labor allocated by the household to the non-*xate* activity, and $\widehat{\beta}_{L^O}$ is the coefficient on the log of labor (0.74 from Table 2.4).

Column one of Table 2.5 shows the mean of the estimated opportunity cost for both *xateros* and non-*xateros*. The difference in means illustrates that those who extract *xate* have a lower opportunity cost of time than those who do not.

In order to validate the results obtained by the method outlined above (the "Cobb-Douglas" method from now on) I estimate the opportunity cost of time using an alternative method (the "Direct" method). Following the procedure used by Fisher et al. (2005), this method uses the ratio of non-*xate* profits to non-*xate* family labor.

Table 2.5. Differences in Opportunity Cost

	"Cobb-Douglas" method (mean)	"Direct" method (mean)
Non-Extractors (pesos per-day)	59.39	66.16
Extractors (pesos per-day)	46.94	51.56
Difference	12.44***	14.60**

** significant at 5%; *** significant at 1%

Column 2 of Table 2.5 presents the results obtained using this second method. The opportunity cost for both groups (*xateros* and non-*xateros*) are very similar across the two methods. Furthermore, the mean values estimated under both methods are similar to the average agricultural wage in the community, 48 pesos per day. The evidence suggests that the opportunity cost estimated by the “Cobb-Douglas” method is a sensible estimate of the opportunity cost of time. In the econometric estimation of the determinants of labor allocated to *xate* extraction we use this (the Cobb-Douglas) method to measure of opportunity cost.

Essay 3: Poverty and Spatial Dimensions of Non-Timber Forest Extraction

3.1. Introduction

It has been argued that the commercial extraction of non-timber forest products (NTFPs) has the potential to promote forest conservation and alleviate poverty. Nevertheless, there is insufficient evidence to support this view. In fact, a number of studies conclude that the effects of extraction on forest conservation and poverty reduction are ambiguous or even negative (Browder, 1992; Wunder, 2001; Lybbert et al., 2002; Angelsen and Wunder, 2003).

In this essay I present a theoretical model that analyzes allocation of labor to NTFP extraction under unmanaged and managed common property regimes. The emphasis is on understanding the role of NTFP extraction in poverty alleviation as well as the challenges that extraction across space implies in terms of managing the resource. The theoretical analysis is complemented by an empirical analysis of the *xate* palm, a NTFP that has the potential to reduce poverty in the short run (see Essay 1).

The next section presents the theoretical model and its solution under the base scenarios of managed and unmanaged common property. Section 3.3 describes the solution to the theoretical model under the assumption of unmanaged common property with heterogeneous and constrained labor. The implications of NTFP extraction on poverty are analyzed in section 3.4. Section 3.5 presents the case study and section 3.6 concludes.

3.2. Extraction of NTFP Over Space

The number of theoretical studies that analyze NTFP extraction is limited. Among existing studies the ones most directly related to the present work are Robinson et al. (2002) and Gunatileke and Chakravorty (2003). Robinson et al. (2002) analyze the spatial aspects of NTFP extraction using a single-period model. In this model it is assumed that all members of a village consume the resource, which is acquired either by extraction or by purchase. Access to markets is affected by transaction costs that are assumed to be homogenous at the village level. Heterogeneity in villagers' opportunity cost of labor leads to heterogeneity in extraction behavior. As a result, individuals can be classified as subsistence, net-buyers or net-sellers of the resource. The study concludes that transaction costs can have an important effect on the spatial pattern of extraction. Policies whose objective is to diminish these costs will have different impacts on extraction patterns depending on a village's internal composition (i.e., the distribution of opportunity costs across village members).

Heterogeneity in opportunity costs is a feature of the present analysis, as well; however, contrary to Robinson et al., this essay focuses on a NTFP that is a source of income for extractors but not consumed domestically. The minimum consumption requirement is a sensible assumption for NTFPs such as fuelwood or perhaps construction materials, but not for resources whose main destinations are national and international markets (e.g., allspice, rubber, or *xate*). The latter are the types of NTFPs for which the present theoretical model is suited.

Gunatileke and Chakravorty (2003) propose a spaceless dynamic model of extraction. They assume that the resource is sold but not consumed by extractors. In order to maximize the discounted value of income the community decides, as a single owner, how much labor should be allocated to agricultural activities and how much to extraction. While I maintain the no-consumption assumption, my analysis differs from that of Gunatileke and Chakravorty in that it considers the spatial aspects of extraction as well as the solution to a problem based on non-cooperative individuals. The non-cooperative solution is not only a good benchmark but it is also the status quo under many NTFP extraction regimes.

3.2.1. A Theoretical Model of NTFP Extraction Over Space

The resource that is being modeled is a marketable NTFP whose extraction is labor intensive. Space is modeled in a single dimension. Extraction takes place in day trips and the only variable input that extractors control is the allocation of their time. In particular, individuals decide how much of their day they will spend traveling to the extraction site and how much time they will spend harvesting the resource. By traveling a longer distance, extractors gain access to less exploited (and thus higher productivity) sites. However, they are left with less time to harvest once at the site.

Total harvest (i.e., harvest by all individuals during a period of time t) at a given point s in space is defined as $H_s = qE_sX_s$, where q is a harvesting constant coefficient, E_s is total effort applied, and X_s is the stock of the resource at distance s. Total effort is defined as $E_s = (T-2s)L_s$, where T is the fixed number of hours that individuals allocate to NTFP work during a day; s is the number of hours walked to the place where the resource is extracted; and L_s is the total number of days worked in NTFP extraction during the period (say one year) at distance s by all individuals. Therefore, total harvest at s is:

$$H_s = q(T-2s)L_s X_s \tag{3.1}$$

I assume that, if left undisturbed, the resource will grow over time according to a logistic function. Other studies have used a logistic function to characterize the growth of harvestable populations of NTFPs (see Bhat and Huffaker, 1991; Bluffstone, 1995; and Gunatileke and Chakravorty, 2003). Therefore, the NTFP growth function under harvesting is represented by:

$$\dot{X}_s = rX_s\left(1-\frac{X_s}{K}\right)-H_s \tag{3.2}$$

where r is the intrinsic growth rate of the NTFP and K is the carrying capacity. I do not allow r and K to vary over space. In this way the spatial heterogeneity that the model predicts is due to differences in labor allocation and not growth rates or carrying capacities over space. The resource equilibrium biomass (i.e., the stock at which $\dot{X}_s = 0$) implies that the sustainable harvest at distance s (with L_s given) is equal to:

$$H_s = q\left(T-2s\right)L_s K\left(1-\frac{q}{r}(T-2s)L_s\right) \tag{3.3}$$

3.2.2. Unmanaged Common Property

The present analysis focuses on NTFPs that are common-pool resources, that is, for which (a) there is rivalry in appropriation, and (b) exclusion of potential appropriators or limitation of appropriation by existing users is nontrivial though not necessarily impossible (Ostrom et al., 1993). These resources can be held under different property rights regimes, the four basic categories being open access, private property, common property, and state property (Feeny et al., 1990). In this essay I concentrate on common property NTFPs.

When the resource is held under common property, all members of the community have access to it. Although no individual has exclusive property rights to the resource, the community can exclude outsiders from appropriation. I assume that this is enforced, and only the right-holders harvest the resource. In addition, the members of the community might establish agreed-upon rules and strategies to manage the resource. The absence of such rules is classified as *unmanaged common property*. The case in which the community members agree to follow a set of rules that lead to achieving a commonly set objective is classified as *managed common property.*

Following Gordon's (1954) seminal paper, under an unmanaged regime effort flows into each patch at distance s until the rents are dissipated. This implies that labor will be allocated to extraction at point s until total revenue (pH_s) is equal to total cost (wL_s). By making $pH_s = wL_s$, where H_s is defined by equation (3.3), p represents the price of the resource and w is the opportunity cost of one day of labor, this behavior leads, in equilibrium, to the following amount of labor being allocated to extraction at each point in distance:

$$L_s^{NM} = \frac{r}{q(T-2s)}\left(1-\frac{w}{pqK(T-2s)}\right) \tag{3.4}$$

Implicit in this solution is the assumption that there is enough labor locally to drive the system into a bioeconomic equilibrium in which rents are dissipated. Section 3.3.1 explores the implications of labor constraints that prevent this from happening.

