ELSEVIER

Ecological Economics 30 (1999) 107–119

ECOLOGICAL ECONOMICS

ANALYSIS

Forest resource use change during early market integration in tropical rain forests: the Huaorani of upper Amazonia

Rodrigo Sierra [a,*], Fabian Rodriguez [b], Elizabeth Losos [c]

[a] *Department of Geography, Arizona State University, 338 JWS, Tempe, AZ 85287-0104, USA*
[b] *EcoCiencia, Isla San Cristobal 1523 e Isla Seymour, Quito, Ecuador*
[c] *Center for Tropical Forest Sciences, The Smithsonian Institution, 900 Jefferson Drive, Suite 2207, Washington DC 20560, USA*

Received 28 May 1998; received in revised form 5 October 1998; accepted 5 October 1998

Abstract

This paper examines the impact of early market integration on the extraction of forest resources by traditional forest-based households, with emphasis on the commercial-subsistence dichotomy. Empirical analysis of resource use transition among the Huaorani People of the Ecuadorian Amazon shows that as markets become more accessible production patterns change but do not seem to affect subsistence production. Huaoranis increase the production of animal resources from forests. However, the extraction of harvested and primarily of farmed commodities seems not to be affected. Data also suggest that trade relies on limited specialization. Trade among the Huaorani communities studied depends on raising the production of some of the same commodities that are found in the subsistence basket. These changes are clearly explained if a flexible-labor theory of early market integration is used. This period is characterized by labor and land abundance and a relative ease to move labor from low return to more productive activities. Under these conditions, market participation need not be accompanied by a reduction in the production of subsistence commodities or commodity specialization. High risks and uncertainty and high transportation costs keep poor forest households from shifting completely to commercial activities. This contrasts with a long presumption that production of individual commodities responds quickly to price changes, based on demand shifts between products, but that total output is slow to respond. Only after all the surplus labor has been allocated to productive activities total output becomes less flexible. At this point increased production requires commodity or technological specialization.

Keywords: Subsistence commodities; Commercial commodities; Tropical rain forest; Markets; Trade

* Corresponding author. Tel.: +1 602 9657533 or 9657346; fax: +1 602 9658313; e-mail: rsierra@asu.edu

0921-8009/99/$ - see front matter
PII: S0921-8009(98)00101-3

1. Introduction

Commodity exchanges have long occurred among tropical forest societies as a means to obtain resources not available locally (Bailey et al., 1989; Headland and Reid, 1989; Stiles, 1994). Forest resources are today traded by traditional peoples in surrounding markets based on cash and market transactions more often than on barter or commodity exchanges. This is the result of reduced isolation, higher population densities, and, most of all, the development of commodity, land and labor markets in and around traditional territories. However, it is still unclear how forest-based communities change their traditional use of local resources as markets become more accessible, trade increases, and as household incomes rise. Advances in the theory and analysis of the impact of income and market accessibility on resource use shifts in tropical areas are primarily based on the empirical examination of stages when access to markets and adopted commercial commodities already play a significant role in traditional households' budgets (Behrens, 1992; Godoy et al., 1992; Behrens et al., 1994; Godoy et al., 1995; Henrich, 1997).[1] A fundamental element of these theories is the trade-off between commercial and subsistence production. Market participation and income generation are said to take place at the expense of subsistence production. Because, with few exceptions (Hart, 1978), early stages of integration have not been studied, it is unclear to what extent these accurately describe resource use shifts among traditional forest-based households who are just beginning their participation in and have limited access to markets, but among which household budgets include a cash (i.e. income) component.

Furthermore, Godoy et al. (1992, 1995) and Redford and Robinson (1987) note that while much work has been done on the transition from hunting and gathering to horticulture and pastoralism, little effort has been dedicated to measuring changes in the composition of goods extracted from the forests as economies modernize and specialize. Often, studies have emphasized only one type of resource (e.g. plants) or data have been gathered for short periods of time, hence not reflecting seasonal variability in forest and agricultural product availability.

This paper examines the impact of market integration and accessibility and increasing incomes on the extraction of forest resources in isolated forest-based households, with emphasis on the commercial-subsistence dichotomy. A flexible-labor framework of early market integration is proposed here for this period, which complements the theories developed for later stages. An analysis of resource use transition among the Huaorani People in the Upper Amazon forest of Ecuador provides empirical detail to these propositions.

2. Frameworks of resource use change in tropical regions: the issue of labor scarcity

Macdonald (1981), Godoy et al. (1992, 1995), Behrens (1992), Behrens et al. (1994), Stearman and Redford (1992), Hammond et al. (1995) and Henrich (1997) have examined various factors related to the shift from subsistence to commercial production among tropical communities. In general, their propositions about resource use changes during market integration agree in the following major conditions:

i. *Market integration and income generation take place in labor scarce environments*. Most analysis of resource use shifts and market integration among forest-based societies implicitly or explicitly assume that total output is constant and that changes in commodity composition are constrained by a variety of factors. Of these the most important is labor. Changes in the quantities of commodities produced respond to re-allocations of labor, and this in turn responds to changes in the marginal return of competing activities. Labor is moved from low return activities to high return activities. In this way, by reducing the labor allocated to the activity with the lowest marginal return there is a net positive gain from the production of another com-

[1] The term household income is used throughout this paper to refer to cash flows from trade, while household budget refers to the value of all resources available to a household, including commodities produced for subsistence.

