Chronic Poverty
Research Centre

Working Paper

January 2010 No. 158

Testing a poverty trap mechanism with Tsimane' panel data

Emilie Perge

University of Sussex
Sussex House
Brighton
BN1 9RH
United Kingdom

What is Chronic Poverty?

The distinguishing feature of chronic poverty is extended duration in absolute poverty.

Therefore, chronically poor people always, or usually, live below a poverty line, which is normally defined in terms of a money indicator (e.g. consumption, income, etc.), but could also be defined in terms of wider or subjective aspects of deprivation.

This is different from the transitorily poor, who move in and out of poverty, or only occasionally fall below the poverty line.

www.chronicpoverty.org

Chronic Poverty Research Centre
ISBN: 978-1-906433-60-4

Abstract

Even if people have asserted the existence of a poverty trap within the forest, it has never been empirically tested that forest and poverty interactions lead to a poverty trap from which poor forest people could not escape (Angelsen and Wunder, 2003). This paper tests whether such a mechanism arises within forest communities and analyses the different livelihoods forest people could implement. Data used are from the Tsimane' Amazonian Panel Study (TAPS 2002–06) and have been complemented by qualitative data collected in June–July 2008. The poverty trap mechanism studied is inspired by Carter and Barrett's model defined for their studies of agrarian communities (Carter and Barrett, 2006). They intend to show that an S-shape exists in the asset accumulation process of households due to the presence of increasing returns to assets at an unstable equilibrium. An asset index is computed through factor analysis to estimate the asset accumulation process. To test the S-shape, different regression techniques are used: parametric, nonparametric and semiparametric. The parametric regression uses a fourth-degree polynomial regression to estimate the relationship between the change in asset index and its lagged value. For both nonparametric and semiparametric regressions, penalised splines and LOWESS estimators are used. All three regressions show that a poverty trap mechanism does not occur for the Tsimane', there is no S-shape in the asset accumulation and it seems concave. These results contradict Carter's and Barrett's results, because here Tsimane' households have a wide range of activities and assets. Households rely on diverse assets to achieve their livelihood. They use forest resources in addition to agriculture, so they are not pushed further into poverty if forest resources are depleted, they would rely more on agriculture as also land constraints are weak.

Keywords: Poverty trap, forest, forest livelihoods, factor analysis, parametric, nonparametric and semiparametric regression.

Acknowledgements

The author would like to thank Ricardo Godoy, Alejandro López-Feldman and Andrew McKay for their invaluable comments. She is also thankful to TAPS for the data and assistance throughout the fieldwork and to the Chronic Poverty Research Centre for the grant to achieve the fieldwork.

Emilie Perge is a DPhil candidate in Economics at the University of Sussex.

Email: e.perge@sussex.ac.uk

Contents

1 Introduction

The situation of people living within forests has been characterised as precarious in terms of wealth, health, education and environmental conditions, and researchers have often concluded that downward spirals are arising, leading to a poverty trap from which forest people could hardly escape (Angelsen and Wunder, 2003). This conclusion has been drawn from a focus on linkages between forest resources as a main component of forest peoples' livelihoods and wellbeing. Forest people are closely dependent on forest resources and have a great impact on their evolution (CIFOR, 2003). They use forest resources to meet their basic needs, e.g. food, shelter, furniture, raw materials (Arnold and Townson, 1998; Coomes *et al.*, 2004; Wunder, 2001), or to develop different types of activities, including hunting, gathering non-timber forest products (NTFPs), farming, logging, trading handicrafts products (Byron and Arnold, 1999; Sunderlin *et al.*, 2005). Forests have a great impact in modelling social relationships, as they are differently used at individual, family or community levels and they participate widely in the spiritual life of the people, as they are often considered as burial or sacred sites, and as spirit homes (Ritchie *et al.*, 2000).

Even if they are still highly dependent upon forest resources, it seems that more frequently forest people develop livelihood strategies relying on more diversified activities and assets. What I would like to test in the following analysis is whether these types of livelihood strategies would lead households living within forests to a poverty trap situation, explaining why forest households cannot reach higher levels of development or whether their low levels of development are due to slow growth rates in their consumption, earnings or asset holdings and thus would improve in time.

This would be an application of a poverty trap mechanism developed by Carter and Barrett, which relies on assets as a way to escape the poverty trap through asset accumulation (Carter and Barrett, 2006; Carter and Barrett, 2007; Barrett, 2007). To proceed to the application of their mechanism and to the test of a poverty trap with forest households, the remainder of the paper is organised as follows. In a second section, forest communities and households on which the test would be drawn are presented, in order to justify the interest in such a test for these households. A third section describes the poverty trap mechanism as defined by Carter and Barrett, and shows its early applications to different types of communities. A fourth section is dedicated to constructing the different elements required to proceed to the test, such as an asset index and the identification of different livelihood strategies. Afterwards, in a fifth section I test the poverty trap mechanism, using different estimation techniques: parametric; nonparametric; and semiparametric. The final section concludes and gives further implications towards which future analyses could focus.

2 Research area and data

The test of a poverty trap mechanism requires panel data in order to analyse the evolution of the economic situation of the agents. Since 1999, an international research centre composed by different Bolivian, US and European researchers has compiled data on an indigenous forest population, the Tsimane', and created a rich panel data set well designed to test a poverty trap.

2.1 Presentation of the Tsimane' population

The Tsimane' are a native Amazonian population living in the plains and rainforests of Béni in Bolivia. The Tsimane' territory represents 1.2 million hectares. In the last census from the Vice-Ministry of Indigenous Affairs, the Tsimane' population exceeds 8,000 inhabitants, while they were only 5,000 inhabitants in 1995. Traditionally a semi-nomadic population, they have settled in 100 communities, mainly situated along the Maniqui and the Apere rivers, although they still move from one community to another (Godoy and Jacobson, 1999; Reyes-García, 2001; Apaza *et al*., 2002). The main town in the area is San Borja, where the Tsimane' can go to sell their products and buy the goods they need. San Borja has various health amenities, such as a public hospital, doctors and an evangelist dispensary. Here they can also find schools up to the highest grade before university, and transport services to the capital-city, La Paz, to Santa Cruz and to other towns (Godoy *et al*., 1998; Reyes-García, 2001).

The Tsimane' practise traditional slash-and-burn agriculture and cultivate rice, maize, manioc and plantains. This type of agriculture consists of clearing the forest with machete and other small tools from May to August, then setting fire to it in September to October, and finally planting once the plot is totally cleared, starting by sowing rice. After the rice harvest, they plant maize, manioc and plantains. The cultivation cycle of these staples lasts only one or two years, after which the plot is left in transition for forest regeneration and they clear another plot. After a normal period of five years a former plot will be cleared again (Godoy *et al*., 1998; Vadez *et al*., 2003; Reyes-García, 2001). Agriculture is their predominant activity, both as a source of consumption products and as a source of earnings. They fulfil their protein needs through hunting small animals and big game, and through fishing, which justifies their localisation along the rivers. But the extinction of game has led them to raise chicken and pigs in order to fulfil their protein needs (Vadez *et al*., 2003; Reyes-García, 2001).

Historically, the Tsimane' were living in autarky, without contacts with outside agents. But the extraction of natural resources, such as gold, quinine and rubber, in the late 19th century and the beginning of the 20th century, led them to multiply contact with the outside economy. In the 1920s, while the extraction of these different resources declined, cattle ranching and logging activities became more important and the Tsimane' started working as unskilled

labourers, either clearing forests for cattle ranchers or finding valuable trees for loggers (Apaza *et al*., 2002; Reyes-García, 2001). Next to these wage activities, they have increased their contacts with outside agents through the expansion of commercial activities. Traders have come frequently to the communities in order to buy/barter agricultural products (rice, maize, manioc and plantains), forest products and hunting game, and to sell durable goods, e.g. clothes, radios, batteries, tools, alcohol and sugar (Apaza *et al*., 2002; Reyes-García, 2001; Godoy *et al*., 2008).

Catholic and protestant missionaries started coming to the indigenous territories during the colonial period with the goal of evangelising them. But the Tsimane' have remained mainly animist and the main contribution of these religious organisations has been the development of monolingual and bilingual schools in Tsimane' and Spanish, the implementation of dispensaries, and the creation of a radio emission that allows the Tsimane' to communicate from one community to another (Reyes-García, 2001).

To these external influences, the Tsimane' have adapted certain aspects of their way of life, none more so than their community organisation. They became increasingly sedentary and have changed the composition of their communities, which are now larger, with three to eight related families, and in which authority has been transferred from a shaman to an elected *corregidor* who is more integrated into the market economy (Reyes-García, 2001).

2.2 Data: quantitative TAPS data and qualitative data

2.2.1 Quantitative data: TAPS

Since 1995, the TAPS (Tsimane' Amazonian Panel Study) has been collecting data on the Tsimane' to analyse the evolution of different welfare indicators. The final panel data available encompasses five years (2002 to 2006), as the first seven years of the surveys aimed to 'identify communities, win the trust of the villagers, train local researchers, build logistical infrastructure, and refine methods of data collection' (Leonard and Godoy, 2008). The data available through the panel covers around 332 households, comprising nearly 1,985 individuals, who have been interviewed every year since 2002 . Out of the 100 Tsimane' communities in Béni, the panel data survey relies on 13 villages located at various distances from the main town of San Borja. While some of these are connected to San Borja by roads, other villages are located along the Maniqui river and only accessible by canoe.

The goal of this data collection has been to analyse the effect of the market economy on the wellbeing of the Tsimane' through data on demography, agriculture, income, consumption and expenditures, the shocks they faced, as well as their psychological status (Leonard and Godoy, 2008). The economic data that the research team have gathered are interesting and well developed. They encompass measures of the Tsimane' income according to different sources, such as wages, sales, barter and remittances. They look at their agricultural activities as well as their forest-product extractions through, for instance, hunting and use of

medicinal plants. They have collected data on their food consumption, their different expenditures and their assets (Leonard and Godoy, 2008). While generally well developed, the data are quite limited when looking at the size of fields and land holdings, as well as the different wage activities the households could undertake. Some data on gifts and education were only reported from 2004 and not over the five waves.

2.2.2 *Qualitative data*

When first analysing the data, some questions arose concerning wage activities, their living conditions and organisation. I have therefore collected qualitative data through observations as well as individual and collective interviews in different Tsimane' communities. Goals that motivated my fieldwork were: to obtain a better understanding of the relations between the Tsimane' and the forest resources; to learn how dependent upon their resources they are; to understand what motivates them to participate or not in wage activities; to appreciate what their rationality is considering the future; and finally to apprehend how organizsed they are, both within the community and in their interactions with non-indigenous communities.

My fieldwork took place during five weeks in June–July 2008. I went to 19 villages, most of them accessible by motorbike, but some only accessible by canoe. On average, the time needed to reach them varied from half an hour up to an hour or so. I was accompanied by a translator who has often been working with the TAPS researchers and was known by all the Tsimane' we interviewed. The interviews lasted up to half an hour and were either run individually or with different members of the household, or more collectively with members of different households. Generally I interviewed the male heads of the household in their houses, as men participate more in wage activities than women. When male heads were away, I tried to put the questions to their wives but most of these interviews were unsuccessful, as they were not willing to answer my questions, or busy taking care of their children. As often as I could, I tried to interview both the *corregidor*, who is the official representative of the community, and the teacher, who is also an important leader within the community. I attended various community meetings, where I gained an insight into both the strength of community among the Tsimane' and also how democracy works in these communities.