The maximum distance that individuals travel to extract NTFP is given by:

$$s_{\max}^{NM} = \frac{1}{2}\left(T - \frac{w}{pqK}\right) < \frac{T}{2} \tag{3.5}$$

At any distance greater than $s_{\max}^{NM}$ the returns from a day of work in the forest are smaller than the opportunity cost of going to the forest. If the price of the NTFP is *too* low (i.e., if $p < w/TqK$) no extraction takes place.

The equilibrium stock of the resource in the scenario of unmanaged common property $\left(X_s^{NM}\right)$ is an increasing function of distance over the relevant range. At distances greater than $s_{\max}^{NM}$ no extraction takes place and the stock reaches the carrying capacity:

$$X_s^{NM} = \begin{cases} \dfrac{w}{pq(T-2s)} & \text{for } 0 \le s \le s_{\max}^{NM} \\ K & \text{for } s > s_{\max}^{NM} \end{cases} \tag{3.6}$$

Equation (3.9) shows that individuals who walk shorter distances extract less per-hour than those who travel farther. Nevertheless, those walking more have less time to expend extracting $(T-2s)$. In the end, in equilibrium, the productivity of a day of work in NTFP extraction is constant over distance (equation (3.8)). That is to say that all extractors obtain the same amount of product in a given day irrespective of the place where they extract. At the optimum, the total harvest, revenue per day, and harvest per hour are given by:

$$\text{Total harvest at } s = H_s^{NM} = \frac{wr}{pq(T-2s)}\left(1 - \frac{w}{pqK(T-2s)}\right) \tag{3.7}$$

$$\text{Revenue per day at } s = \frac{pH_s^{NM}}{L_s^{NM}} = w \tag{3.8}$$

$$\text{Harvest per hour at } s = \frac{H_s^{NM}}{L_s^{NM}(T-2s)} = \frac{w}{p(T-2s)} \tag{3.9}$$

3.2.3. Managed Common Property

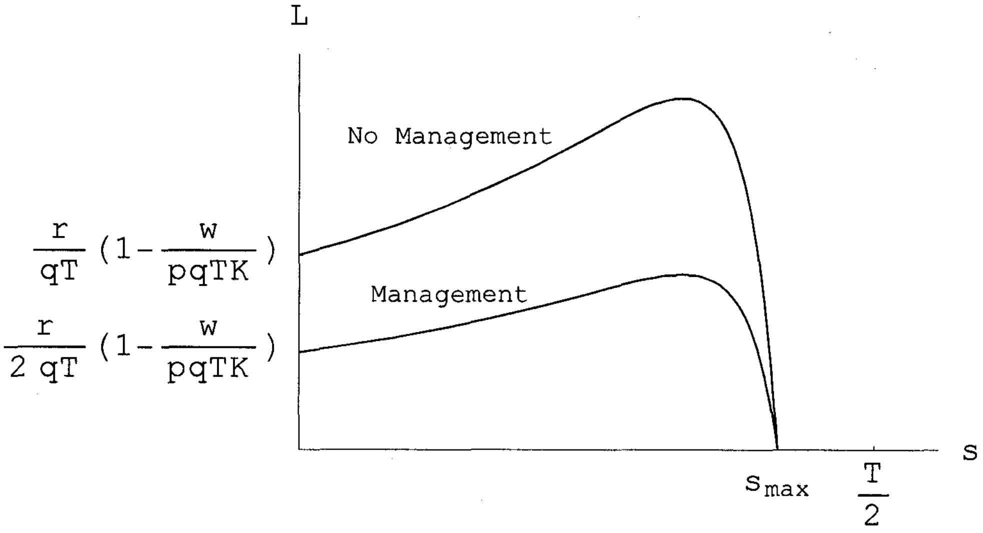
What are the possible gains that can be obtained by setting rules on the management of the resource, assuming that the community agrees to manage the resource in a manner that maximizes sustained net revenues? It has been shown that the maximization of sustained net revenues overlooks the dynamics of both economic and biological processes (see Clark, 1990). Nevertheless, it provides us with a starting point and a simple set of results to compare with the unmanaged case.

It can be shown that in this setting maximizing net revenues over space is equivalent to maximizing net revenue at each point. Therefore, the community seeks the allocation of labor that solves the following problem: $\underset{L_s}{Max}\ pH_s - wL_s$ at each distance s, where H_s is defined as in equation (3.3). The solution to this problem is:

$$L_s^M = \frac{r}{2q(T-2s)}\left(1 - \frac{w}{pqK(T-2s)}\right) \tag{3.10}$$

This shows that if the resource is managed to maximize sustainable economic rent the amount of labor allocated at each point is half of what is allocated under a situation of no management (equation (3.4)). Figure 3.1 illustrates how labor is allocated over space in the two scenarios. This result shows that when space is relevant the rules that need to be established to manage common property go beyond setting a maximum harvest rate or a maximum amount of effort; the community needs to set the effort level at each extracting point.

Figure 3.1. Allocation of Labor Over Space

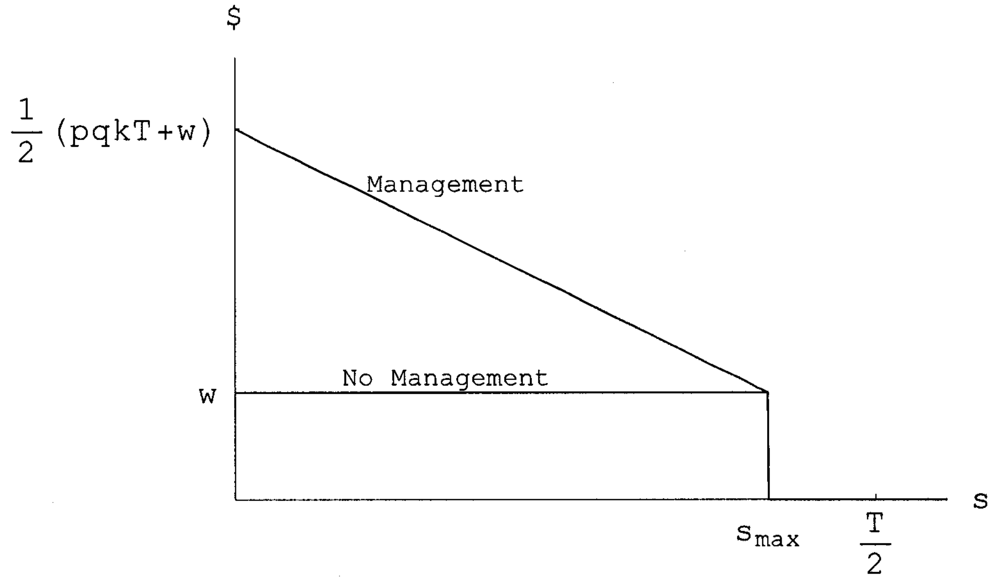


Although proposing a mechanism to achieve this coordination is beyond the scope of this work, I want to stress the importance of the spatial dimension in such a coordination scheme. If the community does not agree on a set of rules regarding both where to extract and how much labor to allocate at each extraction site, individuals face the incentive to extract in places with high returns, with the consequence that condition (3.10) will not be fulfilled.