modity with a higher return. This condition is exemplified by the work of Locay (1989) and Behrens (1992), who assume constant labor in their analysis. Binswanger and McIntire (1987) describe similar conditions for frontier agriculture.

ii. *Increased incomes are accompanied by labor and commodity specialization*. Changes in the opportunity cost of labor or in the relative value of the commodities produced fosters specialization in those activities with the highest marginal return and a drop in the number of commodities produced. In turn, specialization can lead to substantially increased incomes (Padoch et al., 1985; Behrens, 1992; Humphries, 1993; Hammond et al., 1995). Increased income facilitates the adoption of new technologies and progressive specialization to offset high transaction costs (i.e. low yields per unit of area) and labor scarcity. On the output side, specialization results in increases in the volume of commercial commodities extracted from forests or farmed by traditional communities. Specialization on traditional forest commodities also increases the value of the forest value per unit of area and causes a reduction in the area exploited, even if more forest is still available (Godoy et al., 1992, 1995).

iii. *Commercial production occurs at the expense of subsistence production*. The combination of conditions i and ii is critical, because it determines that an increase in the production of commercial commodities must be accompanied by a drop in the production of subsistence commodities. Increases in the opportunity cost of forest laborers cause less labor to be allocated to subsistence activities and proportionally more labor to commercial production. This can occur in two ways. The first one is the replacement of subsistence commodities with non-traditional cash crops. Producing these crops requires land and labor. Land is abundant and can be obtained from clearing forests, so it is not a constraint. Labor, on the other hand, needs to be removed from subsistence activities. The second avenue is by the increase in the trade of traditional forest commodities, which also requires a reduction in subsistence consumption and specialization.

Empirical work shows ambiguous support for these propositions. For example, Behrens' (Behrens, 1992) study of Shipibo Indians found commodity specialization and the formation of local markets based on exchanges between agricultural households and hunting households and the creation of a labor market. However, the study by Godoy et al. (1995) of Sumu Indians of Nicaragua did not find evidence of specialization. The number of commodities produced did not drop when trade occurred. Behrens et al. (1994) found that land and forest area per capita decreased with production for markets in a study of the Barí of Venezuela. In contrast, Godoy and Lubanski (1991), based on a study by Padoch and De Jong (1990) who found that local people in the Brazilian Amazon extracted only 2.5–3.5% of the total value of the forest, suggest that intensification of extraction is possible without increasing the area exploited.

The third proposition is supported by several studies. The study by Kanoeka and Solberg (1997) of the relationship between deforestation, population growth, and farming systems in Tanzania, for example, concluded that diversions of family labor to commercial production are accompanied by a drop in the labor available for subsistence production. Behrens (1992) study of the Shipibo Indians of Eastern Perú analyzed labor allocation using two major types of commodities: purchased goods, which require trade and, often, monetary exchange, and locally produced consumed goods. Behrens found a negative correlation between cash cropping and subsistence hunting and gathering. The labor allocated to traditional activities (including hunting and gathering) dropped as cash crops were adopted. Another study, by Alcorn (1984), notes that the shift to commercial agriculture is accompanied by a deterioration of diet among subsistence communities.

3. Research approach

3.1. The empirical model

An empirical model was developed to evaluate

two summary propositions for the early stages of market integration. These are: (1) market integration and income generation relies on the increase of production of commercial commodities and on the decline in production of subsistence commodities; and (2) expansion of commercial production requires specialization.

Godoy et al. (1992) suggested that an appropriate approach for such analysis would be to study two culturally comparable communities living in similar environments but with different levels of dependence on cash income. This study used three sets of households living in the same general area but with different levels of market interaction possibilities, based on their relative locations to markets. Similar cultural backgrounds allowed to normalize for potential variation in resource use patterns. Still, limited variability in resource endowments and in the level of market integration is a positive factor for this analysis.

Two regression models examine changes in resource extraction patterns among the Huaoranis associated with rising incomes and market accessibility. The role of the three types of commodities in the generation of income among Huaorani households is examined by:

$$HOUSEINC = a_1 + a_2 WHUNTIND + a_3 WHARVIND + a_4 WFARMIND \quad (1)$$

where: *HOUSEINC*, total estimated income for each household in US$ for the study period; *WHUNTIND*, total weight, in kilograms, of animal products from hunting and fishing per adult individual in a household for the study period; *WHARVIND*, total weight, in kilograms, of harvested timber and non-timber products from the forest per adult individual in a household for the study period; and *WFARMIND*, total weight, in kilograms, of farmed commodities per adult individual in a household for the study period.

Eq. (1) represents the proposition relating income with increased extraction of traditional forest resources and limited specialization. Extraction of forest resources is measured as the total weight hunted, extracted or harvested by each household of the three communities studied. The use of weights as independent variables permitted to avoid several statistical issues: circularity (explaining income with income) and the significant price variability among commodities traded (bargaining is a common practice). More importantly, this permitted the analysis of the relationship between income and production, including the production of non-traded (i.e. non-priced) commodities.

