Win-wins in forest product value chains? How governance impacts the sustainability of livelihoods based on non-timber forest products from Cameroon

Ingram, V.J.

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Appendix 9 Equations, aggregations, gini coefficients and logic regression analysis

Income and value aggregations

1. **Gross NTFP-related Income**
   
   Annual gross NTFP income = \[
   \begin{cases} 
   \text{Monthly income} \times 12 \text{ for year-round NTFP actors} \\
   \text{Monthly income} \times n \text{ for seasonal NTFP actors}
   \end{cases}
   \]

   Where n = number of months of NTFP related activity

2. **Quantity of NTFP traded**
   
   Annual quantity of NTFP traded = \[
   \begin{cases} 
   \text{Quantity/trip} \times \text{no of trips} \times 12 \text{ for year-round NTFP actors} \\
   \text{Quantity/trip} \times \text{no of trips} \times n \text{ for seasonal NTFP actors}
   \end{cases}
   \]

   Where n = number of months of NTFP related activity

3. **Annual net NTFP-related income**
   
   Annual net NTFP income = Annual gross NTFP income – annual NTFP cost

4. **Annual NTFP costs**
   
   Annual NTFP cost = Annual material NTFP costs + Annual transport NTFP costs + annual tax and corruption costs + annual labour costs

5. **Annual costs**

   Annual material and tax costs = \[
   \sum_{i=1}^{n} (\text{material costs} + \text{tax & corruption costs}) / \text{lifespan}
   \]

   Where n = ; i = ; j = ;

6. **Annual transport costs**
   
   Annual transport costs = \[
   \begin{cases} 
   \text{total monthly transport costs} \times 12 \text{ for year-round NTFP actors} \\
   \text{total monthly transport costs} \times n \text{ for seasonal NTFP actors}
   \end{cases}
   \]

7. **Annual labour costs**

   Annual labour costs = \[
   \begin{cases} 
   \text{total no of paid workers} \times \text{amount per day} \times 30 \times 12 \text{ for year-round NTFP actors} \\
   \text{total no of paid workers} \times \text{amount per day} \times 30 \times n \text{ for seasonal NTFP actors}
   \end{cases}
   \]

   Where n =

8. **Prunus africana** bark yield volume per tree (following Burkhart (1977):

   \[ V_b = \frac{(D_m^2/4 \times \Pi \times H)}{} - \frac{(D_m - 2t)^2/4 \times \Pi \times H}{\} \]

   Where:
   \[ V_b = \text{Volume of bark} \]
   \[ D_m = \text{Mid height diameter (average of diameters at different heights using a relaskope)} \]
   \[ t = \text{bark thickness} \]
   \[ \Pi = \text{Trunk height (up to first branch)} \]
   \[ \Pi = 3.1416 \]

Aggregations

9. **Total income**

   Total actors’ income = \[
   \sum_{i=1}^{n} (\text{income from ntfps}) + \sum_{j=1}^{n} (\text{income from other sources})
   \]
10. **Total income from other sources**

Income from other sources = \( n_s \sum_{i=1}^{\text{ns}} \text{(other sources)} \)

Where: \( ns \) = number of sources, which includes fishing, farming, hunting, livestock rearing, paid labour, trading and others.

11. **Total income from forest sources**

Total income forest sources = \( ns \sum_{i=1}^{\text{ns}} \text{(INCOME from NTFPs + hunting + fishing + farming + livestock rearing etc.)} \)

12. **Relative NTFP income**

Relative NTFP income = \( \frac{\text{total income from NTFPs} \times 100}{\text{Total NTFP actors’ income}} \)

13. **Relative forest income**

Relative forest income = \( \frac{\text{total income from forests} \times 100}{\text{Total NTFP actors’ income}} \)

An analysis of variance (ANOVA) level one test was used to find differences among two or more independent groups. The mean income was separated from other livelihood parameters and ranked using the multiple comparison Tukey test at 5% level of significance. Similar tests and rankings were conducted to separate the means of the various ways in which actors spend their income.

**Logistic regression analysis**

To apply the logit model, actors were dichotomised into those who were highly dependent on NTFPs and those who had lower dependency. For this study it was assumed that any actor was dependent on NTFPs if the proportion of their total income was more than the calculated average of NTFP-related income. According to Masozera and Alavalapati (2004) and Gujarati (1995), by dichotomising the income of natural resource users into high and low dependencies, better policies and strategies to reduce or improve their dependency can be determined.

The model used to estimate NTFP dependency is follows:

\[
\ln \left( \frac{\pi_i}{1-\pi_i} \right) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_k X_{ik}
\]

where subscript \( i \) denotes the \( i \)-th observation in the sample, \( \pi \) is the probability of the outcome, \( \beta_0 \) is the intercept term, and \( \beta_1, \beta_2, \ldots, \beta_k \) are the coefficients associated with each explanatory variables \( X_1, X_2, \ldots, X_k \) (Tieguhong and Zwolinski, 2008; Vedeld *et al*., 2007; Anderson *et al*., 2006; Dewi *et al*., 2005; Masozera and Alavalapati, 2004; Bahuguna, 2000; Gujarati, 1995).

The explanatory variables used to explain NTFP dependency were: area of production, distance of village to market, number of dependents, sex, education, ethnic affinity, NTFP experience (years), occupation (full-time or part-time) and other sources of income.

