A Bias-Adjusted Three-Step approach for analysing the livelihood strategies and the asset mix of cacao producers in Ecuador

J.M. Gil[1]; J. Díaz-Montenegro[2]; E. Varela[1]

1: Centre de Recerca en Economia i Desenvolupament Agroalimentari (CREDA-UPC-IRTA), , Spain, 2: Universidad Estatal de Milagro, UNEMI, , Ecuador

Corresponding author email: josealdiaz2286@gmail.com

Abstract:

This study applies the Bias-Adjusted Three-Step approach with covariate and distal outcomes for identify the livelihood strategies pursued by small cacao farmers in the Guayas coastal region in Ecuador, where two distinct cacao varieties are grown: the fine flavor variety, cacao Nacional (CN) and a hybrid variety (CCN-51). A detailed household survey sampled 188 households. Four latent profiles of livelihood strategies were identified based on activity variables; these were related to capital assets used as covariate and income share variables used as distal outcomes. Results show that far from existing a neat gap between cultivation of CN and CCN-51, 60% of the sampled households simultaneously grows both varieties. Results indicate that the variable "share of land allocated to CN" does not significantly contribute to discriminate among profiles. Households with a low share of land allocated to CCN-51 show higher income diversification strategies and vice versa. Income diversification encouragement and improvement in livelihood basic services and production assets to improve economic security of smallholders seem to be the pathway to increase the success of the current policy for fine flavor cocoa rehabilitation at the national level.

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Keywords: *three-step approach, latent profile analysis, rural livelihood, external variables, distal outcomes, cocoa.*

1. Introduction

Ecuador is a major player in the world cacao market, both in terms of volume and quality, being the largest producer of fine flavor cacao, with approximately 65% of the global supply (Blare & Useche, 2013; Squicciani & Swinnen, 2016; WFC, 2013). The fine cacao variety in Ecuador, known locally as cacao Nacional (CN) is grown in a traditional-agroforestry system. The modern hybrid variety CCN-51 is a fully-sun species that may double the productivity of its CN counterpart -16 tons/ha vs 8 tons/ha- but at the expense of being more demanding in the use of inputs (fertilizers or herbicides) (Astudillo Paredes, 2014; Blare & Useche, 2013; Franzen & Mulder, 2007; MAGAP, 2013; Ton et al., 2008), among other key differences.

Cacao production, especially with regards to the CN variety, is seen as an economic development strategy (CORPEI-BID, 2009) that may contribute to alleviate poverty in rural communities, which sums up to 38,2% in Ecuador (INEC, 2016). Since 2009, the Ecuadorian government, along with local and international development organizations, has implemented the Project on Restoring CN cultivation (PRCN, hereafter). The assumption underpinning the design of this program is that protecting the quality of the CN variety, and strengthening the linkages between producers, buyers and processors both in local markets and in higher-value markets will lead to an improvement of the living conditions of cacao producers. However, the link between the problem and its solution may not be so straightforward.

The objective of this study is to unveil the factors associated with the choice of livelihood strategies of small rural holders in Ecuador linked to the cultivation of two varieties of cacao, CN and CCN-51, that hold significantly different economic, social and environmental impacts.

This study adopts the sustainable livelihoods approach, a tool developed to improve understanding of the livelihoods of the poor people. We adopt this framework - the access to "capitals and capabilities" (e.g. Bebbington, 1999; Bhandari, 2013; DFID, 1999; Scoones, 1998) - to understand the impact that the PRCN has had on the livelihoods of smallholders. As Bhandari (2013) states, this approach is relevant for it recognizes the importance of capabilities, assets and activities required for a means of living; it also helps understanding the links between household assets and activities, bringing together various critical factors that affect the vulnerability of survival strategies. The household asset mix (typically classified according to five types of capitals) and the contextual factors influence both people activity choices and their livelihood strategies (Brown et al., 2006). These, in turn, may determine household outcomes, such as income earnings.

For this purpose, a detailed household survey was applied in nine cacao-producing villages in the Guayas, the largest cacao-producing province in Ecuador. Latent profile analysis (LPA) is the method adopted to identify discrete profiles of livelihood strategies by measuring the household choice of activity variables (labor and land allocation). Furthermore, a bias-adjusted three-step approach has been applied to acknowledge that external variables may play different roles in LPA. These may act either as predictors of livelihood strategies identified in the LPA but also these latent profiles may act as predictors of external variables.