Considering the findings and observations, I can start by inferring that all the villages visited were either small or widely geographically spread, with the school in the centre of the village. There was no market place in the villages, nor were there official buildings representing either the Tsimane' governing body or the Bolivian government. Sense of community was lacking with the regard to certain villages, as they consisted merely of two or three families living one next to the other. Other descriptive findings from the qualitative and quantitative data are drawn below.

2.3 Descriptive analysis and findings from quantitative and qualitative data

2.3.1 Demographic features and living conditions

In the communities I observed that households were large and mainly composed of young members. The TAPS data shows that most of the households are headed by men aged between 26 and 45 years. Between 2002 and 2006, as reported in Table 1, the average age of a Tsimane' household was 21 years, and the average educational attainment was a first grade in primary school, while the Bolivian system counts 13 grades.

Table 2: Description of an average Tsimane' household

	Average age	Average education	Size of household	Number of children (<15 years old)
2002	21.6	1	6.6	3.0
2003	22.0	1	6.6	3.0
2004	21.0	1	6.2	2.7
2005	30.5	1	6.5	2.7
2006	21.1	1	6.5	2.8

A Tsimane' household is composed of six members, and three of them are under 15 years old. Educational attainments of household head remain low over the period. It seems that male education is improving in these communities and that households are still really young. The small number of old household members reflect the fact that life expectancy for the Tsimane' is low.

This low life expectancy can result from their physical living conditions. I observed that Tsimane' dwellings are ground-floor houses, with or without walls, and with thatch-palm roofs and earth floors. Most of them have everything in a single room, while some have a shelter for the kitchen separate from the main room where they sleep. A few villages have access to a well, but most villages did not have drinkable water, and none has a sanitation system.

2.3.2 Agricultural activities

Considering their agricultural activities, all the households I interviewed were cultivating rice, maize, manioc and plantains mainly for their home consumption, but they also allocated a part of their harvest, often half of it, to sell or barter to obtain durable goods. Each household was doing its own cultivation in nearly the same quantity, and no organisation or cooperative system was implemented.

The TAPS data showed that for the last three waves, from 2004 to 2006, rice production seemed more important than maize production for the Tsimane'. Rice production has increased along the period from 62.4 arrobas (around 717.8kg) in 2004 up to 187.9 arrobas (2160.6kg) in 2006 (see Table 2). At the same time, their rice sales have increased between 2004 and 2006, but in a smaller quantity compared to the rice production, which has resulted in a reduction of the sales on production ratio. When looking at the rice prices in each village, it has increased in nine villages out of 13, increasing on average by two to eight bolivianos. This increase in rice prices has not been accompanied by such a large increase in sales, as half of the households in each village have either increased or decreased their rice sales. The households do not seem to be really responsive to rice price variations. During the same period, corn production and sales have decreased, with sales decreasing in larger measure, leading to a decrease in the sales on production ratio.

Table 3: Household agricultural production and sales, 2004 to 2006

Products	**2004**	**2005**	**2006**
RICE (arrobas)[3]			
Production	62.4	85.3	187.9
Sales	35.0	46.9	35.1
Sales/production ratio	0.5	0.4	0.4
CORN (mancornas)			
Production	70.6	73.2	47.9
Sales	46.3	38.5	18.5
Sales/production ratio	0.5	0.4	0.2

Next to these main crops, the Tsimane' report growing various other crops. Most of the Tsimane' households report cultivating plantains. Other important crops are manioc, sugar cane and sweet potatoes. Only a few households report growing onions and peanuts.

To realise their agricultural production, the Tsimane' households have to clear a plot, and over the period, they cleared around 5.7 tareas, i.e. half-an-hectare, of fallow forest and 3.1 tareas of old-growth forest, one-third of hectare. The data in Table 3 show that the areas cleared are increasing along the period. I wanted to understand what the size of the field sown with rice and corn is, but the limited availability of the data impedes a conclusion on the area sown with rice. Considering corn production, the area sown with corn has remained exactly the same along the period (see Table 3).

3 1 arroba=6 mancornas =11.5kg

Table 4: Size of cleared forest and cultivated areas with rice and corn (2004–06)

Size (tareas)[4]	**2004**	**2005**	**2006**
Cleared fallow forest	5.5	5.6	6.5
Cleared old-growth forest	3.3	4.6	4.4
Rice cultivated area	n/a	n/a	0.9
Corn cultivated area	1.3	1.3	1.3

During my interviews, the Tsimane' reported neglecting to sell the trees that were on it, prefering to dry and collect firewood to use for cooking. Very few of them had ever sold firewood as a way of increasing their earnings. Few households were into a 'rice strategy', which consists of increasing the cultivation of rice as its price increased and becoming specialised in the production of one variety of rice instead of another, as this variety could bring higher earnings.

2.3.3 Earnings and wage activities

This paragraph summarises the different sources of earnings on which the Tsimane' rely. Four broad sources of earnings have been defined by the TAPS researchers: sales, wage, barter and remittances. In the five waves, the earnings generated through wage seem to be the most important, except in 2005, when the Tsimane' households did receive more earnings from sales (see Table 4). But what is interesting is that even if the earnings from wages are the most important, they are not the most important in terms of participation, as more households report earnings from sales and even in some years from barter. The values of remittances received during the period are really high, but fewer than 10 households report them.

Table 5: Mean nominal earnings in bolivianos (US$1=6.970Bol.) during the last two weeks for households reporting earnings from each source

Years	**Sales**		**Wages**		**Barter**		**Remittances**		**Total earnings**	
	N	**Bol.**	**N**	**Bol**	**N**	**Bol**	**N**	**Bol.**	**N**	**Bol.**
2002	116	144.5	99	169.6	101	31.6	9	253.3	173	225.6
2003	109	159.1	88	194.8	106	34.5	8	307.8	163	249.1
2004	128	134.7	117	244.8	113	35.2	9	131.3	196	260.5
2005	145	267.9	119	253.4	115	51.9	8	121.3	196	387.5
2006	128	215.7	116	293.8	124	46.3	4	543.8	189	368.3

4 10 tareas = 1 hectare

What the qualitative survey reveals is that for households taking part in a wage activity, such as working with a cattle rancher or working for a logger, for the ones I could talk to, their main motivation for participating in such an activity was to cope with an unexpected expenditure, such as buying medicines or tools. They were working with these persons on a daily or contract basis, from time to time. The ones who worked more regularly in a wage activity were not present in the household while I was there, as a more permanent tenure of labour required their relocating to live on a ranch or logging company property. Temporary work with a cattle rancher generally consists of clearing forest areas and building fences, while a more permanent employment means that they can take care of the cattle and have more responsibilities. The individuals working more permanently were young unmarried men of the household, and their wage was used to help their family to cope with events and to buy clothes. In the case of important emergency, they said that they can request loans from the cattle ranchers they usually work with and would repay them by working for them. Their main argument for not working every day was that it is tiring and they are not willing to follow someone else's rules and orders. They prefer working on their own than working with and for someone.

2.3.4 Consumption and assets

Looking at the consumption values, I decided to consider the deflated values of consumption aggregates and I calculated a consumer price index using price data. The average consumption of the Tsimane' households increased between 2002 and 2003, then decreased in 2004, increased between 2004 and 2005, and finally decreased between 2005 and 2006, but the 2006 average value remains higher than in 2004 (see Table 5).

Table 6: Household consumption aggregates between 2002 and 2006 (deflated values to 2004 prices)

Years	**Farm products**	**Oil products**	**Market meat**	**Starch products**	**Domestic meat**	**Wildlife products**	**Total consumption**
2002	37.3	7.6	25.1	21.7	9.9	147.3	248.4
2003	38.7	6.0	24.4	18.0	11.4	130.4	229.2
2004	21.9	5.8	20.5	17.2	8.5	161.6	235.6
2005	39.3	8.6	26.7	46.8	9.3	167.3	298.1
2006	53.3	14.5	39.2	46.5	15.5	123.0	292.0

The largest part of their consumption was composed of wildlife products (birds, fish and game), then of staple products that are assumed to be home-produced. The latter category has increased since 2004 and the main products consumed were plantains and rice. The total consumption aggregate has decreased between 2005 and 2006, which is explained by the decrease in wildlife consumption. What is interesting to highlight is that most of their consumption was generated by home production, either through agricultural activities or hunting and fishing.

Looking at their asset holdings, on average, their total wealth has increased since 2002, from 3,896.4 bolivianos in 2002 up to 4,966.6 bolivianos in 2006, but with a small decrease in 2003 and 2004 (see Table 6). The main asset holdings of the Tsimane' is their holdings in modern assets, which include the assets the Tsimane' purchased in San Borja or from traders, such as radios, big pots, rifles, knives, etc. Between 2002 and 2006, their modern asset holdings have increased from 2,225.0 bolivianos to 3,096.0 bolivianos.

Table 7: Household asset holdings between 2002 and 2006 (deflated values to 2004 prices)

Years	**Animal wealth**	**Modern wealth**	**Traditional wealth**	**Total wealth**
2002	734.8	2,225.0	936.6	3,896.4
2003	555.0	2,313.7	858.7	3,727.4
2004	635.0	1,895.1	648.1	3,178.2
2005	806.4	2,708.2	981.2	4,495.8
2006	771.5	3,096.0	1,099.1	4,966.6

They also have high values of traditional asset holdings that are hand-made, but their values have increased from 936.6 bolivianos in 2002 up to 1,099.1 bolivianos in 2006. These assets encompass various objects, from bags and bows to canoes and grinder stones. The last category of assets they can hold is their animal assets, composed of cows, ducks, chickens and pigs. It seems that over the period holdings in animal assets have slightly increased.

Having in mind the different characteristics of the Tsimane' households and communities, and an appreciation of their wellbeing, a poverty trap test seems accurate. In order to proceed with the test, a typical poverty trap model, here referred to as Carter and Barrett's poverty trap mechanism has been selected. The following section will present it.

3 Poverty trap mechanism: Carter and Barrett's model of poverty trap

Many different models have been designed to understand and explain why some individuals are ensnared in a low level of economic development, while others seem to enjoy greater levels of welfare. Some underline the importance of institutions, kin systems and history in the development of multiple equilibria, while others focus on the lack of insurance and the nature of risks individuals face. Bowles *et al.* (2006) provide a good review of the different aspects of this mechanism and related models.