Equation (3.11) illustrates how differences in labor allocated over space impact the equilibrium stock of NTFP, which is always higher for the managed resource than for the unmanaged one (equation (3.6)). In fact, under management, the stock of the resource is always higher than the stock that achieves the maximum sustainable yield (i.e., $K/2$).

$$X_s^M = \begin{cases} K\left(\frac{1}{2}+\frac{w}{2pqK(T-2s)}\right) & \text{for } 0 \le s \le s_{\max}^{NM} \\ K & \text{for } s > s_{\max}^{NM} \end{cases} \tag{3.11}$$

Figure 3.2. Revenue Per Day of Labor Over Space



Equations (3.12), (3.13), and (3.14) show community harvest, revenue per unit of labor, and harvest per hour at each point, when the resource is managed to maximize net revenues:

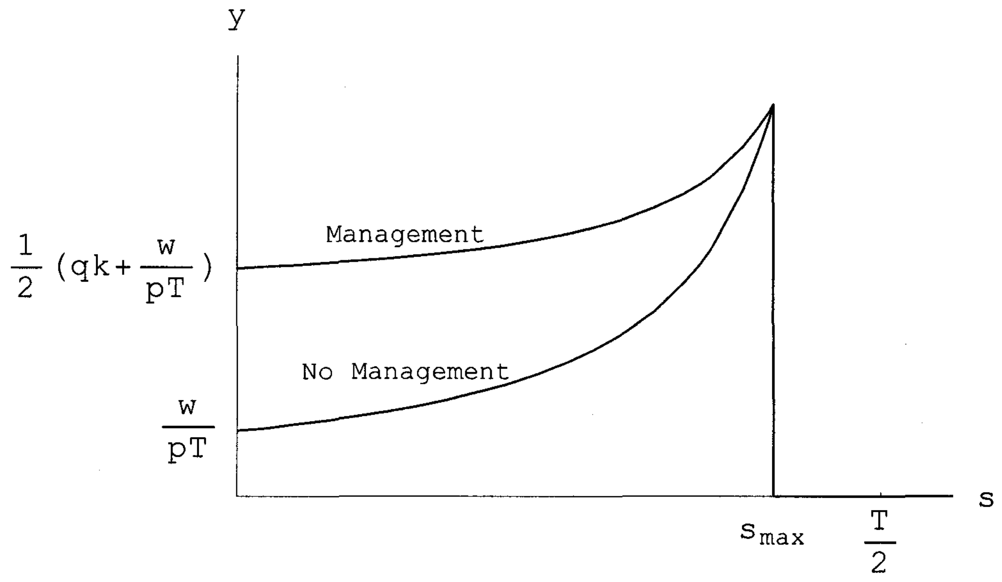
$$\text{Total harvest at } s = H_s^M = \frac{r}{4}\left(K - \frac{w^2}{p^2q^2K(T-2s)^2}\right) \tag{3.12}$$

$$\text{Revenue per day at } s = \frac{pH_s^M}{L_s^M} = \frac{1}{2}\left(pq(T-2s)K + w\right) \tag{3.13}$$

$$\text{Harvest per hour at } s = \frac{H_s^M}{L_s^M(T-2s)} = \frac{1}{2}\left(qK + \frac{w}{p(T-2s)}\right) \tag{3.14}$$

Figures 3.2 and 3.3 illustrate the latter two measures under the scenarios of managed and unmanaged common property. Arguably, the most important distinction between the two is that, under management, the value of a day of work in NTFP extraction is always higher than the opportunity cost of time, although it is decreasing. That is, under management each unit of labor receives more than its opportunity cost of time, which clearly would be an unstable situation without management.

Figure 3.3. Harvest Per Hour of Extraction Over Space



3.3. Unmanaged Common Property with Labor Constraints and Heterogeneous Labor

3.3.1. Labor Constraints

Section 3.2 shows that when there is enough labor available a common property resource that is not managed will be driven to a situation in which rents are dissipated. In a setting of pure open access the natural assumption to make is that there are no labor constraints. However, this is not necessarily the case with common property. To illustrate this, I add the assumption of relative shortage of local or community labor to the assumption that outsiders are excluded from extracting the common-pool resource. To clarify what is meant by a relative shortage of labor consider a case where, given the values of all parameters in the optimization problem, the amount of labor that leads to rent dissipation is greater than the labor available from the right-holders of the resource. That is, there is a relative shortage of labor if $\int_{s=0}^{s_{\max}} L_s^{NM} ds > \overline{L}$, where L_s^{NM} is defined as in equation (3.4) and $\overline{L}$ is total labor available.

How will this relatively limited amount of labor be distributed over space in equilibrium? From the solution to the case of unmanaged common property without labor constraints we know that in equilibrium individuals are indifferent across spatial allocations. The same principle holds here with the exception that, in the presence of a labor constraint, the returns from a day of work are higher than the opportunity cost of time. In order to make the mathematical problem more tractable, the NTFP is characterized as being distributed in a finite number of points over space instead of continuously as above.

Let's start solving this problem by finding the optimal allocation of labor over space for the case where there are only two points at which the resource is available, s_1

and s_2, where s_d measures the distance from the origin. Equilibrium is achieved when $\frac{H_{s_1}}{L_{s_1}} = \frac{H_{s_2}}{L_{s_2}}$. To find the equilibrium allocation of labor over space ($\overline{L}_{s_1}^{NM}$ and $\overline{L}_{s_2}^{NM}$) when there is a labor shortage, the following system of equations needs to be solved:

$$\begin{gathered} q(T-2s_1)K\left(1-\frac{q}{r}(T-2s_1)L_{s_1}\right) = q(T-2s_2)K\left(1-\frac{q}{r}(T-2s_2)L_{s_2}\right) \\ \overline{L} = \overline{L}_{s_1} + \overline{L}_{s_2} \end{gathered} \tag{3.15}$$

where equation (3.3) is used to substitute for H_{s_1} and H_{s_2}. The solution to this is:

$$\overline{L}_{s_1}^{NM} = \frac{-2r(s_1 - s_2) + q\overline{L}(T-2s_2)^2}{2q\left(2\left(s_1^2 + s_2^2\right) - 2(s_1 + s_2)T + T^2\right)} \tag{3.16}$$

$$\overline{L}_{s_2}^{NM} = \frac{-2r(s_2 - s_1) + q\overline{L}(T-2s_1)^2}{2q\left(2\left(s_1^2 + s_2^2\right) - 2(s_1 + s_2)T + T^2\right)} \tag{3.17}$$

Notice that price and wage do not affect the way in which labor is allocated over space once the labor constraint is binding. In this solution it has been implicitly assumed that although there is a labor shortage there is enough labor available to guarantee extraction in both places; this need not be the case. It can be shown that extraction at s_2 requires $\overline{L} > 2r(s_2 - s_1)/q(T-2s_1)^2$; otherwise extraction only takes place in the first patch; i.e., $\overline{L}_{s_1}^{NM} = \overline{L}$ and $\overline{L}_{s_2}^{NM} = 0$.

The procedure to find the labor allocation outlined above extends to J patches. The first step is to find the extensive margin of NTFP extraction, that is, how far in distance will extractors go? Depending on the amount of labor available, some places where extraction would take place if there were no labor constraints (i.e., places at a distance $s_i < s_{\max}^{NM}$) could be left unharvested. It can be shown that the minimum amount of labor that is needed for extraction to take place at a given distance S_e is:

$$L_{\min}^{S_e} = \frac{2r}{q}\sum_{i=1}^{e}\left(\frac{s_e - s_i}{\left(T-2s_i\right)^2}\right) \tag{3.18}$$

Equilibrium is achieved when $\frac{H_{s_1}}{L_{s_1}} = \frac{H_{s_2}}{L_{s_2}} =,\ldots,= \frac{H_{s_J}}{L_{s_J}}$. To uncover the optimal allocation of labor, a system of equations such as the following is solved:

$$\begin{gathered}
q\left(T-2s_1\right)K\left(1-\frac{q}{r}(T-2s_1)L_{s_1}\right) = q\left(T-2s_2\right)K\left(1-\frac{q}{r}(T-2s_2)L_{s_2}\right)\\
\vdots\\
q\left(T-2s_1\right)K\left(1-\frac{q}{r}(T-2s_1)L_{s_1}\right) = q\left(T-2s_J\right)K\left(1-\frac{q}{r}(T-2s_J)L_{s_J}\right)\\
\bar{L} = \sum_{i=1}^{J}\bar{L}_{S_i}
\end{gathered} \tag{3.19}$$

3.3.2. Labor Heterogeneity

Up until now it has been assumed that labor is homogenous in the sense that all individuals have the same opportunity cost of time and the same productivity in extracting the natural resource. This need not be the case. Individuals can have access to different labor alternatives and therefore have different opportunity costs of time, depending on their individual and household characteristics. Those characteristics might also affect productivity in the extractive activity. In this section the assumption of homogeneous productivity in the extractive activity is maintained but heterogeneity in the opportunity cost of time is considered.