This study contributes to the works on livelihood strategies (Babulo et al., 2008; Bhandari, 2013; Nielsen et al., 2013; Scoones, 1998; Walelign et al., 2016) and cacao production system (e.g. (Bentley et al., 2004; Blare & Useche, 2013; Franzen & Mulder, 2007; Melo & Hollander, 2013) and its findings may contribute to inform the implementation of the PRCN policy. The main novelties of this work reside on the explicit focus on assessing the linkages between CN and CCN-51 varieties and livelihood strategies on the one hand and, on the other hand, on the statistically robust latent approach that to the authors' knowledge has not previously been applied in this field.

2. Case study description

In the case of Ecuador, 90% of the production is cultivated by small peasants (Astudillo Paredes, 2014). CN is typically produced in a shade-cultivation system and thrives in landscapes and soils where other crops do not (Bentley et al., 2004; Melo & Hollander, 2013). The shade production of cocoa has been progressively substituted by a full-sun non-fine variety known as CCN-51 that accounted for 48% of the plantings during early 2000s (Bentley et al., 2004; Ruf, 2011). CCN-51 yields are almost four times that of the CN and it is resistant to fungal diseases (Espinosa et al., 2006).

The reduction in quality of the Ecuadorian cacao led to a downgrading on its cocoa rating by the International Cacao Organization (ICCO) from 100% to 75% since 1994; in 2005 further grading reductions were announced as a possibility for the future what motivated the involvement of the Ecuadorian state in the industry (see Melo and Hollander (2013) for a critic and description of the Ecuador cacao market). Furthermore, cacao production is seen as an avenue to help alleviate poverty in rural communities; accordingly, the Ecuadorian government, along with local and international development organizations, has begun to advocate CN as an economic development strategy (CORPEI, 2009).

The Project on Restoring CN cultivation (PRCN) aims at revitalizing its production through the improvement of current CN plantations and establishment of new ones. The project actions tackle both the production and the value chain at large. The creation of a germoplasm bank, capacitation of small farmers, technical and training assistance or strengthening farmers' associations are some of the actions foreseen.

This study was conducted in nine rural sites located in two districts of the Guayas, Lorenzo de Garaicoa and Yaguachi Viejo that represent 10% of the Guayas cacao production. Table 1 summarizes the principal statistics of the two districts.

The government has implemented the PRCN program in these nine rural sites since 2012, to stimulate farmers switching from CCN-51 variety to CN variety. However, farmers decisions are complex and locally specific (Franzen & Mulder, 2007) since they assess with varying degrees of importance factors such as quality, productivity, income or environment when deciding on the final combination of the two cacao varieties they will produce. We hypothesized that this "productive tension" existing in the study area makes it suitable to assess the objectives of our study.

3. Material and Methods

3.1 Modelling approach: the bias-adjusted three-step LPA

Latent profile analysis (LPA) is a person-oriented analytic technique, similar to latent class analysis (LCA), that identifies discrete profiles of individuals who share similar response patterns across a set of indicator variables using probability-based classification (Collins & Lanza, 2010). Conceptually it is similar to cluster analysis, but group membership is treated as latent rather than known and measurement error is allowed (Magidson & Vermunt, 2002). Differently from LCA, LPA uses continuous rather than categorical variables and can be applied even when variables are measured on different scales (Berlin, Parra, & Williams, 2014).

Applications of latent class or cluster analysis also investigate how the clusters found are related to external variables (Bakk et al, 2013). This is usually done in three steps by: i) building the latent or cluster model for a set of response variables; ii) assigning individuals (households, in this study) to latent classes based on their posterior class membership probabilities and iii) investigating the association between the class membership and external variables.

The bias-adjusted three-step approach (Bakk et al., 2013; Bakk & Oberski, 2014; Bakk et al., 2016; Vermunt, 2010) adopted in this study allows examining the association between latent profile classes and external variables acknowledging for uncertainty of group membership (Lanza et al., 2013).