3.1 Carter and Barrett's poverty trap mechanism: presentation and previous applications

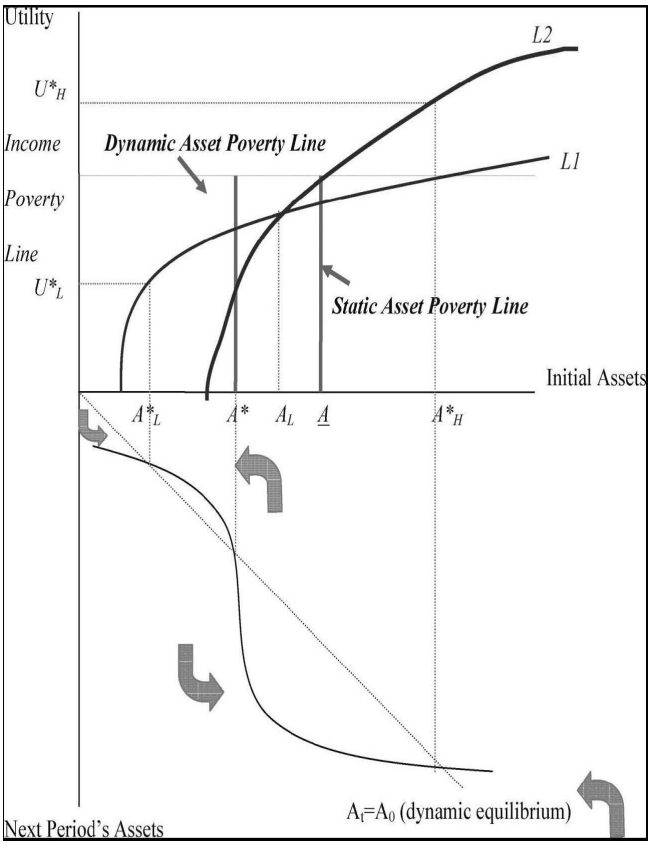
3.1.1 Presentation of the model

The following analysis of the poverty trap mechanism is based on the literature by Carter and Barrett, who test such a mechanism in agrarian societies. A poverty trap could be defined as ''self-reinforcing mechanisms that act as barriers to the adoption of more productive techniques and so cause poverty to persist' (Azariadis and Stachurski, 2004; Barrett, 2007). In their model, as presented in Figure 1 below, a household chooses to allocate its productive wealth to one of two distinct strategies. A household with a low level of assets A_L would choose to use its assets within a strategy L_1 yielding to a low level of well-being $U_{L,}$ while a wealthier household would choose to use its assets A_H in a higher-earning strategy L_2 leading to a higher level of welfare U_H . Both asset allocations lead to locally stable equilibria with non-increasing marginal returns. A high-return strategy has higher returns, while a low-return strategy has lower ones, which creates non-convexities in asset accumulation. Setting a static poverty line at $\underline{A}$ emphasises the point that a household choosing to allocate its assets to a strategy L_1 is caught in poverty. Nevertheless, a level of assets A_S exists from which a household rationally switches from one strategy to the other. To reach this level of assets, however, a poor household must have asset holdings above the dynamic asset poverty line A*, here called Micawber threshold. Below the Micawber threshold, a household has less investible surplus and depressed marginal incentives to save; above this threshold, a household rationally starts accumulating assets through an autarkic accumulation strategy (Carter and Barrett, 2006). Through asset accumulation, a household would reach a level of asset from which it switches from a low return strategy to a high return one. Finding out this threshold requires an assessment of the asset accumulation process which links the current level of assets to the future level. Plotting future asset holdings against current ones is expected to give a S-shaped curve, where the Micawber threshold would simply be the unstable equilibrium where the asset accumulation bifurcates (Carter and Barrett, 2006).

Therefore an asset accumulation process is what allows convergence to the high stable equilibrium and the improvement in welfare (Barrett, 2007). But the poorer households

cannot accumulate assets, and Barrett and his co-writers point out different reasons for this (Barrett *et al*., 2006). They explain that poorer households cannot accumulate assets due to their portfolio choices. They would adopt a defensive portfolio strategy, preferring low-yield, low-risk activities rather than higher-yield, higher-risk activities. As returns on assets are positively correlated to their initial wealth, the rate of returns with this portfolio strategy is even less than the one the richer agents have with higher-yield higher-risk strategy (Zimmerman and Carter, 2003; Carter and Barrett, 2006). Another point they use in accounting for non-asset accumulation by the poor is the subsistence constraints they have to face. Poorer households have such low levels of consumption that they cannot reduce them further in order to increase their savings and start an asset accumulation process. A third justification deals with their lack of liquid savings and credit, which does not allow them to buy more assets and start an asset accumulation (Barrett *et al*., 2006). Both the weak development of banking systems for the poor and their lack of counterpart impede them in obtaining credit. This lack of credit makes them reliant on what they actually earn and they have to accumulate assets. Their asset accumulation is impeded if their earnings are not high enough to increase their asset holdings.

Figure 2: Poverty trap from Carter and Barrett (2006)



Here analysis is centred on strategies and assets instead of on activities and income or consumption expenditures, because assets are expected to better reflect the heterogeneity of the livelihoods of poor people. Further, assets are the source of future earnings, so their

accumulation is what allows individuals to reach higher levels of wellbeing (Coomes *et al*., 2004; Naschold, 2005).

3.1.2 Findings of some previous applications of the model

Lybbert *et al*. (2004) have studied herd size held by Ethiopian pastoralists. They found some non-convexities in the accumulation of cattle, leading to a S-shaped asset accumulation curve with two stable equilibria: a low one, corresponding to a herd size of one head range, and a higher one at herd size of 40-75 head range. They identified a threshold level of 15 animals from which households could rationally change their way of raising cattle and adopt a more productive one.

Barrett *et al*. (2006) show that among Kenyan pastoralists, an S-shape characterises their accumulation of livestock, with two different stable equilibria as well as the unstable equilibria. But while studying asset accumulation in Madagascar they have not found such a pattern among households.

Naschold (2005) has not found a multiple equilibria pattern for asset accumulation amongrural households in Ethiopia and Pakistan. The estimations he has run have presented a unique and low equilibrium.

In their estimation of a poverty trap mechanism in South Africa, Adato *et al.* (2006) explain why some post-apartheid households have succeeded in escaping poverty while others are still ensnared in low levels of economic development. To develop their analysis, first they study poverty dynamics within South Africa from 1993 to 1998 and identify different patterns, e.g. chronic poverty, transitory poverty, with people escaping and others falling into poverty, and non-poverty. They use four different key assets integrated into a weighted asset index in order to estimate the asset accumulation path and the poverty dynamics among these households, so as to identify any possible S-shape in asset accumulation. They find a Micawber threshold equal to twice the poverty line, and the households below this threshold would be captured in a poverty trap at a low equilibrium, with a level of wellbeing about 90 percent of the poverty line. The asset accumulation process they have estimated presents an S-shape and they have used it to determine where households are positioned regarding this poverty line and where they are heading (Adato *et al.*, 2006).

Even if closer to reality than neoclassical growth models, some limits could be highlighted in poverty trap model specifications. In most studies, beside Adato *et al.* (2006), researchers have focused on populations whose livelihoods and strategies depend upon only one type of activity. Lybbert *et al*. (2004) and Barrett *et al*. (2006) have tested the poverty trap model on herders and agro-pastoralists in both Kenya and Ethiopia. These two papers refer to populations whose strategies, both low-return and high-return, are related to cattle and are highly diversified. Therefore, these studied populations rely on only one type of asset to generate their strategies, here cattle, from which it is easier to identify the presence of

exclusionary mechanisms, such as the lack of insurance when animals are lost due to disease, or the lack of liquidity to buy medicines to take care of the cattle. Identifying increasing and non-increasing returns to scale linked to the different levels of cattle holdings is also a more straightforward process.

My contribution to the test of a poverty trap mechanism would be to study households whose strategies rely on more diversified activities when compared to the agro-pastoralists studied by Lybbert *et al*. (2004) or Barrett *et al*. (2006), even if their strategies are not too diversified in comparison to other groups. Another important contribution depends on the fact that I am analysing a population whose strategies require different assets to generate their livelihood, rather than a single asset whose variation in the asset holdings directly influences their livelihood and welfare. This will allow me to demonstrate how to capture a poverty trap mechanism with more diverse asset holdings.

3.2 Exclusionary mechanisms leading to multiple equilibria in the asset accumulation process

Market imperfections, imperfect information and coordination failures are the three main exclusionary mechanisms retained to explain why increasing returns to scale and non-convexities in the asset accumulation process arise. All three are identifiable within Tsimane' communities.

3.2.1 Market imperfections

Markets in developing countries are characterised by imperfections that would in fact impede the convergence of growth rates in the long run. Such market imperfections could involve the existence of negative transaction costs that make the marginal returns from a higher-welfare strategy insufficient to overcome the costs of implementing such a strategy for poor households (Azariadis and Stachurski, 2004; Barrett, 2007). To implement higher-return strategies, agents need to adopt more expensive tools or production processes. Wealthier households are therefore more able to adopt such tools, while poorer households are unable to do so, as the costs to adopt these tools are higher than the returns.

In the case of the Tsimane', they have a weak access to markets. This is a resultof the remoteness of their communities to the main market in San Borja or Yucumo, and the lack of infrastructure, making it difficult for the furthest communities to sell their agricultural products at these markets. Also, selling products at markets requires additional costs that only few households can afford. Poorer Tsimane' households are more dependent upon traders who travel from one community to another, which leads to multiple prices of products and a lack of transparency about a fair price for the products.

The inefficiency of financial markets in developing countries leads to increased financial constraints, credit constraints and uninsured risks, which restrict poorer households from

switching their actual subsistence strategy to a higher welfare strategy. The lack of legal frameworks effective in enforcing insurance contracts in developing countries has been underlined as an important source of failures in the insurance market (Carter and Barrett, 2006; Barrett, 2007). The Tsimane' do not have access to credit and insurance markets. All the credits they report have been obtained on an informal credit system, as both the cattle ranchers and the loggers working with the Tsimane' agree to lend money to those they work with. In 2006, 65 percent of the households received credits from these informal lenders. Such loans require great trust – two stakeholders know each other and repayment is done through extra labour.

Furthermore it appears that among poorer agents risks are often covariant and not idiosyncratic, which makes their repayment more expensive and burdensome in poorer communities. The covariance in the risk these agents face makes informal insurance mechanisms, i.e. self-insurance, risk mitigation and risk transfer, often inapplicable to them (Carter and Barrett, 2006, 2007). Yet, even when risks are idiosyncratic, their neighbours are just as poor as they are and cannot really help them (Azariadis and Stachurski, 2004; Barrett, 2007; Barnet *et al*., 2008). Their main insurance mechanism consists in selling more products when they need extra liquidity to cope with an unexpected event. When they face covariant risks, such as flooding, the only way the Tsimane' can cope with such risks is through external aid from national or international non-governmental organisations.

3.2.2 Incomplete information

The second exclusionary mechanism Barrett and Carter use to explain the existence of multiple equilibria in the asset accumulation process emphasises the importance the of imperfect information available to poor households. While explaining the limits of the neoclassical growth model, creation of knowledge has been advanced as an important feature in the explanation of the divergence in growth rates in the long run (Azariadis and Stachurski, 2004). Low access to information, due to low levels of education and training as well as less diversified social networks, increases the cost of adopting a livelihood strategy relying on more complicated techniques. Also, poorer individuals are unable to perfectly observe the consequences of their actions and even less the consequences of the actions of other agents, making the impacts of such actions observable only in the future. They cannot observe that the techniques used are not as productive as they expect and create more

social costs than private benefits (Carter and Barrett, 2006; Barrett, 2007). The path-dependence nature of information driving the poor to create norms and institutions reflecting their available information is a crucial element in explaining why poorer individuals cannot implement higher strategy. Path dependence of the institutions impedes them from evolving according to emerging information, even if they may be a rational response to an individual's situation (Azariadis and Stachurski, 2004; Barrett, 2007).

The Tsimane' endure a situation in which they do not have access to perfect and complete information. The qualitiative survey reveals that they implement techniques without knowing that better techniques or higher-yielding seeds are available. Their low levels of education restrain them from accessing better technologies and understanding how these technologies work. Limited communication, due to a lack of infrastructure among the Tsimane' communities, prevents them from knowing that these technologies exist. Tight networks seem also to characterise the Tsimane' communities, as the majority of them are composed of a small number of households, often blood-related. The fact that most of the Tsimane' only speak Tsimane' and not Spanish reduces their opportunities to widen their networks with the rest of the population and thus their opportunities to accede to richer information.