Further detail about the impact of market integration on both commercial and subsistence production is provided by following set of equations:

$$WHUNTIND = a_1 + a_2 THUNTIND + a_3 HUNTEFFI + a_4 MARKTDIS \quad (2)$$

$$WHARVIND = a_1 + a_2 THARVIND + a_3 HARVEFFI + a_4 MARKTDIS \quad (3)$$

$$WFARMIND = a_1 + a_2 TFARMIND + a_3 FARMEFFI + a_4 MARKTDIS \quad (4)$$

where: *WHUNTIND*, *WHARVIND* and *WFARMIND* are as defined in (Eq. (1)); *THUNTIND*, total time spent by each adult individual in each household in hunting during the study period; *THARVIND*, total time spent by each adult individual in each household in harvesting forest products during the study period; *TFARMIND*, total time spent by each adult individual in each household in farming during the study period; *HUNTEFFI*, hunting efficiency, measured as the average weight of animal products taken per hour by each adult individual in each household; *HARVEFFI*, harvesting efficiency, measured as the average weight of forest products harvested

per hour by each adult individual in each household; *FARMEFFI*, farming efficiency, measured as the average weight of farmed products harvested per hour by each adult individual in each household; and *MARKTDIS*, normalized distance from household to most frequent market.

This set of equations examines the linkage between labor allocation (i.e. time) and increased production in each of the three groups of commodities. The efficiency variable is expected to account for differences in local resource endowments and the relative ability of producers to extract some products in better conditions than others. Market opportunities are represented by the normalized distance to the nearest market and measures the relative cost of bringing production to markets. It is also assumed to, indirectly, approximate the level of the stimulus markets provide to change production patterns. A complex least cost path was calculated for each production origin to each market destination, based on a cost-surface representing the relative costs of the various types of transportation required to get to and from markets. River transportation was assumed to be twice as costly as road transportation per unit of distance (250 m). The cost of river transportation was estimated to be half that of terrestrial (i.e. walking) transportation. At first glance this may sound as an over-estimation of road transportation costs. However, this is a reasonable assumption because the cost of road transport is sharply increased due to low traffic flows along the isolated road the Huaorani have access to. This approach varies considerably from previous studies, in which the impact of access to markets has been assumed to be a constant or estimated as a one-dimensional variable (i.e. as the crow flies; Hart, 1978; Padoch, 1988; Behrens et al., 1994).

3.2. The Huaorani of the Ecuadorian Amazonia

The Huaorani people live in the rain forests of Upper Amazonia in Ecuador. The Huaorani number less than 1000 and have maintained a significant level of self-imposed isolation until recently. Yost (1979) characterized them as an interrivers group because their traditional territories were bound by big rivers. Furthermore, canoes were not constructed or used nor fishing an important source of protein until recently. Most animal protein was obtained through hunting forest animals. Traditionally, the Huaorani lived spread over a very large territory, with family-based clans using temporary settlements and in an almost complete subsistence economy.

In general, contact with westerners, mostly missionaries, is very recent, dating to the 1950s (Cabodevilla, 1992). Some of the more isolated groups did not even have dogs by the early 1980s (Yost and Kelley, 1983). Encroachment on their traditional territory by colonization and oil development is even more recent, beginning in the late 1970s in some areas and the late 1980s in others. Since then, the impact of oil jobs and related economic opportunities (e.g. markets for meat) and missionary activities has resulted in important changes for a large segment of the population. Many now live in a few newly formed towns, although these are still located along rivers and often, far from road access. Other groups, however, continue to avoid contact with outsiders.

3.3. Study area and data

Data on all products consumed and traded by 64 households in and around the Huaorani communities of Cacataro, Quehueiri-ono and Tiguino were collected for a 9-month period (Fig. 1). These settlement areas existed before any road entered the region (Yost and Kelley, 1983). By 1995 each had a different level of integration to markets. The closest to a market is Tiguino, which is near a dirt road with sporadic traffic, mostly by oil company trucks. Cacataro is far from any road, but is only a few hours walk from a major river, which in turn provides access to markets. Quehueiri-ono is the most isolated of the three and during this study was accessed using helicopters. Data for 47 of these households were considered reliable and included in this study ($n = 6$, 28 and 13, respectively). Income was estimated through periodic interviews about the cash value of the different types of commodities traded by each one of these households. Commodities traded varied drastically both in type and prices

and in time. Income was not discounted for the cost of transportation.

For analysis, commodities produced were grouped into three categories: hunted, harvested and farmed. Given the very large number of forest resources used, grouping commodities was critical for statistical analysis of the relationship between markets, income and subsistence and commercial production. However, commodities in each group were fairly homogenous among the three study areas. In general, there seems to be limited variability in the type of resources extracted from or hunted in the forest by traditional societies in this region. This is consistent with other studies about the use of resource by traditional households living in the Amazon rain forests (Hames, 1979; Yost and Kelley, 1983; Vickers, 1988; Hammond et al., 1995).

4. Results

Regression results from model (1) show that increases in income depend on expanding the production of a particular set of commodities but that the production of others is not affected (Table 1). Income is strongly related to the production of animal products, and to a lesser extent to harvesting forest products, but is not related to farming activities. Among the Huaorani, hunting focused on mammals, primarily woolly monkeys (*Lagothrix lagothricha*) and collared peccaries