First step: Estimating a Latent Profile Model

Following Bakk & Oberski (2014), the first step is a LPA model of K observed indicator variables used to define the latent profile model. Given a sample of n units, the observations Yi are modeled as arising from T unobserved (latent) profiles X,

$$P(Yi) = \sum_{t=1}^{T} P(Xi = t) P(Yi|Xi = t) \quad (1)$$

Furthermore, local independence is assumed and the K indicator variables are assumed to be mutually independent within each *t* profile. The conditional probability of the i^{th} response given the latent profile can then be written as a product of conditional item responses,

$$P(Yi|Xi = t) = \prod_{k=1}^{K} P(Yik|Xi = t) = \prod_{k=1}^{K} \prod_{r=1}^{Rk} \pi_{ktr}^{I(Yik=r)} \quad (2)$$

The first-step log-likelihood of the sample data L1 follows by combining equations (1) and (2) and assuming independence of observations:

$$L_1(\theta_1) = \sum_{i=1}^{N} logP(Yi) = \sum_{i=1}^{N} log \left[\sum_{t=1}^{T} \rho_t \prod_{k=1}^{K} \prod_{r=1}^{R_k} \pi_{ktr}^{I(Y_{ik}=r)} \right] \quad (3)$$

To choose the optimal number of profiles, model estimation usually is undertaken by increasing the number of model profiles and comparing across models using multiple fit statistics, including: the Bayesian information criterion (BIC), the Akaike information criterion (AIC), the consistent AIC (CAIC), classification errors (CE) and entropy R2. *Ceteris paribus*, a low BIC, AIC, CAIC and CE value and a high R2 value indicates a better-fitted model. Finally, bootstrap likelihood-ratio tests measure the significance of the difference in likelihood between two models.

Second step

Following Bakk et al. (2014), after estimating the latent profile model in the first step, a new variable W is created, assigning each unit to an estimated profile. Following Bayes rule, each unit posterior probability of belonging to profile t is

$$P(Xi = t|Yi) = \frac{P(Xi = t)P(Yi|X = t)}{P(Yi)} \quad (4)$$

For assigning units into profiles we adopted a proportional rule that treats each individual as belonging partly to each latent profile, with weights given by posterior probabilities. Irrespective of the assignment method used, the true (X) and assigned (W) profile membership scores will differ. The classification errors must be calculated, and the correction methods for the assignment variable W will apply in the third step.

Summing over all observed data patterns, the amount of classification errors can be expressed as the posterior profile membership conditional on the true value

$$P(W = s|X = \mathrm{t}) = \frac{\frac{1}{N}\sum_{i=1}^{N} P(Xi = t|Yi)P(Wi = s|Yi)}{\mathrm{P(X = t)}} \quad (5)$$

Third Step: Relating Estimated Profile Membership to External variables (Covariates and Distal Outcomes)

The third step of the approach relates the latent profiles to external variables. These can act as predictors of the individual membership to the latent profiles, i.e. covariates. Alternatively, latent profiles can act as predictors of external variables, i.e. distal outcomes.

Following Bakk et al. (2014), in the third step the assigned classification W is related to a vector of covariates, Z, while also correcting for classification error in W. P(X= t|Zi), and P(W= s|Zi) are related to each other, namely that P(W= s|Zi) can be written as a weighted sum of the latent profiles given the covariates, with the classification error probabilities as the weights:

$$P(W = s|Zi) = \sum_{t=1}^{T} \mathrm{P(X = t|Zi)\ P\ (W = s|X = t)} \quad (6)$$

Denoting by Z_{iq} the value of subject *i* on one of the Q covariates, the structural part of the model can be parametrized by means of a multinomial logistic regression model,

$$P(X = t|Zi) = \frac{\exp(\beta_{0t} + \sum_{q=1}^{Q} \beta_{qt} Z_{iq})}{\sum_{s=1}^{T} \exp(\beta_{0t} + \sum_{q=1}^{Q} \beta_{qs} Z_{iq})} \quad (7)$$

Below we present the third-step model with external variables that are predictors of latent profile membership (Bakk et al., 2013). The parameters of interest are the logistic regression coefficients β_{qt}, gathered in the vector θ_3. Consistent estimates $\hat{\theta}_3$ can be obtained by maximizing the third-step log-likelihood (Vermunt 2010),

$$L_3(\theta_3|\theta_2 = \hat{\theta}_2) = \sum_{n=1}^{N} \sum_{s=1}^{T} P(W = s|Yi) log \sum_{t=1}^{T} P(X = t|Zi) P(W = s|X = t) \quad (8)$$

The logistic regression coefficients, contained in the parameter vector θ_3, are freely estimated, while the classification errors contained in the parameter vector θ_2, are held fixed at their estimates, $\theta_2 = \hat{\theta}_2$.

3.2 Description of variables employed

Several variables should be analyzed as indicators to encompass all relevant aspects of households' livelihood strategy choice (Barrett et al., 2001; Nielsen et al., 2013). In this study we identified three sets of variables: i) activity variables that measure the latent profiles, ii) capital asset variables (covariates) that predict household membership to the latent profiles and iii) income variables (distal outcomes) that are predicted by the latent profiles.