3.2.3 *Coordination failures*

The third exclusionary mechanism highlighted deals with coordination failures. The weakness of the institutions and their incapacity to control, monitor and enforce law, and to provide public goods, as well as the actual corruption of these institutions, are factors which prevent poorer individuals from implementing higher-earnings strategy (Barrett, 2007; Carter and Barrett, 2006). The poor definition of property rights and the prominence of common property regimes, wherein agents fail both to communicate on the state of resources and the techniques they use, and to implement sustainable techniques, are also barriers to the adoption of higher-earnings strategies by poorer agents (Baland and Platteau, 1996; Barrett, 2007). The Tsimane' territory is ruled by a common property system, in the sense that any Tsimane' household can clear a part of it to cultivate without asking permission from anyone. This lack of property rights discourages households from adopting more productive technologies and keeps the poorest households in low-yielding activities. At the same time, investing in land does not seem to be a main issue, because soil is highly fertile and the agricultural process involves clearing new land every year and going back to a previous plot every five years. Another coordination failure proceeds from the multiplication of legal bodies to refer to when productive activities are intended. Considering the forestry sector, the Gran Consejo Tsimane' gives concession rights to the logging companies, but coexisting to this institution, the Superintendance of Béni, which is not a Tsimane' body, also regulates the extraction of logging products. If the Tsimane' want to sell any logging products extracted from their territory they have to buy a licence from the Superintendance. This procedure is costly and incites them to extract wood in an illegal way, which brings more inconveniences than benefits. Several rumours of corruption surround the Gran Consejo, regarding receiving grants for the implementation of development projects in the Tsimane' territory.

3.3 Livelihood strategies of the Tsimane'

As part of their model specification, Carter and Barrett highlight the importance of two different livelihood strategies, with higher or lower returns to assets and yielding to different equilibria. The Tsimane' households can generate their earnings either through a high-return strategy, in the sense that these earnings are generated to have more income and to create

a surplus in their outputs, or through a low-return strategy, where all the earnings generated are used in order to fulfil basic needs and to cope with unexpected events. To decompose the households into two categories, I tried different specifications but all results were quite similar. In what follows I use their earnings and their asset holdings in order to find out two different livelihood strategies. I define as households pertaining to a high-return strategy those whose earnings and wealth are in the two upper quintiles for at least four years. I have considered four years in the two upper quintiles because I have assumed that a household could face an unexpected event that would decrease its earnings or its asset holdings. From this specification 16 households seem to be engaged in a high-return strategy and 156 households in a low-return one.

Table 7 presents the different characteristics of the households, whether they are in a high- or low-return strategy. Next to wealth and earnings, households in a high-return strategy have higher levels of consumption. Even if the differences in total consumption are not really important, their consumption of meat they raised is more important. Households in a high-return strategy are larger than households in a low-return strategy, and their household heads and household members are more educated. There are no large differences in the average age of the household head and household members. Another interesting difference between high and low strategies is rice production, which is always larger for households in a high-return strategy. Corn production is either larger or smaller between high and low return strategies. Households in a high-return strategy tend to clear more fallow forest than households in a low-return strategy; but they tend to clear the same area of old-growth forest. When looking at their remittances and gifts, no differences can be pointed out, which could result from the small number of people receiving remittances or gifts.

Table 8: High- and low-return strategies 2002-2006

Variables	2002		2003		2004		2005		2006	
	High	Low	High	Low	High	Low	High	Low	High	Low
Total wealth	**7508.5**	**3566.7**	**5980.4**	**3570.5**	**6455**	**3121.7**	**8301.0**	**4384.5**	**6952.7**	**5114.5**
Animal wealth	1326.1	649.3	864.7	524.7	1773.1	586.6	1946.4	714.3	852.2	786.3
Traditional wealth	1376.5	905.9	1189.1	844.2	1121.9	654.8	1588.9	937.5	1571.3	1136.4
Modern wealth	4805.9	2011.5	3926.6	2201.5	3560	1880.3	4765.7	2732.7	4529.1	3191.7
Total Consumption	**432.8**	**234.8**	**314.9**	**223.9**	**337.4**	**228.7**	**336.0**	**302.7**	**400.4**	**289.7**
Domestic meat	28.7	6.6	18.4	10.9	8.6	8.1	15.4	9.2	23.4	15.4
Staple products	51.5	36.1	51.4	38.0	33.1	21.8	44.9	39.3	56.3	55.2
Wildlife products	230.4	145.2	163.8	129.2	222.6	157.9	179.4	171.8	160.2	122.8
Total earnings	**695.1**	**227.9**	**675.6**	**250.7**	**410.5**	**234.2**	**962.8**	**371.6**	**1013.0**	**433.6**
Sale earnings	367.5	99.6	341.2	116.3	145.1	84.0	490.3	212.9	436.7	178.5
Wage earnings	309.7	105.2	288.0	108.8	227.8	132.8	419.6	125.7	509.5	218.3
Household characteristics										
Household size	8.3	6.4	8.3	6.4	7.7	6.4	8	6.7	7.6	6.7
Age household head	45.1	43.4	43.3	44.7	51.7	44.2	43.5	43.9	48.6	43.4
Education household head	3.8	2.6	4	2.5	3.6	2.3	3.5	2.3	3.9	2.3
Average education for members	2.1	1.6	1.9	1.6	2.0	1.5	1.9	1.6	2.2	1.6
Average age household members	23.4	21.8	17.6	22.3	23.0	22.0	18.7	21.0	20.0	22.0
Agriculture										
Corn production (mancornas)	n/a	n/a	n/a	n/a	88.5	70.9	99.6	77.4	16.8	42.8
Rice production (arrobas)	n/a	n/a	n/a	n/a	119.8	56.4	104.9	84.5	137.4	70.2
Cleared fallow forests (tareas)	6.25	5.1	10.3	6.0	10.4	5.2	8.8	5.7	10.8	6.1
Cleared old-growth forests (tareas)	3.4	4.3	3.2	4.0	3.75	3.3	4.7	4.5	5.2	4.5
Social capital										
Number of gifts received	2.3	1.1	1.9	0.8	1.8	1.1	1.5	1.2	1.1	1.0
Remittances received (bolivianos)	10.9	18.7	5.1	23.9	18.8	2.3	0	1.1	26.0	15.8

4 Definition of an asset index through factor analysis

Carter and Barrett's poverty trap mechanism requires the analysis of an asset accumulation process. The clear goal of the mechanism, as explained above, is to discern an S-shaped curve in the asset accumulation process with a threshold from which a household starts accumulating assets in order to switch from a low-return strategy to a high-return one. TAPS collect data on different assets and with some of these assets I have built an asset index, using a factor analysis technique.

4.1 Methodology to build an asset index with factor analysis

A factor analysis is *'*a statistical technique that consists in representing a set of variables in terms of lower number of hypothetical variables' (Lawley and Maxwell, 1973; Friel, 2007). The aim of factor analysis is to indicate these unobserved variables, also called underlying factors, and to explain that the variables are created out of these underlying factors (Lawley and Maxwell, 1971; Lewis-Beck, 1994). From these underlying factors, the point is to identify common factors that are the source of more than one variable. To do so, factor analysis partitions the variance of each factor into a common variance, which is *'*the common variance accounted for by the common factor which is estimated on the basis of the variance with other variables,*'* and a unique variance, which is on the other hand, *'*combination of the reliable variance specific to the variable and a random-error variance*'* (Lewis-Beck, 1994). The idea is to keep one common factor which accounts for a larger part of the variance of the variables (Lewis-Beck, 1994; Friel, 2007).

Different types of factor analysis methodology are available. The most common ones are the principal component analysis and the principal factor analysis. The difference between both techniques relies on how the factors explain the variance. When considering the principal component analysis, it forces all the components to explain completely the variance of the variables, while the principal factor analysis allows the factors not to explain totally the variance of the variables (Lewis-Beck, 1994; Sahn and Stifel, 2000).

The first step is to determine whether the variables, here the Tsimane' assets, are correlated. To do so, two tests can be done: the Bartlett's test for sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. The Bartlett's test consists of measuring the strength of the correlation between variables, and its null hypothesis consists of stating that the correlation matrix comes from a sample in which the variables are non-collinear. Rejecting the null hypothesis from this test leads us to affirm that the variables share at least one common factor that explains their variance. The KMO measure compares the magnitude of the observed coefficients to the magnitudes of the partial correlation coefficients (Lewis-Beck, 1994; Naschold, 2005). If this magnitude is strong enough, then the factor analysis is a relevant technique to define an asset index representing the wealth of the households.

The second step consists of estimating the different coefficients required to construct an asset index, as described by Sahn and Stifel (2000), whose form is as follows:

$$AI_i = \hat{\gamma}_1 a_{i1} + \ldots + \hat{\gamma}_K a_{iK}$$

AI_i is the asset index estimated for the *i* households in the sample, it is a function of their *k* different assets, a_{ik} whose weights k have to be estimated through factor analysis. What is assumed here is that the ownership of the different assets is explained by a common factor and by a unique element, whose variance is not correlated across assets (Sahn and Stifel, 2000).

$$a_{ik} = \beta c_i + u_i$$

And both the common variance *c* and its coefficient are not observed and must be estimated, which is the aim of a factor analysis. This estimation would lead us to construct a matrix of factor loadings that reflect the relationship between the assets and the common factor, and the common factor would be derived from this unique matrix of factor loadings (Bhorat *et al.*, 2006).

$$c_i = f_1 a_{i1} + f_2 a_{i2} + \ldots + f_K a_{iK}$$

The welfare is a linear combination of the scoring coefficients f_k of each asset and the asset holdings $a_{k.}$ A large factor score would mean that the asset associated to this score is better to explain the differences in welfare between households (Sahn and Stifel, 2003).

And to finally find out the asset index, the factor scoring coefficients are normalised around the mean and the standard variation of each asset (Sahn and Stifel, 2000; Bhorat *et al.*, 2006):

$$AI_i = f_1 \left(a_{i1} - \bar{a}_1\right) / \sigma_{a_1} + \ldots + f_K \left(a_{iK} - \bar{a}_K\right) / \sigma_{a_K}$$

where f_k are the factor scores for each asset, $\bar{a}_k$ the mean value of each factor and σ_{aK} the standard deviation. The asset index would be estimated for each household in each year, and the following subsection illustrates this technique with the Tsimane' data, in order to finally analyse the poverty dynamics among the households.

4.2 Choice of assets included in the asset index

In the definition of this asset index, I use different types of assets representing different categories of capital, as explained by Ellis (2001). Asset selection has been done by studying the correlation coefficients between them. I choose only assets that are highly correlated to one another and I obtained the following sample of assets. The physical assets consist of

various durable goods, such as bike, canoe, mosquito net and radio. These assets are not directly generating earnings through productive use, but they are important in order to increase the welfare of the Tsimane'. Tsimane' with bikes and canoes are more able to go to San Borja and benefit from its amenities. Having a mosquito net is their only way to be protected against malaria. As said before, they communicate by diffusing radio messages, which justifies the importance of having a radio. The productive capital is composed of axe, bow, hook, knife, machete, net, rifle and shotgun. These assets are used for their activities, whether agricultural (axe, machete, knife), hunting (bow, rifle, shotgun and knife) or fishing (net, hook and knife). Considering their agricultural activities, having an axe could lead to an increase in their earnings through bigger agricultural plots or through the sales of the trees they fell with the axe. Rifles and shotguns are better weapons to hunt than a bow, and require additional costs through the purchase of bullets and ammunition. With the same type of analysis, having a net to fish could lead to catching more efficiently fish more efficiently than with a hook and a cane. Natural capital is composed of the number of cows they have and the size of the area of cleared forest. Having cows illustrates that a household has cash earnings it could invest in acquiring a cow, while clearing more plots leads to increased earnings through an increase in agricultural production. The proxy for social capital is the number of gifts received by a household. And human capital is the number of members speaking Spanish within a household, and any members of the household with mathematical skills.