Assume that there are two types of individuals with opportunity costs w_1 and w_2 where $w_1 < w_2$. Type-1 individuals, the low opportunity cost type, will allocate labor to extraction until the value of an additional day of work is equal to the opportunity cost of time. That is, until:

$$pq(T-2s)K\left(1-\frac{q}{r}(T-2s)L_{1s}\right)=w_1 \tag{3.20}$$

Under these conditions and considering that $w_1 < w_2$, type-2 individuals will not find it profitable to participate in NTFP extraction. Therefore, if the resource is not managed and labor is heterogeneous only those with a low opportunity cost of time participate in NTFP extraction, and they receive w_1 as payment for every time-unit of work.

$$\begin{aligned} L_{1s}^{NM} &= \frac{r}{q(T-2s)}\left(1-\frac{w_1}{pqK(T-2s)}\right) \\ L_{2s}^{NM} &= 0 \end{aligned} \tag{3.21}$$

Nevertheless, this is not the case when there is a relative shortage of type-1 labor $\left(\text{i.e., if } \int_{s=0}^{s_{\max}} L_s^{NM} ds > \overline{L}_1\right)$. Under these circumstances even though all type-1 labor is allocated to resource extraction, revenues for a unit of labor are higher than w_1. If in fact the value of the marginal product of a unit of labor is higher than w_2, then type-2 individuals will participate in NTFP extraction, as well. This requirement is captured in the following participation condition:

$$pq(T-2s)K\left(1-\frac{q}{r}(T-2s)\overline{L}_{1s}\right)> w_2 \tag{3.22}$$

where $\overline{L}_{1s}$ is labor allocated by type-1 workers when the labor constraint is binding. If the condition holds, then type-2 individuals allocate labor over space to extract the NTFP until:

$$pq(T-2s)K\left(1-\frac{q}{r}(T-2s)\left(\overline{L_{1s}}+L_{2s}^{NM}\right)\right)=w_2 \tag{3.23}$$

This assumes that that there is no labor shortage of type-2 individuals. Although the generalization of this problem to include more than two types of individuals as well as labor constraints in more than one type of individuals is straightforward, it is arithmetically tedious. Therefore, throughout this analysis I concentrate on the case in which there are two types of labor, only one of which is labor constrained.

To solve for the optimal allocation of labor over space under this scenario it is assumed, as in the previous section, that the NTFP is distributed discretely over space. We begin with the simplest case of only two points in space $(s_1 \text{ and } s_2)$ from which the resource can be extracted. In this case, the type-1 labor constraint will be binding if the solution to equation (3.4) for $s=s_1,s_2$ is such that $L_{1s_1}^{NM}+L_{1s_2}^{NM}>\overline{L}_1$. If this is the case the first step to find the solution is to solve for $\overline{L}_{1s}^{NM}$ using the procedure outlined in section 3.3.1. Accordingly, $\overline{L}_{1s_1}^{NM}$ and $\overline{L}_{1s_2}^{NM}$ are given by equations (3.16) and (3.17). To find the allocation of type-2 labor, the first thing to consider is whether or not the participation condition (equation 3.22) holds. If so, then type-2 labor will allocated according to the following rule:

$$L_{2s_1}^{NM}=\frac{r}{q(T-2s_1)}\left(1-\frac{w_2}{pqK(T-2s_1)}\right)-\overline{L}_{1s_1}^{NM} \tag{3.24}$$

$$L_{2s_2}^{NM}=\frac{r}{q(T-2s_2)}\left(1-\frac{w_2}{pqK(T-2s_2)}\right)-\overline{L}_{1s_2}^{NM} \tag{3.25}$$

If instead of two there are J points in space from which type-1 individuals extract the NTFP and the participation condition holds, then the allocation of type-2 individuals' labor will be:

$$L_{2s_i}^{NM}=\frac{r}{q(T-2s_i)}\left(1-\frac{w_2}{pqK(T-2s_i)}\right)-\overline{L}_{1s_i}^{NM} \quad \forall i=1,\ldots,J \tag{3.26}$$

where $\overline{L}_{1s_i}^{NM}$ is obtained as in section 3.3.1. Note that, depending on the specific value of $\overline{L}_1$, it might be the case that in equilibrium there are not enough type-1 individuals to extract as far as $s_{\max}^{NM}$ and they stop extraction at a point s_k. In this case type-2 individuals might still extract all the way up to $s_{\max}^{NM}$ as long as $s_{\max}^{NM}\leq\frac{1}{2}\left[T-\frac{w_2}{pqK}\right]$. The allocation of type-2 labor under this scenario is:

$$L_{2s_i}^{NM}=\begin{cases}\frac{r}{q(T-2s_i)}\left(1-\frac{w_2}{pqK(T-2s_i)}\right)-\overline{L}_{1s_i} & \forall i=1,\ldots,k\\ \frac{r}{q(T-2s_i)}\left(1-\frac{w_2}{pqK(T-2s_i)}\right) & \forall i=k+1,\ldots,J\end{cases} \tag{3.27}$$

3.4. NTFP Extraction and Poverty

3.4.1. Price Changes, Spatial Distribution of Extraction and NTFP Supply

One of the objectives of this essay is to evaluate the impacts that changes in the price of a NTFP can have on the welfare of extractors. A logical first step towards doing this is to analyze the derivatives of the interior equilibrium solutions to the extraction problem with respect to NTFP price. Table 3.1 summarizes these for both managed and unmanaged common property regimes (under the assumption of homogeneous and unconstrained labor). The exact formulas and proofs are presented in the appendix.

Under both regimes, price increases are reflected in increases in the amount of labor allocated at each point in space. Furthermore, the total area subject to extraction increases as distance traveled increases. The result of price increases is a lower equilibrium stock of the NTFP over space. Similarly, the amount of NTFP that can be harvested in an hour of work decreases as price increases under both regimes.

The impact that a change in price has on total harvest over distance can be decomposed into two effects. On one hand, a price increase results in an increase in labor, and this has a positive effect on total harvest. On the other, the decrease in the stock of NTFP available resulting from the price increase has a negative effect on total harvest. Under the management regime, the combination of these two effects always leads to an increase in extraction at each point in space. In contrast, when there is no management, total harvest can decrease at some distances. When prices are relatively low the positive effect that an increase in price has on labor allocated dominates the negative effect of a decrease in the stock of *xate*. However, the opposite happens when prices are relatively high. In particular, a price increase can have a negative effect on total harvest only if $p > 2w / qKT$, and even then, the effect is negative only at some distances.

Table 3.1. Responses to Price Changes

	No-Management	Management
Change in amount of labor across space $\frac{\delta L_s}{\delta p}$	+	+
Change in maximum distance traveled $\frac{\delta s_{\max}}{\delta p}$	+	+
Change in equilibrium stock over distance $\frac{\delta X_s}{\delta p}$	-	-
Change in harvest per hour of work over distance $\frac{\delta\left(H_s / L_s(T-2s)\right)}{\delta p}$	-	-
Change in revenue per day of work over distance $\frac{\delta\left(pH_s / L_s\right)}{\delta p}$	0	+
Change in sustainable net revenues over distance $\frac{\delta NR_s}{\delta p}$	0	+
Change in total harvest over distance $\frac{\delta H_s}{\delta p}$	≤ 0 if $s \leq s^0$ > 0 if $s^0 < s < s_{\max}$ where $s^0 = \frac{1}{2}\left(T - \frac{2w}{pqK}\right)$	+

Note: The signs of the derivatives with respect to wage are the opposite of those with respect to price with the exception of the derivative of revenue per day with respect to wage. The derivative is equal to 1 for the unmanaged case and to ½ for the managed one.

Total supply (i.e., harvest by all individuals aggregated over all extraction points) can be computed in order to gain a better understanding of the implications of price increases. To do so H_s^{NM} and H_s^{M} are integrated over distance to obtain the total supply of the common property NTFP. The results are as follow:

$$\text{Unmanaged Supply} = \int_0^{s_{\max}} H_s^{NM} ds = \frac{rw\left(w + KpqT*\left(Ln[\frac{KpqT}{w}] - 1\right)\right)}{2Kp^2q^2T} \tag{3.28}$$

$$\text{Managed Supply} = \int_0^{s_{\max}} H_s^{M} ds = \frac{r\left(w - KpqT\right)^2}{8Kp^2q^2T} \tag{3.29}$$

We know from Table 3.1 that the derivative of harvest with respect to price is positive for all distances when the maximization of net revenues obtained from NTFP extraction is the objective. Therefore, it should also be the case that the supply of NTFP is a positive function of price. In other words, under a managed common property regime the supply of NTFP is a *regular* supply function. This is confirmed by taking the derivative of equation (3.29) with respect to price using Leibniz rule.