Activity variables to identify the livelihood profiles

Identification of livelihood strategies was based on the use of the main assets that rural households have: labor and land (Jansen et al., 2006; van den Berg, 2010). Labor allocation is the most direct measure to identify a livelihood strategy (Jansen et al., 2006; Nielsen et al., 2013); we used the proportion of family labor allocation to on-farm activities and to off-farm activities (both agriculture and non-agriculture related), complemented by the proportion of external workforce hired. With respect to land, we identified the share of land allocated to CN and CCN-51 varieties that form the agricultural basis of the farmers in the study site.

Since it may be difficult to accurately determine labor allocation into its different activities (Babulo et al., 2009), we identified instead modalities of on-farm and off-farm employment (i.e. temporary or permanent) while transfer payments (e.g., pensions and remittances) were also included. In total, we considered eight activity variables as shown in Table 2.

Capital asset variables as covariates to predict household membership to the livelihood profiles

Capital asset variables have been assessed in livelihood studies (e.g. Bebbington, 1999; Bhandari, 2013; Hua, Yan, & Zhang, 2017) since the capital asset mix can be considered as the platform for a household to choose its livelihood strategy (Brown et al., 2006; Nguyen et al., 2015). In this study we examine the influence of capital assets as predictors of household membership to the identified livelihood profiles.

Specifically, we examine the influence of access to five types of capital. Natural capital includes all natural resource stocks and environmental services from which livelihoods are derived. In rural agrarian societies, the access to farm land and its ownership is a crucial component of natural capital, being also the economic capital since the access to land provides employment and income to farmers (Bhandari, 2013). Land size and ownership are the variables considered to measure natural capital. Physical capital includes the basic infrastructures and producer goods essential for supporting livelihoods (Bebbington, 1999; Bhandari, 2013; DFID, 1999). Two built-in indexes were considered in this case: the production index (access to machinery, storing installations or transportation) and the basic services index (access to drinking water, health or education). Human capital comprises the amount and quality of labor available, skills, knowledge and health that together enable individuals or households to pursue different livelihood strategies (DFID, 1999). Family size and educational level were the proxies to measure this dimension. Social capital refers to the resources people draw upon to achieve their livelihood objectives (DFID, 1999). It was measured through membership to rural cooperatives. Finally, financial capital was assessed through computation of households' savings and debts.

Income share variables as distal outcomes of livelihood profiles

The share of different income sources was used to determine the income mix that each livelihood strategy was related with. Consideration of income as a distal outcome (i.e. predicted by the livelihood profiles) acknowledges that its nature as a result rather than as a determinant of a livelihood strategy (Jansen et al., 2006). Furthermore, it allows separating asset allocation - and therefore the livelihood strategy- from the stochastic influence of income as a wealth measure, that could be an important determinant of livelihood choice (van den Berg, 2010). Finally, this approach may better enable understanding which livelihood strategies provided a better income level to the rural households.

A pilot questionnaire served to establish the household's main income sources over the past two years. In the final survey farmers were requested to indicate the proportion of income from the following sources: on-farm activities, off-farm agricultural activities, off-farm non-agricultural activities and non-agricultural self-employment activities (Table 2). Distinguishing between on-farm and off-farm income is crucial since the latter generally eases capital constraints and may contribute to higher farm production and income (Babatunde & Qaim, 2010; Chang & Mishra, 2008).

4. Data collection

A detailed household survey was conducted from December 2015 to April 2016. Data collection and handling followed the Poverty Environment Network (PEN) survey guidelines designed to measure income and livelihood patterns (Angelsen et al, 2011; PEN, 2015). The PEN prototype questionnaires were translated into Spanish and thoroughly field tested in the nine rural sites before operationalization.

Meetings were initially held with presidents of the cooperatives and communities in each area to explain them the goals and methodology of the study. A survey schedule was prepared so that heads of the households randomly selected across the nine villages were summoned in the agreed date to complete the questionnaire. Each interview lasted approximately 45 minutes. A total of 188 heads of randomly sampled households were interviewed.

The final questionnaire was divided into three sections. The first one recorded household activity variables; the second section collected data about household income share and the third section compiled information about the capital assets.

5. Results

Under the three-step approach adopted in this study, a LPA model was estimated to identify typologies of rural households that exhibited a similar pattern of livelihood strategy. Eight activity variables were chosen to measure the profiles. Capital asset variables enter in the model as predictors of household membership to each profile[1]. Finally, the profiles are employed as predictors of income share (i.e. income share is a distal outcome), acknowledging this way that income sources are outcomes rather than determinants of livelihood strategies.