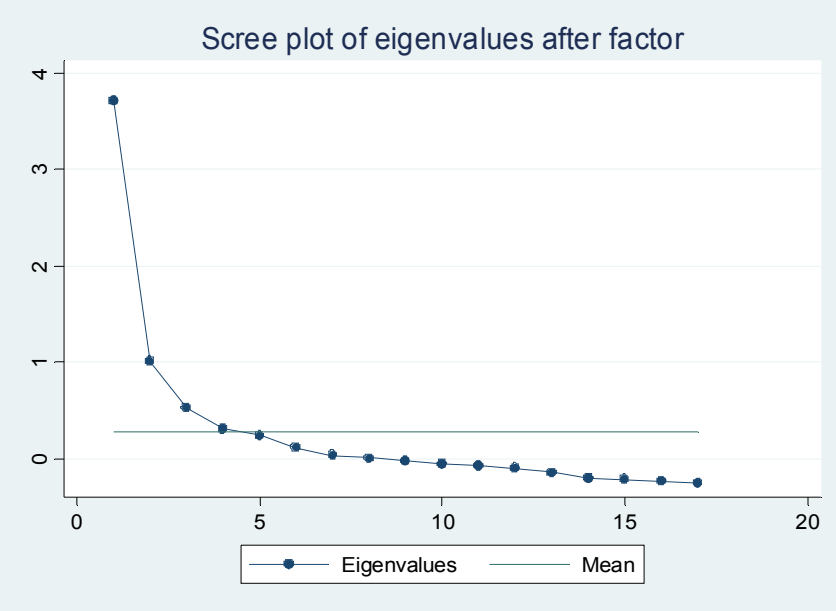
4.2.1 Bartlett's test and KMO measure to justify the factor analysis

The Bartlett's test for sphericity indicates that the correlation matrix of these different assets is not an identity matrix. Its coefficient is equalled to 0.023 and it is null, which allows us to reject the null hypothesis. It seems rational to apply a factor analysis with these assets because the assets are highly correlated and it can be assumed that a common factor explaining the holdings of these assets does exist. The Kaiser-Meyer-Oklin (KMO) measure of sampling adequacy is large, equal to 0.849. It indicates that the assets share a common factor. The factor analysis is relevant and is a good tool to construct the asset index.

I would assume that only one factor explains the variance of the variables and I would label this factor as welfare. I could start the factor analysis using a principal factor methodology, estimating the factor loadings and factor scores from which an asset index would be built.

4.2.2 *Factor loadings, factor scores*

Figure 3: Scree plot of eigenvalues after the factor analysis



As I assume that only one common factor explains the variance in the asset quantities, I run the factor analysis with STATA, specifying that I would retain only one factor. The eigenvalues obtained from the correlation matrix show that two factors explain the variance in the quantities of assets, as the first two factors have eigenvalues above one, and considering the Kaiser criterion I should consider these two factors. The scree plots (see Figure 2) show that first two factors are above one, and the Kaiser criterion explains that I should keep all factors whose values are above one. However, because the eigenvalue of the first factor is quite large and the one of the second factor close to one, and because the first factor explains nearly 80 percent of the variance in the asset quantities, it is rational and sufficient to take into account only one factor.

The factor loadings for each asset show that the common factor labelled welfare explains positively the variance in each asset. The higher a factor loading value, the better the variance of the related asset is explained by the factor. Here the holdings of machete, mosquito net and knife are better explained by the common factor than the other assets. It seems that as their welfare increases, the Tsimane' would rather purchase and accumulate these assets than any other assets.

From these factor loadings, the factor scores could be estimated. The Table 8 is obtained and shows that all the assets have a positive effect on the asset index. The relative large weights of machete and mosquito net can be understood as better criteria to differentiate the households according to this asset index, than the size of plot or gifts.

Table 9: Factor scores of the different assets

Variable	**Factor scores**
Axe	0.14
Bike	0.05
Bow	0.12
Canoe	0.06
Cow	0.03
Hook	0.16
Knife	0.20
Machete	0.26
Mosquito net	0.27
Net	0.08
Radio	0.09
Rifle	0.04
Shotgun	0.07
Size plot	0.09
Gifts	0.03
Spanish	0.04
Maths	0.01

4.2.3 Estimation of the asset index

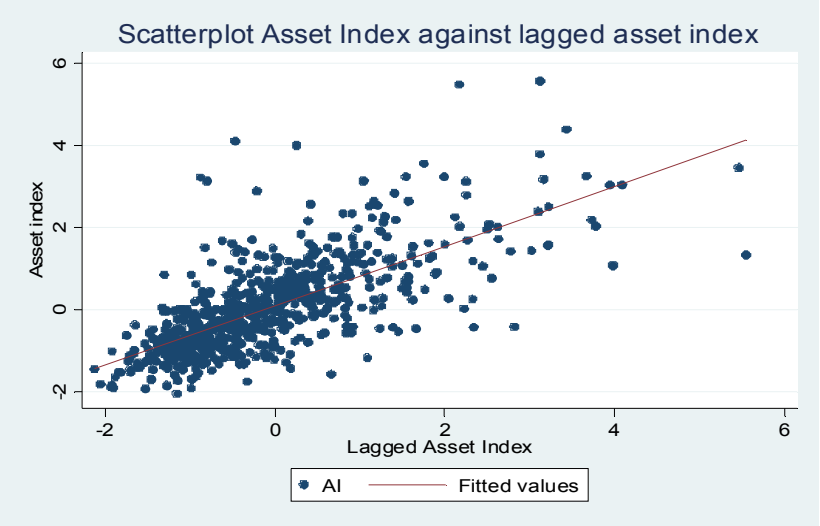
From these factor scores I can define an asset index by normalising the asset quantities around the mean and the standard deviation. The average values of the asset index in each year are reported in Table 9. The mean values of the asset index over the period increase. It seems that some kind of accumulation is happening within the Tsimane' communities. But still it seems that there are some concentrations around 0, which results from the standardisation around 0.

Table 10: Asset index in each wave

Variables	**Obs.**	**Mean**	**Std. dev**	**Min**	**Max**
AI 2002	172	-0.16	1.07	-2.12	3.95
AI 2003	172	-0.14	1.06	-2.05	3.24
AI 2004	175	-0.094	1.07	-1.91	5.47
AI 2005	175	0.12	1.21	-1.53	5.55
AI 2006	176	0.30	1.10	-1.92	4.38

The scatterplot of the asset index versus its lagged value (Figure 3) and the Kernel density of the asset index (Figure 4) confirm that there are concentrations close to zero. The scatterplot of the asset index against the lagged asset index does not allow us to reasonably assume that there is a linear relationship between the asset index and the lagged asset index. Different regression techniques – parametric, nonparametric and semiparametric – should be used to demonstrate this relationship.

Figure 4: Scatterplot of asset index against its lagged values

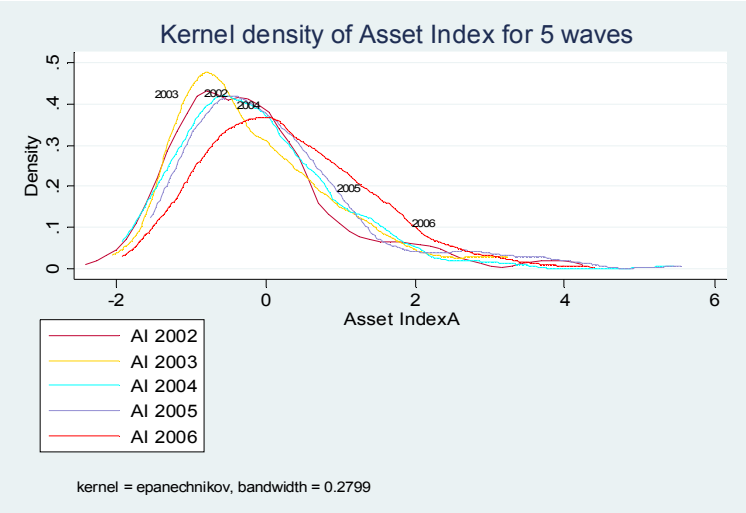


5 Empirical tests on the existence of a poverty trap within the Tsimane'

As concluded previously, the asset index scatterplot does not allow us to show if there is any linearity between the asset index and its lagged value, which is a condition to obtain an S-shaped curve in the asset accumulation with multiple equilibria, both stable and unstable, that proves the existence of a poverty trap. Even if at first my idea was to demonstrate an accumulation process for each household or each strategy, the sample size in each strategy, the length of the TAPS survey and some other construction constraints impede this differentiation. Therefore, I have to assume that households are the same and the asset accumulation process is the same for each household, and I would incorporate household-specific and time-specific effects (Naschold, 2005; Carter and Barrett, 2006). This assumption regarding the existence of an identical pattern of asset accumulation is a major limit to this approach, because strategies lead to different uses of the assets and to different asset accumulation preferences.

To deal with non-linearity, different regression techniques are available. Considering parametric regression techniques, a high degree polynomial could be employed to demonstrate the relationship and to find the threshold. I would use nonparametric techniques, and more specifically a locally weighted scatterplot smoother (LOWESS) and penalised splines to estimate the regression of the asset accumulation. Finally, like Naschold (2005), I would use semiparametric regression techniques to demonstrate whether the relationship in the asset accumulation process does result from both parametric elements and nonparametric elements. I would use a mixed linear model with penalised splines as a way to estimate a nonparametric function.

Figure 5: Kernel density of asset index over five waves



5.1 Different parametric, nonparametric and semiparametric regression techniques

5.1.1 *Parametric estimation using a high-degree polynomial*

Different tests on the existence of a poverty trap have used polynomial regression techniques to estimate the asset accumulation process (Ruppert *et al*., 2003; Barrett *et al*., 2006). As they did, I would use a fourth degree polynomial regression to estimate the relationship between the change in asset index over four years (2006–05, 2005–04, 2004–03, 2003–02) and their lagged values in 2005, 2004, 2003 and 2002. Using the change in asset index instead of its current value is supported by the idea that there could be some over/underestimations in asset index values which would bias the model (Naschold, 2005).

$$\Delta AI_{it} = \beta_0 + \beta_1 AI_{it-1} + \beta_2 AI_{it-2}^2 + \beta_3 AI_{it-3}^3 + \beta_4 AI_{it-4}^4 + \Gamma_i Z_i + T_t + \varepsilon_{it}$$

with $\varepsilon_{it} \sim N\left(0;\sigma_\varepsilon^2\right)\ \ 1 \le i \le N$ and $1 \le t \le T$

The change in asset index over time is function of a fourth order polynomial of its lagged value AI_{t-1} and also function of household characteristics Z_i that include the age of the household head, the squared age of the household head, the size of the household and the average educational attainment of household members. Then, in this polynomial regression, there is a time-specific effect represented by time dummies T_t that take value one if time is t and zero otherwise (Naschold, 2005).

Naschold (2005) clarifies that the age of the household head and its squared value are used to include life-cycle effects in the analysis and that only one single lag in the asset index is possible, due to the shortness of the survey period.