When the resource is not managed (equation 3.28) and the price is high ($p > 2w/qKT$) the derivative of harvest with respect to price is positive over some distance ranges and negative over others. At relatively high prices, the supply can be a decreasing function of price due to overexploitation of the resource. We can find the price at which the slope of the supply curve becomes negative by taking the derivative of equation (3.28) with respect to price. Using Leibniz' rule, this derivative is equal to:

$$\frac{\delta\left(\int_0^{s_{\max}} H_s^{NM} ds\right)}{\delta p} = \frac{rw\left(KpqT*\left(Ln[\frac{w}{KpqT}] + 2\right) - 2w\right)}{2Kp^3q^2T} \tag{3.30}$$

The price that makes this derivative equal to zero is implicitly defined by the equation:

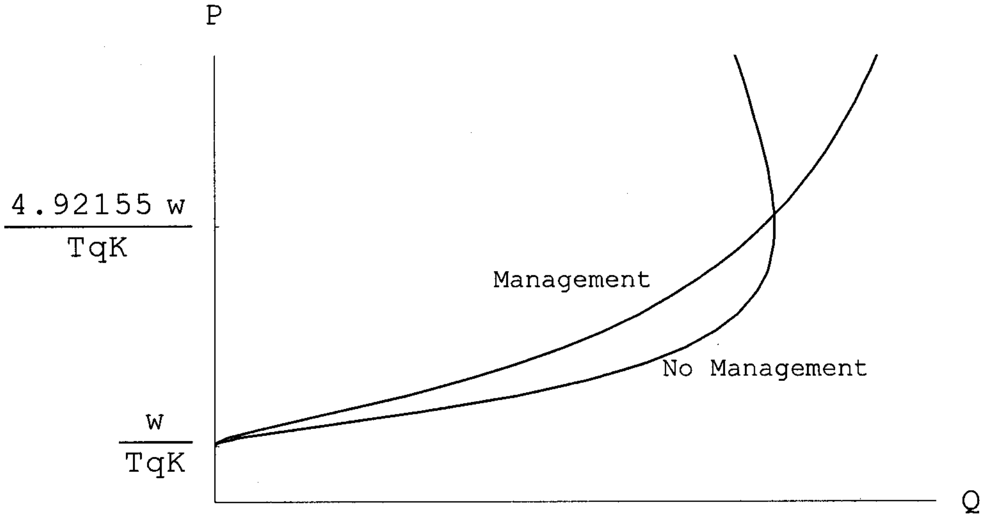
$$Ln[\frac{w}{KpqT}] + 2 = \frac{2w}{KpqT} \tag{3.31}$$

The solution to equation (3.31) was numerically approximated using *Mathematica* as:

$$p_{back} \approx \frac{4.92155w}{KqT} \tag{3.32}$$

Therefore, when there is no management, the NTFP supply has a positive slope as long as $w/qKT < p < p_{back}$. When the price is higher than p_{back} the slope of the supply curve becomes negative. Figure 3.4 shows how the supply of the resource bends backwards when the price is *too* high. If one is interested in the conservation of the stock of the NTFP this backward-bending NTFP supply is not good news, inasmuch as it derives from an overexploitation of the resource.

Figure 3.4. Non-Timber Forest Product Supply



From the extractor's welfare point of view, the most important impact is the effect of the price change on revenue per day of work. When the resource is managed by the community to maximize sustainable net revenues, a price increase has an unambiguous positive impact on revenues per day. In contrast, when the resource is not managed, rent is dissipated at all distances, implying that the revenue per day of work is equal to the opportunity cost. This means that price increases have no impact on the revenue that extractors receive from a day of extraction.

Under these circumstances, the implementation of price mechanisms does not improve the welfare of NTFP extractors. Consider a policy whose main objective is to alleviate poverty via the introduction of a price premium. Providing the price premium in the absence of management results in an increase in the number of days allocated to extraction and in distance traveled. Nevertheless, extractors receive the same net revenue as before (i.e., w) for a day of work. If w is the wage earned in an alternative employment activity, then the only effect of the NTFP premium will be a reallocation of labor from the alternative activity to resource extraction. Notice that although the price increase could ultimately result in a decrease in the quantity of NTFP supplied (see Figure 3.4), the effect of a price increase is always neutral in terms of revenue per day of extraction.

In spite of these discouraging results, under some circumstances it is possible for an unmanaged common property resource to contribute towards poverty alleviation. This possibility is analyzed in the next section, which considers price changes when the resource is not managed and there is a binding labor constraint. In this case price changes do not have an effect on extraction but they do affect revenues. If, in addition, labor is heterogeneous, the positive effect of a price increase on revenue prevails as long as the high-opportunity-cost individuals do not participate in extraction.

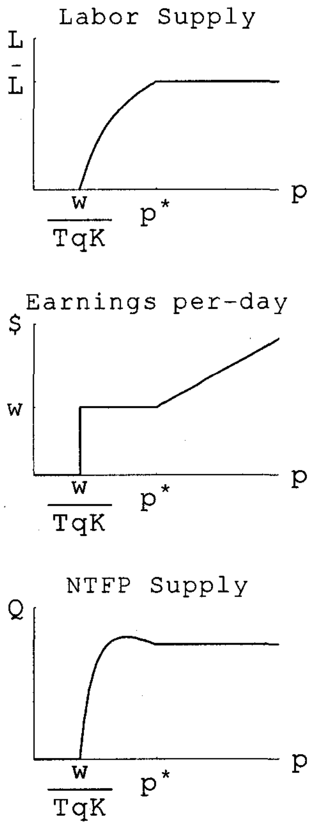
3.4.2. Extraction and Poverty with Labor Constraints and Heterogeneity

The results of the previous section show that, when there is no management of the common pool resource, revenue from a day of work in extraction is equal to the opportunity cost of time. Rent dissipation in the unmanaged regime is a consequence of the assumption of the relative abundance of labor. In section 3.3.1 this assumption was relaxed and I showed that if a relatively small group owns the resource, they can earn from extraction more than their opportunity cost of time even if they do not have any internal rules to manage it.

The labor constraint could be binding depending on the specific values of the parameters of the problem. Consider the case where all parameters except price are fixed. Then there is a price that makes the amount of total labor allocated to extraction equal to the labor available from the right holders of the resource. That is, there is a price p^* at which $\int_0^{s_{\max}} L_s^{NM} ds = \bar{L}$, where L_s^{NM} is defined as in equation (3.4) and $\bar{L}$ is total labor available in the community. If outside labor is effectively excluded from extracting the resource, a price increase above p^* will not change the supply of the NTFP or the allocation of labor, but it will increase the income received by individuals above and beyond their opportunity cost of time.

Figure 3.5 illustrates these results. For $w/TqK < p < p^*$, the supply of labor is increasing as price increases, while earnings per day remain constant at w. On the other hand, when $p > p^*$, earnings per day become an increasing function of price. As soon as $p = p^*$, all available labor is allocated to extraction; therefore, NTFP supply is constant for all $p > p^*$.[19] Under this institutional setting a policy that introduces a NTFP price premium can in fact have a positive impact on the income received by extractors, even without the need to coordinate behavior.

Figure 3.5. Solutions Under Relative Scarcity of Labor



Another possible setting is the one analyzed in section 3.3.2 with labor being not only constrained but also heterogeneous. The relative scarcity of low opportunity cost

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[19] Note that in the case illustrated in Figure 3.5 the slope of the NTFP supply becomes negative before $p = p^*$. This result is a consequence of the specific values of the parameters used and is therefore not a necessary conclusion of the model.

labor (i.e., $\overline{L}_1 < L_1^{NM}$) implies that type-1 individuals receive a return for their participation in NTFP extraction that is higher than their opportunity cost of time. In this situation, price increases can reduce poverty, although earnings per day of work do not increase continuously with respect to price as they do when labor is scarce but homogeneous (and $p > p^*$).