5.1 Profiles of livelihood strategies

A 4-profile model performed the best according to BIC, CAIC and conditional bootstrap tests. Table 4 shows mean values, standard deviations and the overall Wald test for each profile activity variable as well as size and name for each profile. All activity variables contributed significantly to discriminate among the profiles ($p<0.05$), except for transfer income and, more importantly for the CN variable. Hence, land share devoted to CN cultivation does not contribute to discriminate between profiles.

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[1] All these analyses were estimated with Latent Gold 5.1 software (Vermunt & Magidson, 2015), after performing a correlation analysis among all variables under investigation using SPSS V.23 software (IBM Corp., 2015).

Profile 1 (P1) accounts for 37% of the sample, followed by profile 2 (P2) with 31% of the observations while profiles 3 (P3) and 4 (P4) gather around 15% of the sample each.

P1 farms allocate approximately the same share of land to CCN-51 (M=0.32) than to CN (M=0.28), being the group with a largest share of land devoted to the former. Labor on the farm mostly relies on family members (M=0.67) while off-farm family labor (M=0.04) and on-farm non-family labor (M=0.03) are irrelevant. We have named this group *Mixed cocoa varieties & family-labor profile.*

P2 is the most cacao-oriented profile with two thirds of the farm land devoted to this crop; CN doubles the land share of CCN-51. They make the most intensive use of family labor (M=0.79) and also rely on hired workforce (M=0.56) while off-farm family labor (M=0.08) is not relevant. We have tagged this group as *CN-predominant & intensive-labor profile.*

P3 is the most CN-specialized profile with marginal participation of CCN-51 (M=0.08). On-farm family labor (M= 0.58) is as important as off-farm family labor (M=0.55), being permanent employment (M= 0.57) the main modality for the latter case. Hired workforce is not relevant (M=0.03). We have named this group *CN & diversified family-labor profile*.

Finally, P4 also shows specialization on CN variety (M=0.41) but differently from previous groups, it presents a high labor diversification among the different labor-options: family labor on and off farm (M=0.65) (being the group with the highest share of the latter), and external workforce (M=0.52). We have named this group as *CN & diversified-labor profile*.

5.2 Capital asset variables as predictors of household profile membership

All capital asset mix variables proved to be significant predictors of profile membership (overall Wald test with $p<0.05$). Pivotal comparisons were established (see table 5) between the profiles to assess the role of capital assets in defining the profiles. First P1 (the profile with the highest share of CCN51) was taken as a base level to pivot P2, P3 and P4. On a second phase, P2 (the more intensive in family labor and in cocoa land share) was taken as a base level, to compare P3 and P4 with it.

In the first pivotal comparison, we see that households belonging to farmer associations are more likely to belong to P2, while these with large family size and primary education are more likely to be found in P3. P4 is the group showing more significantly different capital asset values to P1; medium and large farms are more likely to belong to P4, while being owner of the land reduces their probability to be in this group. Furthermore, having a positive and relatively high capital production index does increase household likelihood to be in P4, while a low basic service index plays in the opposite direction. Finally, having savings and low debt does also increase probabilities for being in P4.

The second pivotal comparison shows that the probability to belong to P3 or P4, with respect to P2, increases with land size and decreases with land ownership. Also, the bigger the family size, the more likely to belong to any of these two profiles. Households with primary education are more likely to belong to P3. Finally, and as in the previous, having savings and low debt does also increase probabilities for being in P4.

5.3 Income share predictions by livelihood strategy profiles

We computed the profile-specific means for income share variables related to four labor types (see Table 6). The overall Wald test was significant for three of them: on-farm agricultural activities, off-farm non-agricultural activities and off-farm agricultural activities.

Income share from on-farm agricultural activities significantly discriminates between P1-P2 and P3-P4 profiles; the former have a greater share of their income from these activities, while the latter achieve only 50% of their income from on-farm agriculture.

P3 shows a distinctive share of income proceeding from off-farm agricultural activities, while P4 has the highest share of its income originating from off-farm non-agricultural labor.

6. Discussion

This study addresses the livelihood strategies of smallholders in the Guayas region of Ecuador, one of the main cocoa producing areas in the country and where a productive “tension” is found between cacao nacional (CN), the source of fine flavor cocoa and CCN51, its more productive lower-quality counterpart. For this purpose, 188 heads of randomly sampled households were interviewed in nine rural sites. The national policy to stimulate the production of CN has a double-fold objective to improve the competitiveness of Ecuadorian cacao on the global markets and also to reduce poverty of smallholders through premium prices earned by CN beans (MAGAP, 2013).