5.1.2 *Nonparametric regression techniques: LOWESS and penalised splines*

Contrary to parametric regression, the relationship between the asset index and its lagged value is unknown and must be estimated by fitting a function *f* through a scatterplot without any assumptions about its functional form (Ruppert *et al.,*2003; Naschold, 2005). The following function would be estimated:

$$AI_{it} = f\left(AI_{it-1}\right) + \varepsilon_{it}$$

with $\varepsilon_{it} \sim N\left(0;\sigma_\varepsilon^2\right)\ \ 1 \le i \le N$ and $1 \le t \le T$

Different estimation techniques could be used to smooth this relationship and I would privilege a smoothing through penalised splines and one through locally weighted scatterplot smoother (LOWESS).

5.1.2.1 Penalised splines

Adapting the notation from Ruppert *et al*. (2003) and Naschold (2005), in a spline model, the function *f* takes the following form:

$$f(AI_{it-1}) = \beta_0 + \beta_1 AI_{it-1} + \sum_{k=1}^{K} u_k (AI_{it-1} - \kappa_k) + \varepsilon_{it-1}$$

with $\varepsilon_{it} \sim N(0;\sigma_\varepsilon^2)$, $1 \le i \le N$, $1 \le t \le T$ and $u = [u_1,\ldots,u_K] \sim N(0;\sigma_u^2)$

κ represents a knot and there are *K* number of knots (Ruppert *et al*., 2003; Naschold, 2005). The penalised spline model can be explained by a mixed model methodology, where there is a smoothing parameter which controls the amount of smoothing and penalises the number of knots. This smoothing parameter is estimated through a restricted maximum likelihood (REML) and the penalised splines are estimated as best linear unbiased predictors (BLUPs) from the mixed model (Ruppert *et al*., 2003).

5.1.2.2 Locally weighted smooth scatterplot (LOWESS)

This is a method for smoothing the scatterplot (Ai_{it-1} AI_{it}) with *i = 1;...; n*. At each value of AI_{it-1}, a fitted value is estimated by running a regression in a local neighbourhood of AI_{it-1} using weighted least squares. The neighbourhoods are defined as a proportion of the total number of observations (Naschold, 2005; Cleveland, 1979). The weight is large if AI_{it-1} close to the fitted value, and small if it is not. Therefore the points close to AI_{it-1} play a large role in the determination of the fitted value of A_{it} while the ones further away play a smaller role (Cleveland, 1979). Then *n* weighted local regressions would be estimated at each value of AI_{it-1} in order to find the smoothed value of AI_{it} (Naschold, 2005).

5.2 Semiparametric regression technique

As explained by Ruppert *et al.* (2003), the semiparametric regression techniques consist in combining both parametric and nonparametric regression techniques (Ruppert *et al*., 2003). Considering the asset accumulation model I would like to estimate, it consists of adding to the nonparametric specification in equation 6 a parametric element. The semiparametric model could be written as:

$$AI_{it} = \beta_0 + \beta_x X_{it} + f(AI_{it-1}) + \varepsilon_{it}$$

with $\varepsilon_{it} \sim N(0;\sigma_\varepsilon^2)$, $1 \le i \le N$ and $1 \le t \le T$

This equation is an extension of the nonparametric equation with a parametric element, X_{it} that could either be some household characteristics (education, size of household, age,...), or

time-dummies taking the value one at time t and the value zero otherwise. These time dummies, as well as the age of the household head and its square value, would absorb the time-specific effects, while the household-specific effect would be contained by the household characteristics (Naschold, 2005).

To fit the regression, the nonparametric element would be smoothed using penalised splines through the mixed model, as described before (Ruppert *et al.,* 2003; Naschold, 2005).

5.3 Results from these different tests

5.3.1 Parametric estimation

I have run the regression on pooled data, but introducing either a fixed effect or a random effect. A Hausman test shows that the fixed effect is more appropriate to estimate the change in the asset index. The results reported in Table 10 show that the lagged asset index has a negative and significant impact on the change in the asset index. All the different lagged asset indices with different power have a negative impact on the change in the asset index. The negative sign of the lagged asset index illustrates the fact that the higher the asset index in the previous period, the lower the change in the asset index at the current period. The fact that only the lagged asset index at a single power is significant reinforces the idea that the asset accumulation process is quite linear, which would lead to a single equilibrium in the asset accumulation.

The life-cycle effects, represented by the age of the household head and the squared age of the household head, are significant. What these two variables show, however, is that the age of the household head has a positive impact on the asset index changes – as the household head becomes older, the asset index varies more from one year to the other, it accumulates fewer assets than when he was younger, but the squared value of the age of the household head shows that this increase would become smaller when the household head becomes older. From this estimation, young households would accumulate more assets than older ones but at a decreasing rate over time.

The education level of the household has a positive effect on the change in asset index. Even if not significant, this relationship shows that the more educated the household head is, the more he/she would accumulate assets from one year to the other. The effect of education is coherent with the observations in the descriptive analysis, as the households engaged in a high-return strategy have higher educational attainment. Household size has a positive and significant effect on the change in asset index, which is also coherent with the observations in the descriptive analysis. Larger households need more assets than smaller households and would be incentivised to accumulate assets from one period to another, because more household members are supposed to enter the household than are leaving it.

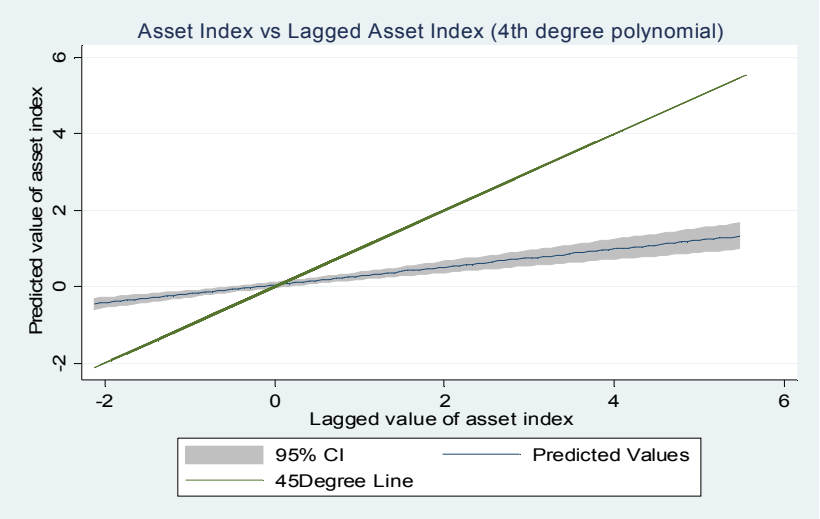
Table 11: Estimation in the change of asset index through a fourth degree polynomial

Variables	Coefficients
Lagged asset index	-1.071*** (0.08)
Squared lagged asset index	0.05 (0.04)
Cubed lagged asset index	0 (0.02)
Fourth degree lagged asset index	0 (0)
Age household head	0.0449** (0.02)
Square age household head	-0.000449** (0)
Education household head	0.02 (0.03)
Household size	0.280*** (0.03)
Dummy for 2002	0 (0)
Dummy for 2003	-0.189**(0.07)
Dummy for 2004	-0.1 (0.07)
Dummy for 2005	0 (0)
Dummy for 2006	0.170**(0.07)
Constant	-2.902***(0.58)
Observations: 580 Number of hhid: 176 R-squared: 0.6	
Standard errors in parentheses (***)p<0.01, (**)p<0.05, (*)p<0.1	

Dummy variables for 2003 and 2006 are significant, which underlines the fact that there is a time-specific effect to this estimation. In 2003, the change 2002 to 2003 would have been negative, while in 2006, the change 2005 to 2006 is positive.

I predict the values of the asset index by predicting first the change in asset index with the previous coefficients. I add to these results the lagged value in assets index to find the value in asset index. The scatterplot of the predicted value of asset index against its lagged value shows that there is no S-shape in the asset accumulation process, there is no Micawber threshold which would allow us to conclude the non-existence of a poverty trap. It seems that there is a really smooth concavity in the asset accumulation process, which leads to a single equilibrium in the long term.

Figure 6: Scatter plot of the predicted asset index against its lagged value



5.3.2 *Results from nonparametric estimations*

5.3.2.1 Penalised splines results

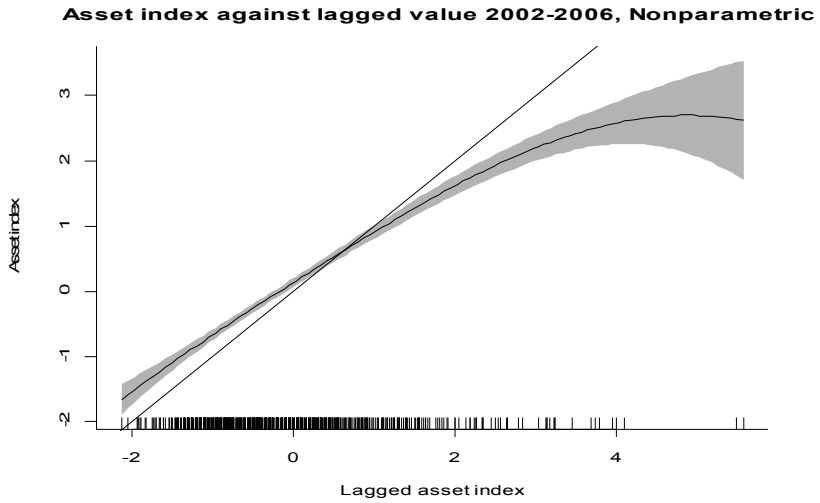
Estimation by penalised splines through a mixed model shows that there is not an S-shape as required to obtain a poverty trap mechanism (Figure 6). However, there is a really smooth concavity in the asset accumulation process, leading us to conclude that asset accumulation would be larger when there were small quantities of assets. The asset accumulation would reach a single equilibrium, represented on the curves by the intersection point between a 45-degree line and the smoothed curve, but reaching this asset equilibrium would take time.

With this asset index, the equilibrium households should reach over time seems to be between [0.9;1.1] point of asset index, because the graph shows where the smoothed curve cuts the 54-degree line. The estimation of the penalised splines on R using the package SemiPar 1.0 (Wand *et al.*, 2005) specifies that 3.335 degrees of freedom and 35 knots have been used to proceed to this nonparametric regression.

Small degrees of freedom suggest that the asset accumulation is not very non-linear (Naschold, 2005). According to Naschold (2005), both degrees of freedom with the penalised splines estimation are fairly small, therefore the dynamic asset accumulation process seems to be quite linear.

I try different degrees of freedom and different numbers of knots and I obtain the results, only the concavity of the curve is changing.