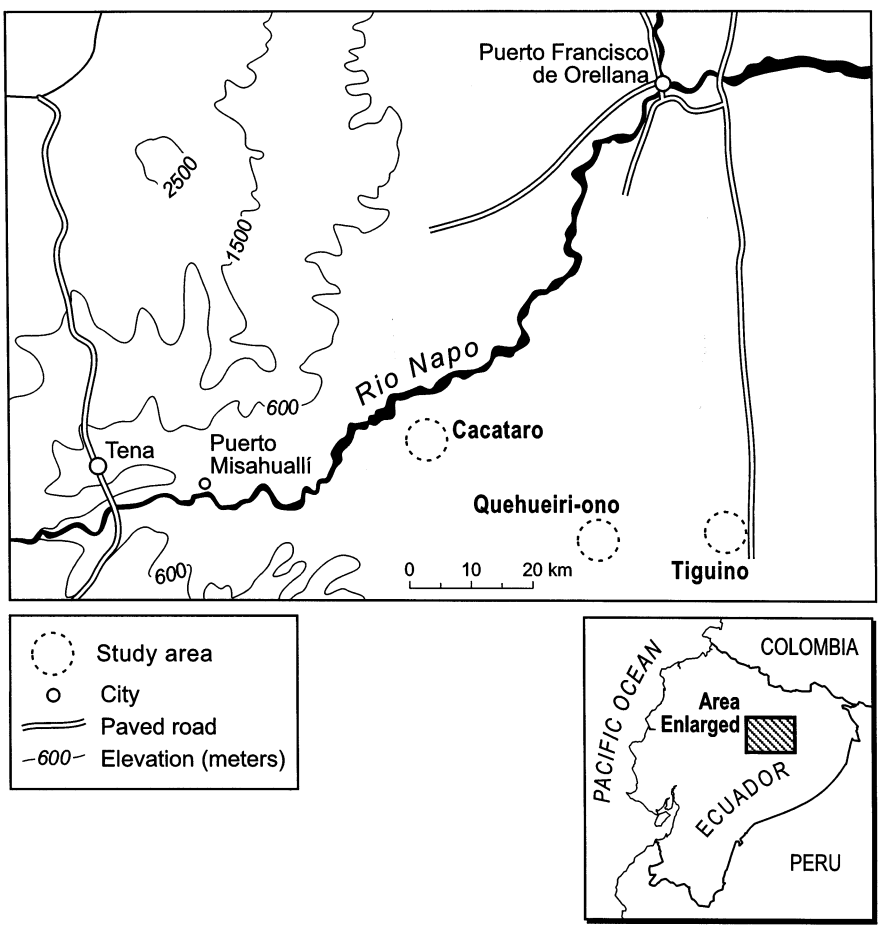

Fig. 1. Study areas.

Table 1
Coefficient estimates for commodity factors affecting income among Huaorani households

Variables[a]		β Coefficient	t	P-value
Dependent	Independent			
(1) *HOUSEINC*	*WHUNTIND*	0.54	4.123	0.0002
	WFARMIND	−0.08	−0.627	0.5339
	WHARVIND	0.27	2.007	0.0510

[a] $N = 47$.

(*Tayassu tajacu*). These were used for consumption, but were also sold as meat and sometimes as pets. Many species of birds, especially guans and parrots, were also captured for food or sold as pets. Harvested production was traded less. The Huaorani exploited 76 plant species in 31 families; 60.1% of which were used as food, 13.1% for construction purposes, 4.8% for fuel wood, 2.9% for medicinal purposes, and 1.6% for other users. Only the remaining 17.5%, used for crafts (e.g. natural fibers), dyes, and the like, were sometimes sold in nearby markets. Farmed products offered a good example of subsistence commodities, as these were rarely sold or traded, and had almost no impact on household incomes. The Huaorani cultivate swidden fields with a small number of staples, primarily manioc (*Manihot sculenta*) and banana (*Musa sp.*), and include managed wild crops, such as fruit trees. Manioc and bananas are widely produced and producers with high transportation costs, such as the Huaorani, are at a disadvantage. The specific types of commodities affected may, however, vary from place to place.

The relative independence between market access, and hence commercial production, and subsistence production is confirmed by results of Eqs. (2)–(4) (Table 2). Only hunting is clearly affected by access to markets. The closer a household is to a market the more animal resources it would extract from the forest. The production of harvested or farmed commodities is not affected by market access. Commodity production per individual is directly and strongly related to the time spent producing all types of commodities. Individuals and households increase the production of certain commodities by putting more time on these. This is important, because if time were a major productive constraint, income should be significantly but negatively related to income in model (1). The fact that it is not shows that commercial production did not affect non-commercial (i.e. subsistence) production among the Huaorani. This in turn suggests that intensified production draws upon unused productive resources. Models (2) through (4) suggest that time is such a resource. To be sure, the ability of producing more per unit of effort (i.e. per hour) is also a key factor explaining increases in output. Efficiency is related to environmental and resource endowment variability and other factors, such as skill development and technological change, but these were not studied here. In the case of the Huaorani it probably reflects technological change more than commodity changes. Interestingly, shotguns, the easiest technological adoption, are something relatively new among the Huaorani, and their value is not always certain as using them scares other potential prey. Furthermore, due to isolation, ammunition is difficult to come by. It is also rare to find other types of technological adaptations, like the use of flashlights for night hunting, common in other forest groups in the area, such as the Cofanes and Sionas (Yost and Kelley, 1983). According to Yost and Kelley (1983) the use of dogs is probably the most important adaptation because it increases hunting efficiency significantly. Dogs first appeared among the Huaorani in the mid-1970s.

Data also show that initial market integration is based on limited specialization. Animal products traded were the same as those used for

subsistence, as in the case of woolly monkeys and peccaries, but the amount produced rose as market opportunities increased. If the households in each of three study areas are grouped, the total number of animal species hunted (not including fish species) ranges from 41 to 72, with the lowest number in Cacataro, an area with an intermediate level of isolation, and the highest in Quehueiriono, the most isolated of the study areas. This is similar to the data in Yost and Kelley (1983), who listed 37 species as being hunted by the Huaorani, not including those that did not add to at least 10 kg total weight.