This work builds on previous studies assessing Ecuadorian cocoa production (e.g. Melo and Hollander, 2013; Useche and Blare, 2013; Galarza, 2012) and on the livelihood strategy approach through the livelihood asset framework (Babulo et al., 2008; Fang et al., 2014; Rakodi, 1999). However, we adopt a robust statistical focus (Collins & Lanza, 2010; Magidson & Vermunt, 2002) that differently from traditional cluster analysis (Babulo et al., 2008; Nielsen et al., 2013; Walelign, 2016) considers classification errors and allows relating profiles of livelihood strategies with external variables in a rigorous manner.

Cocoa producers face some opposing goals and trade-offs when cultivating coffee. While CN may accrue biodiversity benefits and premium prices in specialty markets, full-sun, high-yield CCN51 does benefit from less labor but more dependence on external inputs and lower prices (Franzen & Mulder, 2007). Most studies assessing the role played by these two varieties and their distinctively different implications in terms of ecosystem service provision, cultivation or market access (Andres et al., 2016; Jano & Mainville, 2007; Ton et al., 2008; Vaast & Somarriba, 2014) suggest that farmers would either opt for one or the other variety. In contrast, our survey shows that more than two thirds of the sampled households (P1 and P2) solve this productive tension by allocating a substantial share of their land to concurrently cultivate CN and CCN51. While short-.term benefits from cultivating CCN51 allowed its spread (Franzen & Mulder, 2007; MAGAP, 2013; Melo & Hollander, 2013), it also seems that many farmers acknowledge the benefits of maintaining shade production (Blare & Useche, 2013; Franzen & Mulder, 2007). Furthermore, our results indicate that the variable "share of land allocated to CN" does not significantly contribute to discriminate either of the profiles.

Two broad patterns can be disentangled from this study, where P1 and P2 profiles are highly dependent on their agricultural production, while P3 and P4 show a more diversified farm economy. These profiles less diversified towards off-farm activities also have the highest shares of land devoted to CCN51 production. Diversification towards off-farm activities is a key strategy in rural livelihoods (Hua & Zhang, 2017; Nielsen et al., 2013; Walelign, 2016) since it may reduce vulnerabilities to prevailing agricultural risk (Davis, 2006; Kandulu et al., 2012) and it generally shows a viable strategy to improve living standards in rural areas (Nielsen et al., 2013; Walelign et al., 2016).

Labor is a building block for acquiring livelihood objectives and sustaining livelihood outcomes (Bhandari, 2013) and its analysis shows how P2 farmers relay on external workers to support their farm activities. P2 is the group with more land allocated to cocoa production and a substantial share of it allocated to CN. CN cultivation requires more labor while with CCN51, some labor is replaced by the use of agrochemicals (Bentley et al., 2004; Franzen & Mulder, 2007). Therefore, for less diversified livelihood strategies, cultivation of CCN51 may be seen as a way of obtaining benefits on the short-term and reducing the needs for external workforce hiring while CN cultivation may allow for premium prices and key ecosystem services for the farm functioning, such as erosion protection.

Cultivated land resource endowment has proved to be a key factor influencing differentiation of livelihoods (Hua et al., 2017; Jansen et al., 2006; Winters et al., 2009). A high share of land resource endowments allocated to CN production (around 40%) and marginal land allocated to CCN-51 seems to indicate pathways of off-farm income diversification activities such as these followed by P3 and P4 whose income shares related to off-farm activities are around 20%.

Large farmers tend to have better access to economic/financial capital and can afford to purchase modern farm inputs that will allow them to strengthen their livelihood (Bhandari, 2013). Households in P4 can easily be identified with this pattern, showing positive and significant values for medium and large property sizes, a positive and significant production implements index when compared to P1 and a diversified economy with off-farm income based on no agricultural activities. Furthermore, our results also show that it is access to the land, but not land ownership the key factor contributing to engage with higher income opportunities (Jansen et al., 2006; van den Berg, 2010).