Figure 7: Scatterplot of asset index against its lagged value with penalised splines (non parametric)



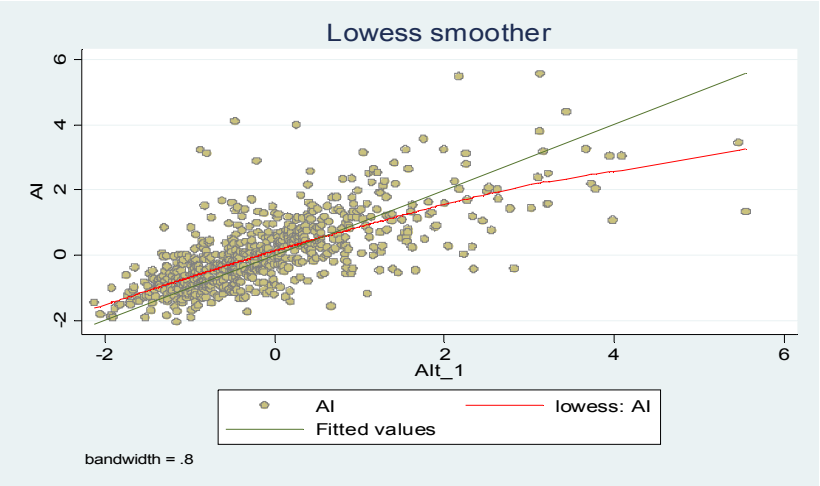
5.3.2.2 LOWESS results

The estimation of the asset index with a LOWESS used as smoothing parameter gives a curve quite similar to the one obtained with the penalised splines (Figure 7). There is no S-shape in the asset accumulation process, there is no evidence of a poverty trap situation. On the other hand, the concavity of the curve when regressing the equilibrium the asset index would reach relies on between [0.9;1.1] asset units.

5.4 Results from semiparametric regressions

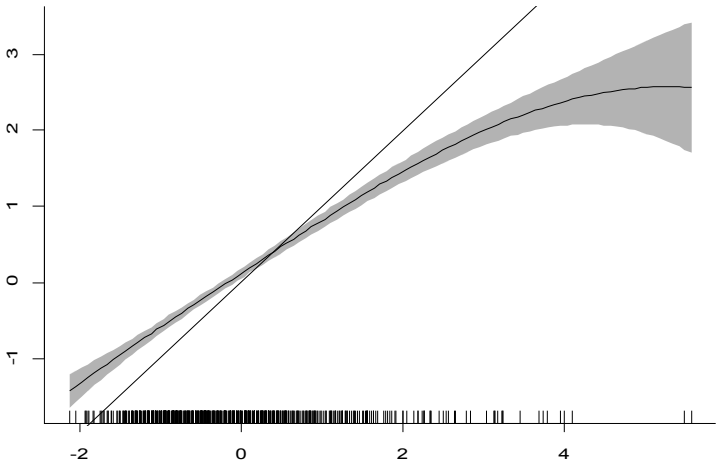
I try different specifications, starting by considering only the time dummies, then all the time dummies and some household characteristics, but these tests have crashed using the SemiPar 1.0. R package (Wand *et al*., 2005). Finally, two different specifications (the first one presented below and the second one in the Appendix) have been retained and estimated. Parametric elements for a first specification are the size of the household and the time dummy for 2006, while parametric elements for a second specification consider these same elements completed by the age of the household head, its squared value, and the dummy for 2003.

Figure 8: Scatterplot of asset index against its lagged value through LOWESS (nonparametric)



Therefore in the first specification, time-specific effects would only be captured by a time dummy for 2006. In this specification, results report that both the household size and the time dummy have positive and significant effects on the current asset index. To proceed to the smoothing of the lagged asset index through penalised splines, 35 knots have been retained and the degree of freedom is equal to 2.194.

Figure 9: Scatterplot asset index against its lagged value through non penalised splines (semiparametric)



The curve in Figure 8 shows that there is no S-shape in the asset accumulation process. There are no multiple equilibria and no Micawber threshold. There is an equilibrium which lies between [0.5;0.7] asset unit. In the long term, Tsimane' households would converge to this equilibrium and would not stay in low levels of poverty.

The second specification presented in the Appendix confirms this result, i.e. the absence of a poverty trap mechanism.

Even when introducing more flexibility in the estimation of the asset accumulation process by using semiparametric regression, none of these models shows that a poverty trap could arise while considering the Tsimane' assets. All these models have a concave shape with a single equilibrium, which varies according to the specification applied between 0.5 and 1.1 asset unit. The concavity of the curves implies that households with low levels of assets would need more time to reach the equilibrium than households with higher levels of assets.

6 Conclusion and further implications

6.1 Key findings from the Tsimane' analysis

Instead of finding an S-shaped curve in the asset accumulation, all the different regressions have led to finding slightly concave curves in the asset accumulation process. The smaller the degree of concavity and the smaller the distance between the curve and the 45-degree line, the more slowly households would move along the asset accumulation path in order to reach the equilibrium.

The parametric regressions show that the lagged asset index, the household size, the age of the household head and its squared value, as well as two time dummies, have a significant effect on determining the change in the asset index over time. Predicting the values of the asset index with these coefficients and plotting these values against their lagged value confirm the absence of multiple equilibria in the asset accumulation process, which is linear and converging to a single equilibrium.

The nonparametric and semiparametric regressions present curves where the concavity in the asset accumulation process is identifiable. In all specifications the smoothed curves are below the curves of fitted values. The different regressions show that a single equilibrium exists and households would finally converge to it. The concavity in their asset accumulation curve implies that the initial asset level matters to determine how households would reach the equilibrium. Households with lower levels of wealth would need more time to reach the equilibrium than households with higher levels of wealth.

Therefore, as the scatterplots in the analysis show that most of the households are concentrated in low levels of asset accumulation and few of them have higher levels of

wealth, the Tsimane' still need time in order to escape poverty. The different shocks, both idiosyncratic or covariant, which they would face, would even increase the amount of time they would need to reach the equilibrium if their wealth levels were pushed further down.

6.2 Comparisons between this test and other poverty trap tests

6.2.1 *A single asset or an asset index*

A first element consists in the type of assets used in the different studies. Both Lybbert *et al*. (2004) and Barrett *et al*. (2006) test the poverty trap mechanism on pastoralist households whose main asset is their livestock. More precisely, their analysis of the asset accumulation process relies only on the accumulation of livestock, excluding any other types of assets. What is interesting to note, and what Lybbert *et al.* (2004) remark, is that livestock is not only an asset but fulfils many essential roles in the livelihood of the pastoralists. Besides being a source of wealth, livestock is usually used as a source of food, and as a provider of services like transport. Livestock holdings are also an *'*object of status' and they *'*regulate the ecosystems' (Lybbert *et al.,* 2004). By their nature, livestock fulfil many more essential needs than the assets in the asset indices.

The assets in the asset indices are much more diversified, with different functions, and different assets can fulfil the same function. On the other hand, the pastoralists rely largely on the livestock and they do not seem to have any other means to perform these functions. Their total reliance on livestock explains that the loss of even a small number of livestock leads to a situation where, as they do not have any other survival means, they would be ensnared in this situation without knowing how to escape it. The papers that have not concluded the existence of a poverty trap mechanism develop specifications similar to the Tsimane' one, where instead of considering a single asset, asset indices covering a wide range of assets have been constructed. Naschold (2005) has built an asset index encompassing different asset holdings which are less subject to sudden drops than only the livestock holdings could be. Barrett *et al.* (2006) construct an asset index to study the Malagasy households whose main activity is rice cultivation, which requires more diversified assets.

6.2.2 *Mono activity or wide portfolio of activities*

A second element linked to the first one relies on the fact that these papers have considered households with similar activities. In Lybbert *et al*. (2004) and Barrett *et al.* (2006) the households have one main activity, which is raising cattle for milk. On the contrary, the Tsimane' households have at their disposal a wide range of activities which they use either as a source of income or as an insurance mechanism. This mono-activity, depending mainly on livestock to generate livelihood, explains why a poverty trap could arise, as they do not have any other activities to generate their livelihood. On the other hand, the Tsimane' households, with their wide range of activities, seem to have more possibilities to engage

themselves in one activity instead of another, and to change from one activity to another according to their needs and the labour opportunities.

6.2.3 *Internal characteristics of the sample*

Adato *et al*. (2006) have not studied pastoralists households but South African households with different activities and assets. They develop an asset index regrouping four types of assets and the asset index accumulation process leads to multiple equilibria. Their study is quite similar to the Tsimane' one and the only difference that could explain why they have found the evidence of a poverty trap mechanism could rely on the fact that the South African households in their sample present more different characteristics from one another than the Tsimane'. The Tsimane' population is much more homogeneous than other populations studied by Adato *et al*. (2006). The Tsimane', even after differentiating in terms of strategy and wealth, remain quite homogeneous, while the South African households have more diversified patterns. The homogeneity of the Tsimane' sample is visible through the analysis of the asset index while using the dummy variables for any types of assets and durable goods.Very few households are poor in terms of the asset index – the majority of the households report holding the asset. Adato *et al.*, (2006) in their asset index include assets and household characteristics that vary according to each household.

6.2.4 *Short time period or long time period*

The last element justifying why Lybbert *et al*. (2004), Barrett *et al.* (2006) and Adato *et al.* (2006) have proved the existence of a poverty trap could be the time period. Both pPapers use data from surveys that cover at least 10 years, while the TAPS data in the analysis cover only three years. Asset accumulations and poverty dynamics seem more relevant over longer periods of time than shorter ones, which could explain why they find multiple equilibria in the asset accumulation.

Similarly to the Tsimane' study, Naschold (2005) uses only a short period of time data, up to five years, which could explain why no real asset changes could occur and why he does not find any poverty trap (Naschold, 2005).

6.3 Policy implications and further points to develop

Failing to prove that a poverty trap does exist among the Tsimane' households does not imply that they are ready to escape the low levels of economic developmenton which they rely. The concavity of their asset accumulation path suggests that reaching a higher equilibrium for the poorer households is a long process.Different measures are required to try to accelerate their asset accumulation and improve their wellbeing. A striking element while doing the fieldwork was that all the households are cultivating the same type of crops without cooperating. Better organisation at the village level, leading to the creation of cooperatives and more bargaining power when dealing with the traders, could be a way to incite the

households to become more productive in their agricultural activity. The high diversification of their livelihood, without being specialised in any activity, in order to generate higher earnings when becoming more productive could explain why the Tsimane' households are still really poor and would reach higher levels of welfare over a long period of time. When doing only one activity, most of the households in the sample do it in order to fulfil their basic needs, so it might be interesting to help them develop such activities and cooperation.

Also, different elements could be added to this analysis to improve it and capture other effects. The idea could be to focus more on the activities in order to understand the rationality that leads one household to undertake one type of activity to generate an income while others would use the activity as a way to face unexpected events. Their vulnerability seems to keep them in non-productive activities. It would therefore be interesting to identify whether they have any other insurance mechanisms that could replace the activities as insurance mechanisms. The rationality would be to find a way to separate the activities from the insurance mechanisms, inciting the households to engage themselves in more productive activities that would reduce their vulnerability and increase their wellbeing. It might be also interesting to study how the current changes in the availability of game, and the depletion of medicinal plants would lead the Tsimane' households to engage themselves more in wage or sale activities in order to afford the meat and western medicines they need. These losses are supposed to increase their vulnerability and their dependence on the market.