Figure 3.6. Solutions Under Relative Scarcity of Heterogeneous Labor

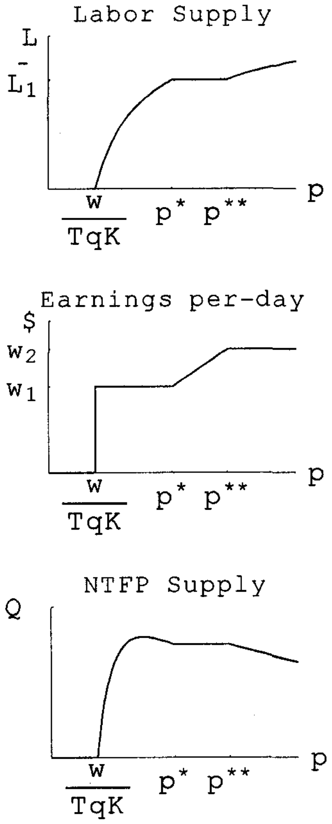

Figure 3.6 illustrates this when there are two types of individuals. Along the price range $\left(\frac{w}{TqK}, p^*\right)$ the supply of labor from type-1 individuals increases as price

increases, and all receive w_1 for a day of work. Beyond p^*, all type-1 labor is allocated to extraction. Although type-2 individuals could reallocate labor from other activities to extraction, they do not do so until the price is right, that is, until price is such that earnings per day are equal to w_2. The price at which this happens in Figure 3.6 is p^{**}. Therefore, in the price range $\left[p^*, p^{**}\right]$ the supply of labor and NTFP remain constant, while earnings per day increase with price. When the price surpasses p^{**}, type-2 individuals enter into extraction, and earnings per day are constant at w_2.[20]

Although the level that revenue per day of extraction can reach is bounded by w_2, a price premium can have a positive impact on the income received by extractors as long as the original price is between p^* and p^{**}. Furthermore, NTFP extractors can indirectly benefit from an increase in w_2 when that implies a reduction in the amount of labor that type-2 individuals allocate to NTFP extraction.

3.5. Case Study: The *Xate* Palm in the Lacandona Rainforest

I use an original data set to illustrate some of the results derived in the previous sections. The data come from the two household surveys carried out in Frontera Corozal, México, during the years 2001 and 2004. (For more detail on the case study see the introduction to this dissertation.) The analysis focuses on the resource *xate* palm (*Chamaedorea* spp.),

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[20] In Figure 3.6 the slope of the NTFP supply is negative before p^* and it becomes negative again after p^{**}. As was the case with Figure 3.5, the price at which this slope becomes negative depends on the parameters of the problem. Although in the figure this happens before p^* is reached it could as well be the case that the slope becomes negative at a price well above p^{**}.

a marketable NTFP. *Xate* extraction in the rainforest is a physically demanding and risky activity that involves walking long distances (a one way trip takes an average 3 hours).

Table 3.2. Descriptive Statistics

Variable	Description	Mean	(s.e.)
Dxselv	1= Participates in *xate* extraction	0.15	
Head	1= Individual is head of household	0.252	
Male	1= Male	0.534	
Age	Age in years	30.180	(14.876)
Educ	Years of education	4.857	(3.659)
HH-elem	Number of household members (except individual) with elementary school completed (6 years)	1.568	(1.491)
HH-sec	Number of household members (except individual) with at least 9 years of education	1.117	(1.236)
Adults	Number of adults in the household [13, 59] years old	5.100	(2.490)
Dependent	Number of children and elderly in the household	2.368	(1.430)
Land	Hectares of land (at beginning of the period)	46.138	(20.374)
Capital	1= Owns a car or a boat (at beginning of the period)	0.119	
Cattle	Number of animals owned (at beginning of the period)	3.811	(10.677)
Assets	Index of dwelling characteristics and assets (Principal Components Analysis)	0.649	(0.224)
Tradition	1= Parents of household head and/or spouse have a history of non-timber forest products extraction	0.444	
Year	1= 2004	0.514	
N	Pooled observations (individuals older than 12 years)	683	

The surveys provide socio-demographic information and data on labor allocated to NTFP extraction for all household members. Table 3.2 presents some descriptive statistics estimated from the survey data. In addition to these variables, the 2004 round of the survey gathered information on the time traveled by each individual to the places where they extracted the resource in day trips.

In Frontera Corozal, community members have exclusive rights to extract natural resources from the contiguous rainforest. Nevertheless, there are no community rules on how these resources, including *xate*, should be managed (Sánchez-Carrillo and Valtierra-Pacheco, 2003; Tejeda, 2004). *Xate* can therefore be considered as an unmanaged common property resource.

3.5.1. Xate Extraction Over Space

The returns from an hour of work at a given extraction site can be calculated for the 2004 sub-sample. Using this information I can illustrate (Figure 3.7 and Table 3.3) how, as predicted by the theoretical model (equation (3.9)), the amount of resource extracted in an hour of work is an increasing function of the distance walked. Figure 3.8 and Table 3.4, on the other hand, show how extraction per day of work is practically constant with respect to distance. That is, as expected from equation (3.8), the returns of a day of work are equalized across extractors, irrespective of distance traveled to the extraction point.

3.5.2. Xate Extraction and Opportunity Cost of Time

In section 3.3.2 I showed that, when there is heterogeneity in the opportunity cost of time, those with a relatively low opportunity cost are the ones who extract the unmanaged common property resource. This section presents the results of an econometric test of this hypothesis. Specifically, it uses the Frontera Corozal data set to estimate the effect