Human assets enable households to pursue different livelihood strategies to achieve their livelihood objectives (Bhandari, 2013). Family size plays a crucial role in this respect since larger families are able to pursue non-agricultural livelihood strategies due to their higher labor capacity, (Hua et al., 2017). Family size does play a key role in defining household allocation to each of the profiles. P3 and P4 show distinctively bigger family size than P2, what translates into more labor capacity and ability to diversify income sources. Some studies also signal how family size has a positive impact on adoption of innovation in crop management and more specifically on the adoption of innovation to restore CN cultivation (Tiwari et al., 2008).

The importance of cocoa as a major global commodity, makes the establishment of effective cocoa policy a high priority (Franzen & Mulder, 2007) and our findings may contribute to shaping current and future policies in Ecuador.

Our results show that these farmers that are more dependent on on-farm income are the biggest producers of CCN51, probably because shifting completely to CN may be seen as a risk. To improve the success of the policy aimed to stimulate CN production, diversification strategies may need to work hand in hand with CN rehabilitation and improved breeding. Previous experiences show that the assumption of the niche marketing of fine cocoa compensating farmers for the lower productivity of CN has not always been met (Astudillo Paredes, 2014) and therefore, farmers may be reluctant to put all their eggs in one basket (Melo & Hollander, 2013). Furthermore, previous lessons learned from exposition of farmers to AFN, should be considered in the second phase of the current plan aimed at strengthening the cocoa value chain.

Findings in our study show that P4 households are more likely to have a high production service index and less likely to have a low basic service index. Since asset thresholds are key to improve poverty transitions (Mutenje et al., 2010; Scoones, 2015; Walelign, 2016), national policies oriented to reduce poverty of cocoa small holders may need to consider not only increasing cocoa productivity but also undertaking investments in infrastructure and social safety nets to develop sustainable livelihoods (Bhandari, 2013; Davis & Lopez-Carr, 2014; Mahdi est al., 2016; Mbaiwa, 2011; Park et al., 2012; Reenberg et al., 2013; Timmer, 2012).

Finally, the agroforestry low-input CN cultivation system has also benefits for biodiversity conservation. Furthermore, some studies indicate how agroforestry systems may also be a more viable long-term strategy to face climate change impacts (Smith Dumont et al., 2014; Vaast & Somarriba, 2014). Our study shows that CN cultivation is more prevalent among income-diversified households, suggesting that farm diversification may be a way of simultaneously benefit biodiversity and the economic security of small farmers (Franzen & Mulder, 2007).

9. Conclusions

Cocoa is major global commodity whose production namely relies on smallholder farmers. Establishment of effective cocoa policies to improve their cultivation is commonly seen as a way to improve the livelihood of small producers. Ecuador as the largest global producer of fine flavor cocoa (CN) has developed a national policy to rehabilitate and stimulate the production of CN variety over its hybrid counterpart (CCN51). Fine flavor cocoa may achieve premium prices allowing small holder to increase their livelihood standards.

This study explores livelihood strategies of cocoa producers in the Guayas region of Ecuador through a robust latent class approach. Our results show that 60% of the sampled households combine the production of the fine flavor cocoa (CN) with the hybrid variety (CCN-51). Households with a lower share of land allocated to CCN-51 show higher income diversification strategies and vice versa.

Outcomes of this study point towards support of income diversification pathways and improvement in basic services and production assets as key side-action to increase the success of the current Ecuadorian National policy for fine flavor cocoa rehabilitation.