Appendix

Bartlett's test and KMO measure

Determinant of the correlation matrix
Det= 0.023
Bartlett test of sphericity
Chi-square=3242.965
Degrees of freedom = 136
p-value = 0.000
H0: variables are not intercorrelated
Kaiser-Meyer-Olkin Measure of Sampling Adequacy
KMO = 0.849

Factor loadings coefficients

Factor analysis/correlation — Number of obs = 870
Method: principal factors — Retained factors = 1
Rotation: (unrotated) — Number of params = 17

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.71410	2.70345	0.7959	0.7959
Factor2	1.01066	0.47873	0.2166	1.0125
Factor3	0.53193	0.22753	0.1140	1.1265
Factor4	0.30440	0.06685	0.0652	1.1917
Factor5	0.23755	0.11913	0.0509	1.2426
Factor6	0.11842	0.07890	0.0254	1.2680
Factor7	0.03952	0.03596	0.0085	1.2765
Factor8	0.00357	0.02701	0.0008	1.2772
Factor9	-0.02344	0.02751	-0.0050	1.2722
Factor10	-0.05095	0.02502	-0.0109	1.2613
Factor11	-0.07597	0.02074	-0.0163	1.2450
Factor12	-0.09671	0.04845	-0.0207	1.2243
Factor13	-0.14516	0.05694	-0.0311	1.1932
Factor14	-0.20210	0.00992	-0.0433	1.1499
Factor15	-0.21201	0.02055	-0.0454	1.1044
Factor16	-0.23256	0.02228	-0.0498	1.0546
Factor17	-0.25484	.	-0.0546	1.0000

LR test: independent vs. saturated: chi2(136) = 3246.72 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Uniqueness
axe	0.5847	0.6581
bike	0.3118	0.9028
bow	0.5488	0.6988
canoe	0.3286	0.8920
cow	0.2032	0.9587
hook	0.6264	0.6076
knife	0.6825	0.5342
machete	0.7359	0.4584
mosquito net	0.7432	0.4477
net	0.4197	0.8238
radio	0.4404	0.8061
rifle	0.2467	0.9392
shotgun	0.3764	0.8583
size plot	0.4562	0.7919
gifts	0.1662	0.9724
Spanish	0.2399	0.9424
maths	0.0810	0.9934

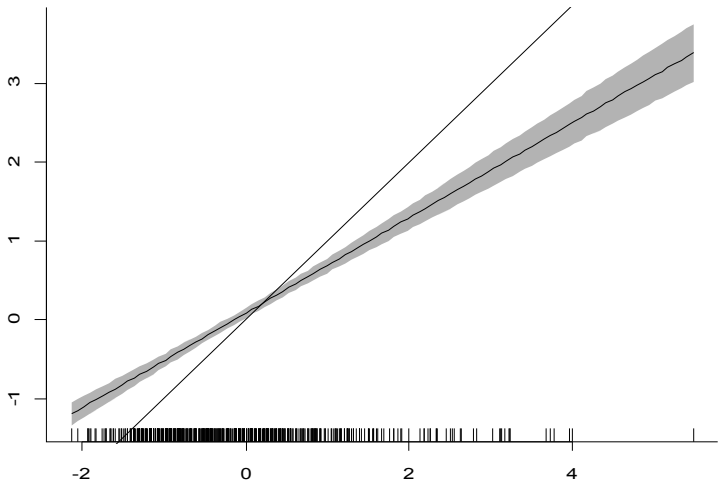
Mean values of assets used in the asset index

Variable	Obs	Mean	Std. dev.	Min	Max
axe	875	1.386286	.9788586	0	6
bike	875	.3565714	.7538989	0	5
bow	875	1.616	1.381049	0	11
canoe	875	.4685714	.6881522	0	4
cow	875	.4822857	2.088016	0	24
hook	875	5.469714	3.577508	0	26
knife	875	3.505143	2.285345	0	18
machete	875	3.506286	1.963254	0	15
mosquito net	875	4.193143	2.281244	1	15
net	875	.7954286	1.016107	0	5
radio	875	.8902857	.8686423	0	6
rifle	875	.5085714	.5962178	0	3
shotgun	875	.4228571	.5594445	0	3
size plot	875	10.10131	7.528318	0	100
gifts	880	1.1375	1.303868	0	10
Spanish	880	1.225	1.141547	0	7
maths	880	.9227273	.2671755	0	1

Second test with semiparametric regression

This test includes as parametric elements the age of the household head, its squared value, the size of the household and two time dummies for 2003 and 2006. Only the household is significant and has a positive effect on the asset index. The asset accumulation curve does not have an S-shape, but seems linear with a smooth concavity. An equilibrium lying between [0.2;0.5] seems to exist and Tsimane' households should converge towards it over time (Figure 9).

Figure 10: Asset index against its lagged value (second semiparametric estimation)



References

Adato, M., Carter, M. R. and May, J. (2006).'Exploring poverty traps and social exclusion in South Africa using qualitative and quantitative data'. *Journal of Development Studies,* 42(2), 226-247.

Angelsen, A. and Wunder, S. (2003, May). 'Exploring the forest-poverty link: key concepts, issues and research implications' . CIFOR Occasional Paper 40. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Apaza, L., Wilkie, D., Byron, E., Huanca, T., Leonard, W., Pérez. E., Reyes-Garcia, V., Vadez, V. and Godoy, R. (2002). 'Meat prices influence the consumption of wildlife by the Tsimane Amerindians of Bolivia'. *Oryx* 36(4), 000.

Arnold, M. and Townson, I. (1998). 'Assessing the potential of forest product activities to contribute to rural incomes in Africa'. *ODI Natural Resource Perspectives, 37.*

Azariadis, C. and Drazen, A. (1990). 'Threshold externalities in economic development'. *The Quarterly Journal of Economics, 105(2)* 501-526.

Azariadis, C. and Stachurski, J. (200). 'Poverty traps'. *Handbook of Economic Growth, 1(1), 295-384.*

Baland, J.-M. and Platteau, J.-P. (1996). *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?.* Oxford:Clarendon Press.

Barnett, B. J., Barrett, C.B. and Skees, J.R. (2008). 'Poverty traps and index based risk transfer products'. *World Development,* 36(10), 1766-1785.

Barrett, C. B. (2007). 'Poverty traps and resource dynamics in smallholder agrarian systems'. Working Paper. Ithaca, NY: Cornell University, Department of Applied Economics and Management.

Barrett, C. B.,Marenya, P.P., McPeak, J., Minten, B.,Murithi, F., Oluoch-Kosura, W.; Place, F., Randrianarisoa; J.-C., Rasambainarivo, J. and Wangila, J. (2006).'Welfare dynamics in rural Kenya and Madagascar'. *Journal of Development Studies,* 42(2), 248-277.

Bhorat, H., Naidoo, P. and van der Westhuisen, C. (2006). 'Shifts in non-income welfare in South Africa: 1993-2004'. Development Policy Research Unit Working Paper 06/108. Rondebosch, South Africa: Development Policy Research Unit, University of Cape Town.

Bowles, S., Durlauf, S.N. and Ho, K. (2006). *Poverty Traps*. Princeton, NJ: Princeton University Press.

Byron, N. and Arnold, M. (1999). 'What futures for the people of the tropical forests?' CIFOR Working Paper 19. Bogor, Indonesia: Center for International Forestry Research (CIFOR).Carter, M. and Barrett, C. (2007). 'Asset thresholds and social protection'. *IDS Bulletin*, Special issue on social protection.

Carter, M. R. and Barrett, C. B. (2006). 'The economics of poverty traps and persistent poverty: an asset-based approach'. *Journal of Development Studies,* 42(2), 179-199.

CIFOR (2003). 'Forests and people: research that makes a difference'. CIFOR Working Paper 7. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Cleveland, W. S. (1979). 'Robust locally weighted regression and smoothing scatterplots'. *Journal of the American Statistical Association,* 74(368), 829-836.

Coomes, O. T., Barham, B. L. and Takasaki, Y. (2004). 'Targeting conservation-development initiatives in tropical forests: insights from analyses of rain forest uses and economic reliance among Amazonian peasants'. *Ecological Economics*, 51(1 and 2), 47-64.

Ellis, F. (2001). *Rural Livelihood and Diversity in Developing Countries*. Oxford: Oxford University Press.

Friel, C. M. (2007). 'Notes on factor analysis'. Criminal Justice Center, Sam Houston State University, Faculty lecteure notes.

Godoy, R., Reyes-Garcia, V., Leonard, W.R., Tanner, S., Huanca,T., Vadez,V., Wilkie, D., and TAPS Bolivia Study Team8 (2008). 'Short and long-run effects of household income on household forest clearance among native Amazonians: panel evidence (2002-2006) from the Tsimane, Bolivia'. Tsiname' Amazonian Panel Study Working Paper 43. Available at: http://www.tsimane.org/working%20papers/TAPS-WP-43.pdf

Godoy, R. and Jacobson, M. (1999). 'Covariates of private time preference: a pilot study among the Tsimane' Indians of the Bolivian rainforest'. *Evolution and Human Behavior,* 20(4), 249-256.

Godoy, R., M. Jacobson, and D. Wilkie (1998). Strategies of rain-forest dwellers against misfortunes: The Tsimane' indians of Bolivia. Ethnology 37(1), 55-69.

Lawley, D. and Maxwell, A. (1971). Factor Analysis as a Statistical Method. London: Butterworths.

Lawley, D. and Maxwell, A. (1973). 'Regression and factor analysis'. *Biometrika,* 60(2), 331-339.

Leonard, W. R. and Godoy, R. (2008). 'Tsimane Amazonian Panel Study TAPS:the first five years (2002–2006) of data available to the public in 2008'. TAPS website. Available at: http://www.tsimane.org/research/pgs/research.html. Accessed 3 December 2009.

Lewis-Beck, M. S. (1994). *Factor Analysis and Related Techniques*. London: Sage.

Lybbert, T. J., Barrett, C. B., Desta, S. and Coppock, D. L. (2004). 'Stochastic wealth dynamics and risk management among a poor population'. *The Economic Journal,* 114(498), 750-777.

Naschold, F. (2005). 'Identifying asset poverty thresholds. new methods with an application to Pakistan and Ethiopia'. American Agricultural Econmics Association, 2005 Annual meeting, 24-27 July, Providence, RI.

Reyes-Garca, V. (2001). 'Indigenous people, ethnobotanical knowledge, and market economy. A case study of the Tsimane' Amerindians in lowland Bolivia'. PhD thesis, Department of anthropology, University of Florida, Gainseville.

Ritchie, B., McDougall, C., Haggith, M. and Burford de Oliveira, N. (2000). 'Criteria and indicators of sustainability in community managed forest landscapes: an introductory guide'. Bogor (Indonesia): Center for International Forestry Research

Ruppert, D., Wand, M. P. and Carroll, R. J. (2003). *Semiparametric Regression*. New York: Cambridge University Press.

Sahn, D. E. and Stifel, D. (2000). 'Poverty comparisons over time and across countries in Africa'. *World Development,* 28(12), 2123-2155.

Sahn, D. E. and Stifel, D. (2003). 'Exploring alternative measures of welfare in the absence of expenditure data'. *Review of Income and Wealth,* 49(4), 463-490.

Sunderlin, W., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L. and Wunder, S. (2005). 'Livelihoods, forests,and conservation in developing countries: an overview'. *World Development,* 33(9), 1383-1402.

Chronic Poverty
Research Centre

www.chronicpoverty.org

The **Chronic Poverty Research Centre** (CPRC) is an international partnership of universities, research institutes and NGOs, with the central aim of creating knowledge that contributes to both the speed and quality of poverty reduction, and a focus on assisting those who are trapped in poverty, particularly in sub-Saharan Africa and South Asia.

Partners:

Bangladesh Institute of Development Studies (BIDS), Bangladesh

Development Initiatives, UK

Development Research and Training, Uganda

Economic Policy Research Center, Uganda

FIDESPRA, Benin

HelpAge International, UK

Indian Institute of Public Administration, India

IED Afrique, Senegal

Institute of Development Studies, UK

Overseas Development Institute, UK

Programme for Land and Agrarian Studies, South Africa

University of Legon, Ghana

University of Manchester, UK

University of Sussex, UK

Contact:
cprc@manchester.ac.uk