Trade depends on commodities households are familiar with and for which production does not require jeopardizing the minimum acceptable self-sufficiency level. The comparative advantage of the Huaorani at this early stage of market integration lies in the production of forest products. These findings are consistent with data from other similar settings. Among the Ticuna of neighboring Colombia, for example, only one of 77 managed species was used exclusively for commercial trade. Most were managed solely for consumption, and a few for both consumption and trade (Hammond et al., 1995). Similar findings are reported by Behrens (1992) for the Shipibo Indians in Eastern Peru.

5. Resource use shifts during early market integration: the role of hidden labor resources

Attempts to interpret the results of the statistical analysis carried out here would find that the propositions outlined above do not explain several of the conditions found among the Huaorani. Two stand out: (i) there seems to be no trade-off in the production of commercial and subsistence commodities; and (ii) there is no evidence of significant commodity specialization.

The propositions that follow attempt to provide a framework under which such conditions can be interpreted and formalized. Of particular concern is the treatment of labor and the impact of labor reallocations in the analysis of the early market integration. It is important to note that this framework does not contradict the propositions outlined in Section 2. It is argued here that these apply in later stages of market integration. The following propositions apply to the period in which forest-based household's participation in markets is dependant on traditional commodities and, more importantly, trade does not constitute a critical element of the household's budget.

i′. *Early market integration occurs under labor surplus environments*. Time and labor allocation is a factor of production that has been consis-

Table 2
The impact of market accessibility and specialization

Variables[a]		β Coefficient	t	P-value
Dependent	Independent			
(2) *WHUNTIND*	*THUNTIND*	0.23	3.33	0.0018
	HUNTEFFI	0.64	8.08	0.0000
	MARKTDIS	−0.28	−3.57	0.0009
	(Constant)	0.56	0.58	
(3) *WHARVIND*	*THARVIND*	0.75	14.04	0.0000
	HARVEFFI	0.38	8.15	0.0000
	MARKTDIS	−0.03	−0.61	0.5442
	(Constant)	−2.67	0.0108	
(4) *WFARMIND*	*TFARMIND*	0.66	13.09	0.0000
	FARMEFFI	0.63	11.88	0.0000
	MARKTDIS	−0.08	−1.49	0.1435
	(Constant)	−3.47	0.00	

[a] $N = 47$.

tently examined in tropical traditional communities (Yost and Kelley, 1983; Behrens, 1986, 1992). However, it has rarely been examined in the light of its potential budget of productive resources or in relation to the maximum availability of labor. Several studies (Boserup, 1965; Hart, 1978; Macdonald, 1981; Yost and Kelley, 1983; Swetman, 1989; Anderson, 1992; Behrens, 1992) directly and indirectly suggest that traditional households have a labor reservoir that makes them labor-surplus units. The well known work by Boserup (1965), for example, recognizes the role of flexible resource allocation in agricultural intensification and its impact on output. This resource reservoir is primarily contained in the time spent by household members in social (i.e. non-productive) or communal activities. In isolated areas, where markets or regular trade are absent, people will tend to work fewer hours than if these opportunities exist, because once a sufficient supply of commodities has been met the marginal utility of labor is very low (Chayanov, 1966; Binswanger and McIntire, 1987). Subsistence producers aim to produce a stable level of production to maintain a culturally defined level of comfort. Beyond this level, surplus resources are dedicated to activities designed to improve that minimum acceptable level of comfort and specifically to deal with uncertainty and risk.

ii′. *Early market articulation is accompanied by limited labor and commodity specialization*. Because key factors of production (i.e. labor, land) are abundant, and markets risky, the composition or types of commodities produced is likely to remain stable. Maintaining traditional commodities facilitates commercial production without affecting subsistence production. Indeed, cash production may be an undesirable alternative to subsistence production in high transaction costs environments. Hence, limited specialization refers to the increase in the production of a particular set of traditional commodities while maintaining the production of the other commodities which were also produced before the change. Also, because the distribution of valuable commodities in tropical forests is dispersed and commercial production is based on subsistence production, increasing extraction also requires expanding the area under production. The use of traditional products continues until their marginal return drops below that of non-traditional commodities and when factors of production are fully employed. This happens during later stages of market integration for various reasons, such as the rise in transaction costs from the exhaustion of local natural resources, development of land markets, tenure insecurity, etc.

iii′. *Early commercial production is compatible with subsistence production*. Based on i′ and ii′ it is possible to anticipate that initial market participation takes place without a significant impact in subsistence production. Increases in output are obtained by reallocating labor from non-productive to productive activities. In this way the labor used in subsistence activities does not need to be reduced. This is reasonable, since the opportunity cost of social and community activities is likely to be lower than that of subsistence production. In other words, labor surplus means that beyond some level of production, labor's marginal product from subsistence hunting, gathering and farming is below its opportunity cost in non-productive activities. This surplus can be reallocated to other activities, such as commercial hunting, gathering and farming, if their marginal product becomes positive and close to the wage rate. Land abundance facilitates such reallocation. During early market integration there is little incentive for local households to change their subsistence activities because market participation is risky and labor markets non-existent. Even wage opportunities can be matched by intensification of forest product extraction when wages are discounted by living costs outside home areas, transportation costs, and other risks. Work by Swetman (1989) suggests that the time needed for wage work to be an attractive alternative to subsistence labor may be long in isolated communities, facing low wage markets and uncertainty.