Figure 3.7. ***Xate*** **Harvest Per Hour of Extraction Over Space**

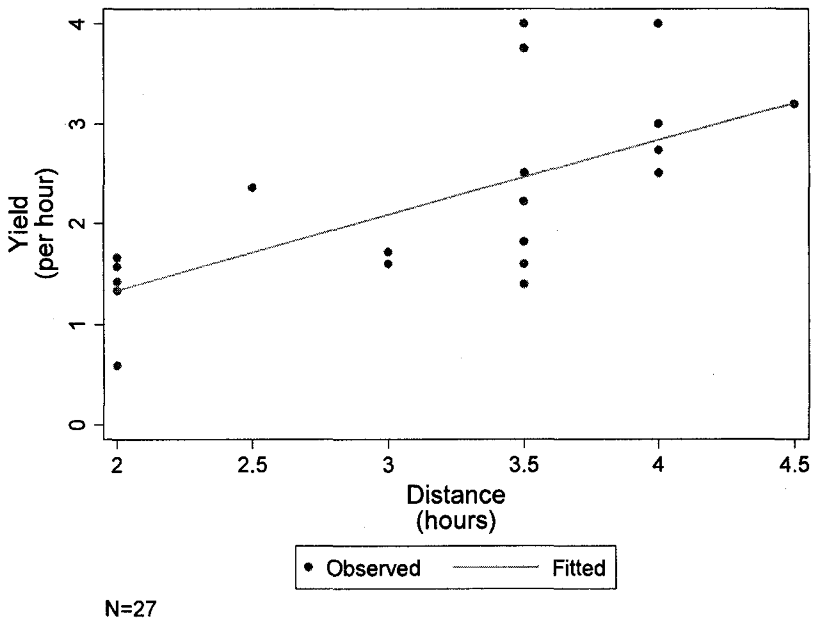


Table 3.3. ***Xate*** **Harvest Per Hour of Extraction**

	Coefficient
Distance	0.75***
	[0.16]
Constant	-0.16
	[0.46]
R^2	0.47
N	27

Cluster robust standard errors in brackets
*** significant at 1%

Figure 3.8. *Xate* Harvest Per Day of Extraction Over Space

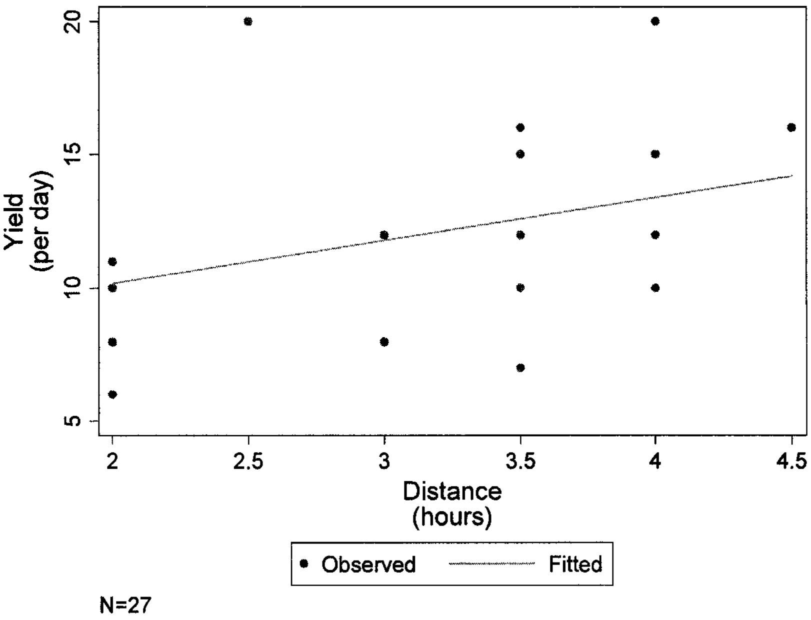


Table 3.4. *Xate* Harvest Per Day of Extraction

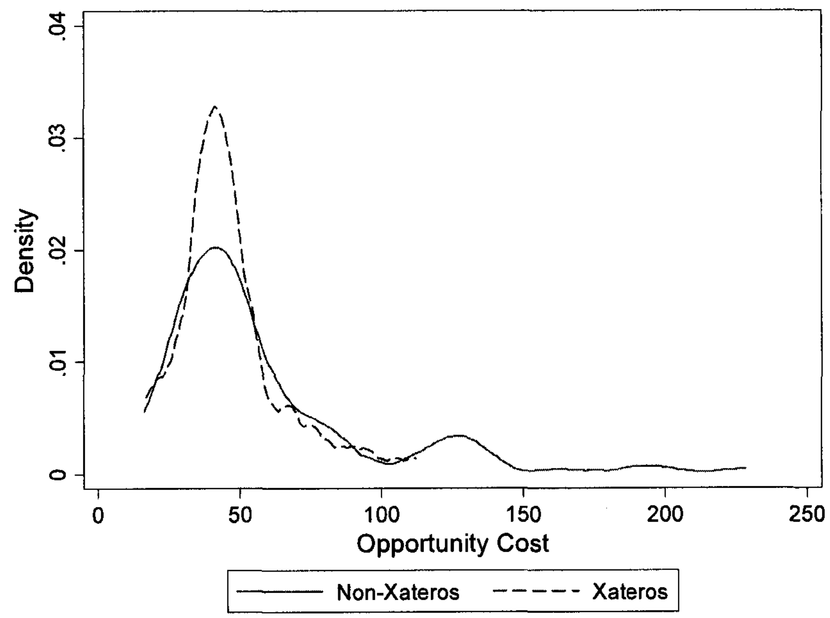
	Coefficient
Distance	1.61
	[0.94]
Constant	6.94**
	[3.25]
R^2	0.12
N	27

Cluster robust standard errors in brackets
*** significant at 1%

that the opportunity cost of time has on the decision to participate in *xate* extraction, controlling for other possible determinants of extraction.

Following Jacoby (1993) and Skoufias (1994) the opportunity cost of time is derived from the estimation of a Cobb-Douglas production function. The value of household's production in all the non-*xate* activities is the measure of production used (for more details see Essay 2). According to this estimation, the average opportunity cost of a day of work is 46 pesos for *xate* extractors and 58 pesos for non-extractors (the difference in means is statistically significant at the 5% level). Figure 3.9 shows the distribution of the opportunity cost of time for *xateros* and non-*xateros* and illustrates how non-*xateros* tend to have higher opportunity costs of time than *xateros*.

Figure 3.9. Kernel Density



A probit model is used to estimate the effect that the opportunity cost of time has on the probability that a given individual will participate in *xate* extraction. Because the estimated opportunity cost of time is endogenous, an instrumental variables approach is employed. The instruments used to identify the model are land, cattle, capital, and an index of households' durable assets and dwelling characteristics. The logic is that these variables affect the income generating capacities of the individual in non-*xate* activities (i.e., the opportunity cost) but not *xate* labor allocation once one controls for the opportunity cost.

The results in Table 3.5 show that there is in fact a negative relationship between the opportunity cost of time and the probability of participation in *xate* extraction. The marginal effect, evaluated at the mean of all the variables, implies that an exogenous increase of 10 pesos in the opportunity cost of time decreases the probability of participation in *xate* extraction by 3%. An alternative way of showing the impact of changes in the opportunity cost of a day of work is to look at the predicted probabilities. Figure 3.10 shows a nonlinear relationship between predicted probabilities of participation in *xate* extraction and the opportunity cost of time. Marginal changes in the opportunity cost have a relatively higher impact on the probability of participation when the opportunity cost is low than when it is high. At high opportunity costs (in particular above 80 pesos per day) the probability of participation is close to zero and small changes in the opportunity cost do not change that.

Results for the other variables included in the estimation show that males are more likely to participate in extraction and age has an inverted u-shaped relationship with participation. In addition, even though the opportunity cost captures the effect that

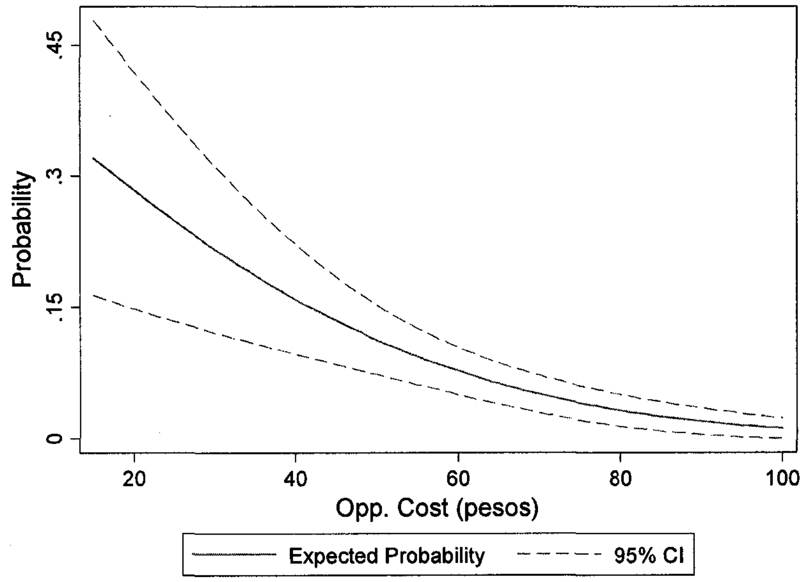
Table 3.5. Participation in *Xate* Extraction
Instrumental Variables Probit

Dependent Variable	Point Estimates	Marginal Effect
Opportunity Cost	-0.021***	-0.003***
	[0.004]	[0.001]
Head	0.145	0.024
	[0.275]	[0.048]
Male	0.815***	0.127***
	[0.243]	[0.035]
Age	0.072**	0.011**
	[0.034]	[0.005]
Age^2	-0.001**	-0.000**
	[0.000]	[0.000]
Educ	-0.070**	-0.011**
	[0.031]	[0.005]
HH-elem	-0.168*	-0.026*
	[0.092]	[0.014]
HH-sec	-0.056	-0.009
	[0.101]	[0.016]
Adults	0.042	0.007
	[0.073]	[0.011]
Dependent	0.008	0.001
	[0.052]	[0.008]
Tradition	0.485***	0.080***
	[0.167]	[0.030]
Year	-0.558***	-0.090***
	[0.118]	[0.023]
Constant	-1.097	
	[0.697]	
Chi^2	26.811	
P_exog	0.000	
Log-likelihood	-3056.011	
N	683	

* significant at 10%; ** significant at 5%; *** significant at 1%
Cluster robust standard errors in brackets
Instruments in the first stage: land, capital, cattle and assets index

education (own and of other household members) has on the income generating capabilities of the individual, the education variables turn out to be negative and statistically significant. This finding suggests that more educated individuals (and individuals from more educated households) have distaste for participating in *xate* extraction. Finally, the variable tradition has a strong and positive effect on participation in extraction.