**Test of income inequality and the role of NTFP income**

A test to determine how NTFP income could narrow or widen the gap between the rich and the poor in the production zone, taking into account environmental resources, was performed by calculating Gini coefficients (Vedeld *et al*., 2004). This enables a test of inequality associated with dependence on NTFP income. The Gini coefficient of absolute total NTFP actors income per product was calculated as:

\[ G_{AI} = \frac{n}{nn} \]
\[
\sum_{i=1}^{n} \sum_{j=1}^{n} (A_{i} - A_{j}) I_{i,j}
\]

\[
\frac{2}{n^2} \mu
\]

Where \( n \) is the sample size and \( \mu \) is the sample average. So the Gini coefficient for income inequality is simply the relative mean difference between all possible income pairs \( i \) and \( j \) in the sample. If we construct a new variable “absolute non-NTFP income (ANNI)”, that is, absolute income from all sources other than mining, such that:

\[
ANNI = AI - ANI
\]

This allows the calculation of another Gini coefficient for absolute incomes excluding NTFP income:

\[
G_{ANNI} = \frac{2}{n^2} \mu
\]

\[
\sum_{i=1}^{n} \sum_{j=1}^{n} (ANNI_{i} - ANNI_{j}) I_{i,j}
\]

A comparison of these two Gini coefficients should reveal whether, and to what extent, NTFP incomes contribute to reducing inequality (Vedeld et al., 2004). If \( G_{ANNI} > G_{AI} \), then it implies that NTFP incomes help reduce income inequality in the region, else the reverse holds true. For instance, Aryal (2002) found \( G_{AI} \) in his study at Budongo, Uganda increased from 0.55 to 0.61 when forest income was excluded (Vedeld et al., 2004).

**Prunus africana bark yield equations**

Average sustainable yield of bark per tree (kg fresh weight/tree/harvest) (area x thickness) and rate of recovery of the bark (in years).

expressed by;

\[
SY = \frac{(D \times A \times Y_t)}{R}
\]

Where:

- \( SY \) = Sustainable yield of *Prunus* bark per annum per unit
- \( D \) = Population density of exploitable trees (stems/ha)
- \( A \) = Area of exploitable forest containing *Prunus africana*
- \( Y_t \) = Average sustainable yield of bark per tree (kg fresh weight/tree/harvest) (area x thickness)
- \( R \) = Rate of total recovery of the bark (in years)

This formula requires concrete data rather than estimates of each of the parameters (\( D, A, H, \) and \( R \)) as best and worst possible estimates may impact sustained yield dramatically. An inventory of the number of trees (\( D \)) in each exploitation zone or allocation unit (\( A \)) is one factor. Other factors can be estimated during a static (at a single point in time) inventory, such as the average sustainable yield of bark per tree (\( H \)). Other variables are the degree of historical debarking, tree growth rates, mortality rates, and tree health. A dynamic inventory, involving regular re-measurement of some sample trees over time, appears the best method to determine the long-term impacts of exploitation on the rate of recovery of bark (\( R \)) (Acworth et al., 1999). To calculate a sustained yield for period of rotation, the PAU Sustained Yield calculation below is proposed:

\[
Q_{au} = \sum Q \quad kg \ dry \ weight \ equivalent
\]

\[
Q_{pau} = A_{pau} \times P_{au} \times RME_{g} \times Y_t \times F_h \times P_{te} \quad kg \ dry \ weight \ equivalent
\]
Where:

- \( Q_a \) = Annual Quota  
  - kg dry weight equivalent
- \( Q_{pa} \) = Annual Quota per PAU  
  - kg dry weight equivalent
- \( A_{pa} \) = Area of PAU  
  - hectares
- \( P_{ae} \) = Proportion of Area Exploitable in PAU  
  - percent
- \( RME_d \) = Reliable minimum estimate of density in PAU  
  - Stems per hectare
- \( Y_t \) = Average yield per tree in one harvest  
  - kg dry-weight equivalent
- \( P_{te} \) = Proportion exploitable trees (alive & not over-exploited)  
  - percent
- \( F_h \) = Number of years between harvests (8 Years)  
  - years

This estimate is expected to be valid for a seven-year period, based on the study of bark regeneration (Nkeng et al. 2009 – see Appendix 1). The long-term rate of mortality, recruitment and growth of \( Prunus \) must be estimated to determine the sustainability of the harvesting cycle. At the beginning of the inventory, growth rates can be calculated by size class distribution (the diameter size over a range of tree ages) in a PAU. This should take account of the level of previous harvesting as size class distribution varies significantly in Cameroon. At least a higher number of the smallest two size classes and a large number of the oldest classes should be present to assure regeneration. Given mortality rates averaging 17% in Cameroon, a verification of tree health and the recovery rate of sustainable and un-sustainably harvested trees is necessary to determine mortality after first and second harvest (i.e. when the entire circumference of the tree has been stripped). These can be verified using a Mortality, Recruitment and Growth equation:

\[
N_p = N_i - N_m + N_r
\]

\[
\frac{Y_t}{\text{per size class}}
\]

Where:

- \( N_p \) = Number of \( Prunus \) trees standing at the end of eight year harvesting cycle
- \( N_i \) = Initial number of \( Prunus \) trees at beginning of eight year harvesting cycle
- \( N_m \) = Number of tree mortalities during eight year harvesting cycle
- \( N_r \) = Number of tree recruitments during eight year harvesting cycle.
- \( Y_t \) = Average yield of bark per tree (kg fresh weight\/trees\/harvest) (by size class)