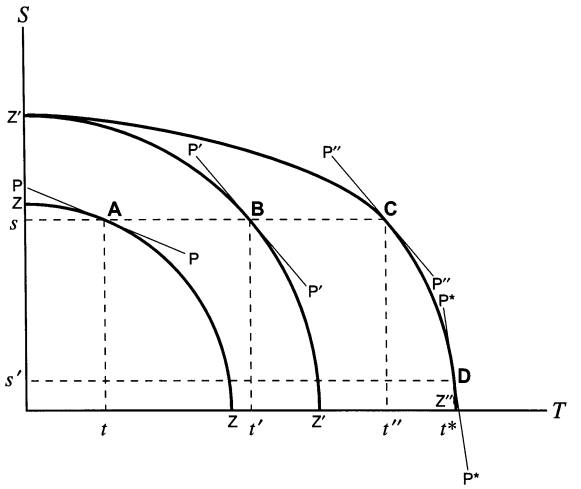

Fig. 2. Flexible labor model of resource use and subsistence and commercial production change during market integration. Axis represent quantities of hypothetical commodities T and S.

Fig. 2 illustrates the most important features of the model proposed here. In this model the curve ZZ is the production possibility frontier which defines output combinations available to forest-based households. Any combination within this frontier is possible but only those on the border are efficient and desirable. Both T and S can be interpreted in different ways, without any change in the analytical results. T and S may represent the same broad set of commodities, which is the basis of the household economy, but T is the fraction destined for exchange and the purchase of commodities produced outside. S represents consumption of locally produced commodities. T and S may also represent a different set of commodities, one for consumption and the other for trade. Based on the discussion above, the first scenario is more likely to occur, so let in this case T be the production fraction that is traded from any commodity. T and S are used to satisfy an optimal consumption level, which is defined both by culture and environmental constraints. As before, it should be expected that $T > 0$ for any period. In the absence of significant market incentives, forest based households will produce at point A, that is an s amount of S and a t amount of T, with terms of trade PP.

An increase of the relative price of T, denoted by a steeper P′P′ line, fosters the reallocation of labor from non-productive activities to productive activities, pushing the production possibility frontier to Z′Z′. At this stage a higher level of consumption can be reached at point B. The new production possibility curve has been pushed out because new productive resources, namely labor, are made available. More importantly, such a shift does not require a reduction in the output of S. Also, limited specialization, in the form of increased extraction of the commodities needed for trade, allows forest based households to change the shape of the production possibility curve (or alternatively, to change the scale of the T axis), so that an even higher consumption level is achieved (i.e. farther away from the origin) at point C. Even if specialization is based on technological change, subsistence output need not drop, as the capital required to purchase such technology is obtained in the move from ZZ to Z′Z′. At this point, all the labor stored in non-productive activities is depleted and the production of one unit more of T (e.g. from t'' to t^*) requires a reduction in the production of S (e.g. from s to s^*). Under this scenario, the move from condition C to condition D is consistent with the propositions outlined in Section 2, and is considered here a second stage in the process of market integration.

In the case of the Huaorani, the move from condition A to condition B is met by producing more animal products, from t to t'. To do this no new commodities (or animal species) were added nor subsistence production sacrificed. In theory, the Huaorani would continue this pattern until condition C, when all the labor available has been allocated to either subsistence or commercial production, or when another limiting factor (e.g. land) forces them to do that. Other empirical studies also support these propositions. Macdonald's (1981) study of the Quichua Indians of Upper Amazonia found that increases in agricultural activities affected primarily the community and social activities that were common before markets were accessible. Similarly, Behrens (1992) found that increases in market activity among the Shipibo brought about more independence of house-

hold production activities from the community. Jayne (1994) shows a direct relationship between commercial production and surplus subsistence production of poor farmers in Zimbabwe. Hart's (1978) study of the Mbuti found that market participation was dependent on the production of a surplus of meat for sale. Hart concluded that the Mbuti's commercial production was not, in any way, a commitment to change but was accepted as a temporary shift to take advantage of certain opportunities.

6. Conclusions

The discussion above highlights and empirically evaluates the shifts in resource uses that should be expected during the early stages of market integration in traditional forest-based communities. These stages are characterized by labor and land abundance and a relative ease to move labor from low return to more productive activities. For this reason, market participation does not necessarily entail a reduction in the production of subsistence commodities. This contrasts with a longstanding presumption that production of individual commodities responds quickly to price changes, based on demand shifts between products, but that total output is slow to respond. It was shown here that only after all the surplus labor has been allocated to productive activities total output becomes less flexible. At this point increased production requires commodity or technological specialization. When surplus resources are used up, increasing labor opportunity costs will first foster specialization in high return commodities and a reduction of subsistence output. The stability in subsistence production is a logical characteristic of risky early market integration. Also, it should be expected that commercial activities be more constrained by locational conditions (closeness to a river or flood plain, closeness to a road, existence of non-timber products in demand, etc.) than subsistence activities.

Results also suggest that initial trade relies on limited specialization. This means increasing the production of some of the same commodities that are found in the subsistence basket. This is consistent with previous propositions noting that traditional communities increase extraction of non-timber forest products for trade up to a point when it stabilizes (Vincent and Binkley, 1991; Homma, 1992). Production of these commodities drops due to the increase in non-forest based activities such as cash agriculture, cattle ranching, or logging. Among the Huaorani, all households seem to produce a similar mix of products for commerce, based primarily on animal products.