Figure 3.10. Opportunity Cost and Probability of *Xate* Participation



Note: For all variables, except opportunity cost, values are set at the mean

3.6. Conclusions

This essay shows that because of the spatial nature of extractive activities, the solution to the problem of optimal management of common property resources goes beyond limiting the amount of total effort (total extraction). The solution to this problem requires extractors to coordinate the allocation of labor optimally across space. The analysis illustrates an important distinction in the productivity of a day of work in NTFP under managed and unmanaged regimes. Under management, the productivity of a day of work in NTFP extraction is decreasing over distance but always higher than the opportunity cost of time. In contrast, when there is no management, productivity is always equal to the opportunity cost of time. That is, each unit of labor receives more than its opportunity cost of time when management of the common-pool resource is instrumented to maximize sustainable economic rent.

The findings from this analysis have important implications for policies with the dual goal of alleviating poverty and promoting conservation. A key objective of recent conservation initiatives has been to increase the price paid to NTFP extractors (see the Introduction to this Thesis). However, under an unmanaged common property regime, an increase in the price of the natural resource, say due to a 'green product' price premium, does not necessarily help alleviate poverty. Irrespective of how much the price increases, the revenue per day of work is always equal to an individual's opportunity cost of time. On the other hand, if there are constraints on the availability of local labor, price increases can in fact raise extraction income above the opportunity cost of time and help alleviate poverty even under local open access. That is to say, if a relatively small group controls the resource, its members can earn from extraction more than their opportunity cost of time even if they do not have any internal rules to manage it, provided that they can exclude outsiders from extracting.

These results underline the importance of local management practices, both in terms of exclusion and coordination (across time and space). Green-marketing programs might be more successful in alleviating poverty if, instead of concentrating only on price mechanisms, they linked price premiums to improved local management practices.

3.7. Appendix. Response to Changes in Price and Wage

Change in amount of labor across space-

$$\frac{\delta L_s^{NM}}{\delta p} = \frac{rw}{p^2 q^2 K(T-2s)^2} > 0\,; \qquad \frac{\delta L_s^{NM}}{\delta w} = -\frac{r}{pq^2 K(T-2s)^2} < 0$$

$$\frac{\delta L_s^{M}}{\delta p} = \frac{rw}{2p^2 q^2 K(T-2s)^2} > 0\,; \qquad \frac{\delta L_s^{M}}{\delta w} = -\frac{r}{2pq^2 K(T-2s)^2} < 0$$

Change in maximum distance traveled-

$$\frac{\delta s_{\max}}{\delta p} = \frac{w}{2p^2 qK} > 0\,; \qquad \frac{\delta s_{\max}}{\delta w} = -\frac{1}{2pqK} < 0$$

Change in equilibrium stock over distance-

$$\frac{\delta X_s^{NM}}{\delta p} = -\frac{w}{p^2 q(T-2s)} < 0\,; \qquad \frac{\delta X_s^{NM}}{\delta w} = \frac{1}{pq(T-2s)} > 0$$

$$\frac{\delta X_s^{M}}{\delta p} = -\frac{w}{2p^2 q(T-2s)} < 0\,; \qquad \frac{\delta X_s^{M}}{\delta w} = \frac{1}{2pq(T-2s)} > 0$$

Change in harvest per hour of work over distance-

$$\frac{\delta\left(H/L(T-2s)\right)_s^{NM}}{\delta p} = -\frac{w}{p^2(T-2s)} < 0\,; \qquad \frac{\delta\left(H/L(T-2s)\right)_s^{NM}}{\delta w} = \frac{1}{p(T-2s)} > 0$$

$$\frac{\delta\left(H/L(T-2s)\right)_s^{M}}{\delta p} = -\frac{w}{2p^2(T-2s)} < 0\,; \qquad \frac{\delta\left(H/L(T-2s)\right)_s^{M}}{\delta w} = \frac{1}{2p(T-2s)} > 0$$

Change in revenue per day of work over distance-

$$\frac{\delta\left(pH_s^{NM}/L_s^{NM}\right)}{\delta p} = 0\,; \qquad \frac{\delta\left(pH_s^{NM}/L_s^{NM}\right)}{\delta w} = 1$$

$$\frac{\delta\left(pH_s^{M}/L_s^{M}\right)}{\delta p} = \frac{1}{2}qK(T-2s) > 0\,; \qquad \frac{\delta\left(pH_s^{M}/L_s^{M}\right)}{\delta w} = \frac{1}{2}$$

Change in sustainable net revenue over distance-

$$\frac{\delta NR_s^{M}}{\delta p} = \frac{r}{4}\left(K - \frac{w^2}{p^2 q^2 K(T-2s)^2}\right) > 0\,;$$

$$\frac{\delta NR_s^M}{\delta w}=\frac{r}{2}\left(\frac{w}{pq^2K\left(T-2s\right)^2}-\frac{1}{q\left(T-2s\right)}\right)<0$$

Proof.-

At $s=0$ we have that $\frac{\delta NR_s^M}{\delta p}=\frac{r}{4}\left(K-\frac{w^2}{p^2q^2KT^2}\right)>0$ if $p>\frac{w}{qTK}$ which is the condition that needs to be satisfied for any extraction to take place. We also have that for $s\in\left(0,s_{\max}\right)$ there is only one point at which $\frac{\delta NR_s^M}{\delta p}=0$, $s_{\max}$. Since NR_s^M is continuous it should be the case that $\frac{\delta NR_s^M}{\delta p}>0\ \forall\ s\in\left(0,s_{\max}\right)$.

At $s=0$ we have that $\frac{\delta NR_s^M}{\delta w}=\frac{r}{2}\left(\frac{w}{pq^2KT^2}-\frac{1}{qT}\right)<0$ if $p>\frac{w}{qTK}$. For $s\in\left(0,s_{\max}\right)$ there is only one point at which $\frac{\delta NR_s^M}{\delta w}=0$, $s_{\max}$. Since NR_s^M is continuous it must be the case that $\frac{\delta NR_s^M}{\delta w}<0\ \forall\ s\in\left(0,s_{\max}\right)$.

Change in total harvest over distance-

$$\frac{\delta H_s^{NM}}{\delta p}=\frac{wr}{p^2q\left(T-2s\right)}\left(\frac{2w}{pqK\left(T-2s\right)}-1\right)\left\}\begin{matrix}\leq 0 \text{ if } s\leq s^0\\ >0 \text{ if } s^0<s<s_{\max}\end{matrix}\right.;$$

$$\frac{\delta H_s^{NM}}{\delta w}=\frac{r}{pq\left(T-2s\right)}\left(1-\frac{2w}{pqK\left(T-2s\right)}\right)\left\}\begin{matrix}\geq 0 \text{ if } s\leq s^0\\ <0 \text{ if } s^0<s<s_{\max}\end{matrix}\right.$$

Where s^0 is the value that makes $\frac{\delta H_s^{NM}}{\delta p} = 0$ (and $\frac{\delta H_s^{NM}}{\delta w} = 0$), that is to say $s^0 = \frac{1}{2}\left(T - \frac{2w}{pqK}\right)$. Notice that the derivative of total harvest with respect to price can be negative only if $p > \frac{2w}{qKT}$. Similarly the derivative of total harvest with respect to wage can be positive only if $p > \frac{2w}{qKT}$.

Proof.-

Over the relevant range of distance $\left(s \in (0, s_{\max})\right)$ there is only one point at which $\frac{\delta H_s^{NM}}{\delta p} = 0$, s^0, and we know that $s^0 < s_{\max}$. Furthermore, we know that $\left.\frac{\delta H_s^{NM}}{\delta p}\right|_{s_{\max}} > 0$, therefore, it should be the case that to the right of s^0, $\frac{\delta H_s^{NM}}{\delta p} > 0$ and to its left $\frac{\delta H_s^{NM}}{\delta p} < 0$. The same reasoning proves that to the right of s^0, $\frac{\delta H_s^{NM}}{\delta w} < 0$ and to its left $\frac{\delta H_s^{NM}}{\delta w} > 0$.

$$\frac{\delta H_s^{M}}{\delta p} = \frac{rw^2}{2p^3q^2K(T-2s)^2} > 0; \qquad \frac{\delta H_s^{M}}{\delta w} = -\frac{2w}{p^2q^2K(T-2s)^2} < 0$$

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