Overall, results show that market integration goes through two general stages. The first one is based on traditional resources and the stability of subsistence production. This stage is represented in Fig. 2 by the shift from conditions A to B and from B to C. Because isolated forest-based societies are labor surplus and because they face poorly developed labor markets (i.e. the opportunity cost of labor is zero), the most important costs associated with commercial production are the cost of social activities, which is low, and the time needed to transport commodities to markets. As markets become more accessible the opportunity cost of certain activities increases so that less and less low return activities are carried out, and more and more high value forest commodities are needed to keep up with wage levels. At the same time, high risks and uncertainty, and high transportation costs keep people from shifting completely to commercial activities.

The second stage is characterized by the adoption of new commodities and other factors identified and summarized by Godoy et al. (1992, 1995): decrease in households' dependence on subsistence production, reduction in the number of commodities produced, increase of the forest value per unit of area, and reduction of the area exploited even if more forest is still available. In Fig. 2 this is represented as the shift from condition C to condition D. This shift may occur, however, after a considerable time of market participation and once all labor has been incorporated into productive activities. Traditional commodities may also be replaced by new commodities due to resource depletion. Specialization in particular high-value forest commodities can speed up rates of extraction beyond the natural replenishment rate (Nietschman, 1973; Hart,

1978; Headland and Bailey, 1991; Layton et al., 1991; Godoy et al., 1992; Behrens et al., 1994; Godoy et al., 1995). Vincent and Binkley (1991), Homma (1992), and Godoy et al. (1995) argue that the stock of wild commodities goes through a cycle, with an initial stage of abundance, an intermediate stage of depletion, and a final stage of recovery. Recovery occurs because pressure on local resources drops when populations emigrate, industrial or fully domesticated commodities replace forest goods, and increased transaction costs and labor intensity makes them less desirable. Vickers (1988) provides empirical evidence for this assumption. Vickers show that the total output of animal resources extracted from the forest by the Cofán of Ecuador is affected by the number of people in the community. When the size of the community dropped, resources and output recuperated. However, a constant decline in local resources is also possible even if pressure on them subsides. This may occur because during the later stages of market integration, forest-based activities are replaced by non-traditional activities requiring forest clearing (i.e. commercial agriculture).

A key inference is that tropical forest resources could be threatened even in the absence of new commodities and without major changes in the technological and cultural setup of forest based communities. Ecocentric constructs often surface as calls for maintaining traditional institutions and rescuing traditional knowledge (Bunyard, 1989; Posey, 1993; Place, 1994). Low intensity productive strategies and community organization are assumed to guarantee environmental conservation, cultural survival, and the economic and political independence of forest-based groups. As commendable as these calls are, they may not be consistent with the economic and productive objectives of poor forest-based households, nor with the need to support economic development and to improve standards of living to achieve conservation. The reality is that forest-based communities are increasingly managing their resources for commercial purposes, which often results in resource degradation and biodiversity loss. To be sure, this is not a challenge to the rights of traditional communities over the resources they manage or their traditional territories. Simply, the premise is that resource use shifts among traditional communities are a 'natural' consequence of the economic goals of local communities. These shifts, in turn, result from rapidly changing relations of production (i.e. from land abundance and relative labor scarcity to land scarcity and relative labor abundance) and from the spatial-temporal location of households within a productive-opportunity continuum. Under this light, conservation is possible if both the economic goals of traditional households, such as the Huaorani's, and the resource base that makes those goals attainable complement each other. Culture and traditional resource use strategies are important as these provide the basis for sustainable management, but do not seem to offer an alternative by themselves.

References

Alcorn, J., 1984. Huastec Mayan Ethnobotany. University of Texas Press, Austin, TX.

Anderson, A., 1992. Land-use strategies for successful extractive economies in Amazonia. Adv. Econ. Botany 9, 67–77.

Bailey, R., Head, G., Jenike, M., Owen, B., Rechtman, R., Zechenter, E., 1989. Hunting and gathering in the tropical rain forest: is it possible? Am. Anthropol. 91 (1), 59–82.

Behrens, C., 1986. The cultural ecology of dietary change accompanying changing activity patterns among the Shipibo. Hum. Ecol. 14 (4), 376–396.

Behrens, C., 1992. Labor specialization and the formation of markets for food in a Shipibo subsistence economy. Hum. Ecol. 20, 435–462.

Behrens, C., Baksh, M., Mothes, M., 1994. A regional analysis of Barí land use intensification and its impact on landscape heterogeneity. Landscape Ecol. 22 (3), 279–315.

Binswanger, H., McIntire, J., 1987. Behavioral and material determinants of production relations in land-abundant tropical agriculture. Econ. Dev. Cult. Change 36 (1), 73–99.

Boserup, E., 1965. The Conditions of Agricultural Growth. Aldine, Chicago, IL.

Bunyard, P., 1989. Guardians of the Amazon. New Sci. 35, 38–41.

Cabodevilla, M., 1992. Misión Capuchina y Huaorani. In: Jass, J. (Ed.), Naúfragos del Mar Verde. La Resistencia de los Huaorani a una Integración Impuesta. Editorial Abya-Yala, Quito, pp. 76–74.

Chayanov, A.N., 1966. The Theory of Peasant Economy. Richard D. Irwin Homewood, Illinois.

Godoy, R., Lubanski, R., 1991. How Much is the Forest Worth? Guidelines for the Valuation of Non-Timber Tropical Forest Products. Harvard Institute of Development, Cambridge.

Godoy, R., Brokaw, N., Wilkie, D., 1992. The Effects of Economic Development on the Extraction of Non-Timber Tropical Forest Resources: Hypothesis, Methods, and Information Requirements. Manuscript. Harvard Institute for International Development, Harvard University.

Godoy, R., Brokaw, N., Wilkie, D., 1995. The effect of income on the extraction of non-timber tropical forest products: model, hypothesis, and preliminary findings from the Sumu Indians of Nicaragua. Hum. Ecol. 23, 29–52.

Hames, R., 1979. A comparison of the efficiencies of the shotgun and the bow in Neotropical forest hunting. Hum. Ecol. 7 (3), 219–252.

Hammond, D., Dolman, P., Watkinson, A., 1995. Modern ticuna swidden-fallow management in the Colombian Amazon: ecologically integrating market strategies and subsistence-driven economies? Hum. Ecol. 23 (3), 335–356.

Hart, J., 1978. From subsistence to market: a case study of the Mbuti net hunters. Hum. Ecol. 6 (3), 325–353.

Headland, T., Bailey, R., 1991. The tropical rain forest: is it a productive environment for human foragers? Hum. Ecol. 19 (1), 261–279.

Headland, T., Reid, L., 1989. Hunter-gatherers and their neighbors from prehistory to the present. Curr. Anthropol. 30 (1), 43–66.

Henrich, J., 1997. Market incorporation, agricultural change, and sustainability among the Machiguenga Indians of the Peruvian Amazon. Hum. Ecol. 25 (2), 319–351.

Homma, A., 1992. The dynamics of extraction in Amazonia: a historical perspective. In: Nepstand, D., Scwartzman, S. (Eds.), Non-Timber Products from Tropical Forests. Evaluation of a Conservation and Development Strategy. Advances in Economic Botany 9. New York Botanical Garden, New York.

Humphries, S., 1993. The intensification of traditional agriculture among the Yucatec Maya farmers: Facing up the dilemma of livelihood sustainability. Hum. Ecol. 21 (1), 87–101.

Jayne, T., 1994. Do high food marketing costs constrain cash crop production? evidence from Zimbabwe. Econ. Dev. Cult. Change 42 (2), 387–395.

Kanoeka, A., Solberg, B., 1997. Analysis of deforestation and economically sustainable farming systems under pressure of population growth and income constraints at the village level in Tanzania. Agric. Ecosyst. Environ. 62, 59–70.

Layton, R., Foley, R., Williams, E., 1991. The transition between hunting and gathering and the specialized husbandry of resources. Cult. Anthropol. 32 (3), 255–278.

Locay, L., 1989. From hunting-gathering to agriculture. Econ. Dev. Cult. Change 37 (4), 737–756.

Macdonald, T., 1981. Indigenous response to an expanding frontier: Jungle Quichua economic conversion to cattle ranching. In: Whitten, N. (Ed.), Cultural Transformations and Ethnicity in Modern Ecuador. University of Illinois Press, Urbana, IL, pp. 357–383.

Nietschman, B., 1973. Between Land and Water: The Subsistence Ecology of the Miskito Indians. Simnar Press, New York.

Padoch, C., 1988. The economic importance and marketing of forest and fallow products in the Iquitos Region. In: Denevan, W., Padoch, C. (Eds.), Swidden-Fallow Agroforestry in the Peruvian Amazon. New York Botanical Garden, New York, pp. 74–89.

Padoch, C., De Jong, W., 1990. The impact of forest product trade on an Amazonian Village. In: Prance, G.T., Balick, M. (Eds.). New Directions in the Study of Plants and People. Advances in Economic Botany 8. New York Botanical Garden, New York.

Padoch, C., Chota Inuma, J., De Jong, W., Unruh, J., 1985. Amazonian agroforestry: a market-oriented system in Peru. Agrofor. Syst. 3, 47–58.

Place, S. (Ed.), 1994. Tropical Rainforests: Latin American Nature and Society in Transition. Scholarly Resources, Wilmington Delaware, 229 pp.

Posey, D., 1993. Indigenous ecological knowledge and development of the Amazon. In: Ramakrishna, K., Woodwell, G. (Eds.), World Forests for the Future: Their Use and Conservation. Yale University Press, New Haven, CT, pp. 59–78.

Redford, K., Robinson, J., 1987. The game of choice: patterns of indian and colonist hunting in the Neotropics. Am. Anthropol. 89, 650–667.

Stearman, A., Redford, K., 1992. Commercial hunting by subsistence hunters: Sirionó Indians and the Paraguayan Caiman in Lowland Bolivia. Hum. Org. 51 (3), 235–244.

Stiles, D., 1994. Tribals and trade: a strategy for cultural and ecological survival. Ambio 23 (2), 106–111.

Swetman, J., 1989. What else did indians have to do with their time? alternatives to labor migration in pre-revolutionary Guatemala. Econ. Dev. Cult. Change 37 (4), 89–112.

Vickers, W., 1988. Game depletion hypothesis of Amazonian adaptation: data from a native community. Science 239, 1521–1522.

Vincent, J., Binkley, C., 1991. Forest based industrialization: A dynamic perspective. Harvard Institute for International Development. Development and Discussion Paper 389.

Yost, J., 1979. Desarrollo Comunitario y Sobrevivencia Etnica. El Caso de los Huaorani, Amazonia Ecuatoriana. Cuaderno Etnolinguístico No 6. Instituto Linguístico de Verano, Quito, Ecuador.

Yost, J., Kelley, P., 1983. Shotguns, blowguns and spears: The analysis of technological efficiency. In: Hames, R., Vickers, W. (Ed.), Adaptive Responses of Native Amazonians. Academic Press, New York, pp. 189–224.