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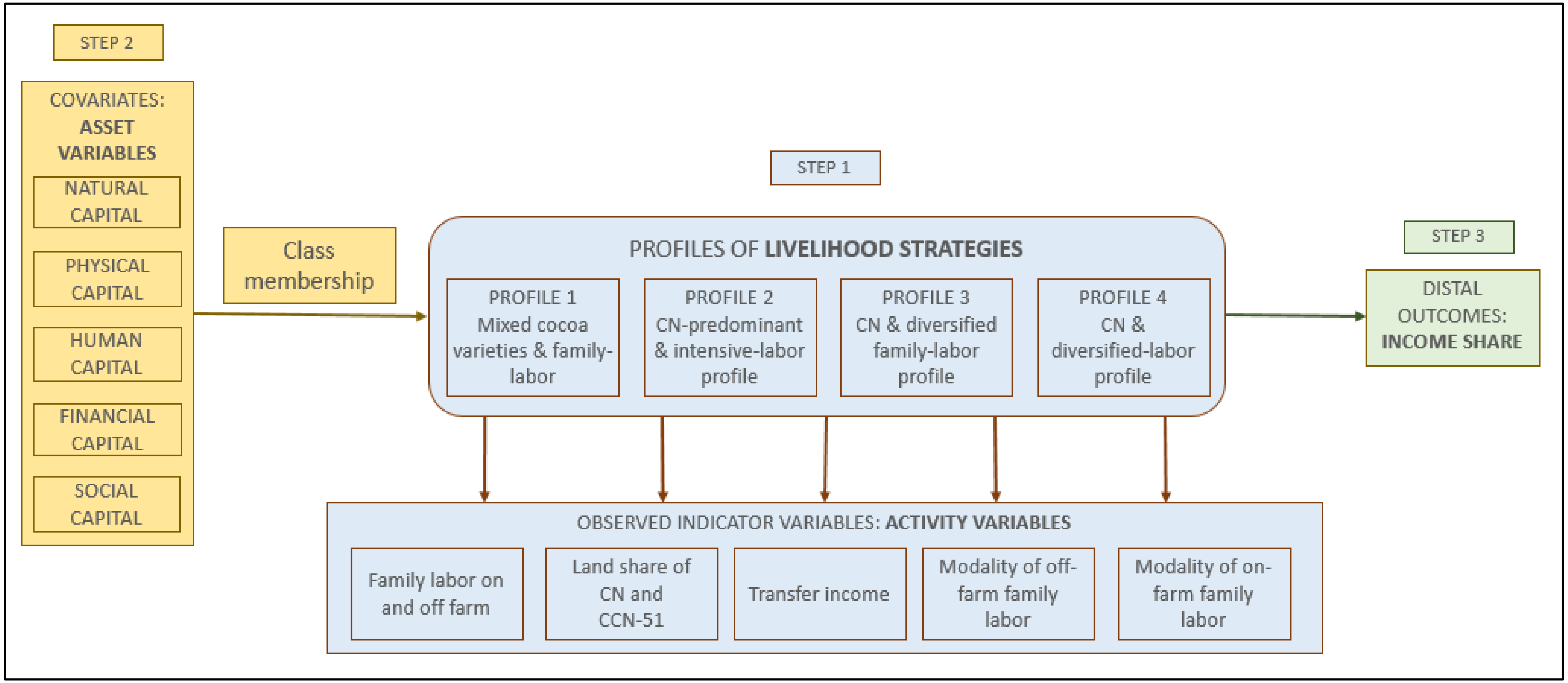

Figure 1. The three step approach methodology adapted to the livelihood strategy framework. Source: own elaboration on Magidson Vermunt (2015) and Nielsen et al. (2013). First step: Activity variables (land and labor) measure the livelihood strategies. Second step: Capital asset variables are covariates that predict class membership of the households to the latent profiles. Third step: The latent profiles identified act as predictors income share variables.

Table 1. Summary statistics of surveyed respondents

VARIABLES	Lorenzo de Garaicoa		Yaguachi Viejo		Full sample			
	M	SD	M	SD	M	SD	Min.	Max.
Age (years)	48.47	13.94	54.19	15.36	50.23	14.59	18	86
Gender (% female)	22.00	-	20.70		21.80	-	-	-
Education (years)	8.03	4.52	8.38	3.89	5.33	4.01	0	15
Household size	2.50	1.23	3.31	1.74	2.75	1.46	1	7
Land size (ha)	4.99	6.46	4.49	3.48	4.96	5.79	0.38	47.5
Married or live together (%)	70,00	-	74.10	-	71.30	-	-	-
Nacional Cacao variety (ha)	1.23	2.45	2.56	2.26	1.64	2.46	0.20	12.00
CCN-51 Cacao variety (ha)	1.23	2.30	0.17	0.74	0,9	2.02	0.45	13.50
Permanent crops (ha)	0.71	1.66	0.76	2.06	0.73	1.79	0	13.50
Others crops (ha)	1.81	4.98	0.84	1.61	1.51	4.25	0	44.50

Table 2. Activity, income and asset variables

Activity variables	*Description*
On-farm family labor	Household adults working on-farm/Total household adults
Off-farm family labor	Household adults working off-farm/Total household adults
On-farm non family labor	External workers/Total on-farm workers
Cocoa National CN	Ha of CN/Total ha
Hybrid cocoa CCN-51	Ha of CCN-51/Total ha
Transfer income[a]	This measures the participation of transfer income in total income. Transfer income/Total income
Modality of off-farm family employment[b]	1= permanent employment, 2= temporary employment, 3= other forms of employment, 4= does not apply
Modality of on-farm non family employment[c]	1= permanent employment, 2= temporary employment, 3= other forms of employment, 4= does not correspond
Income share variables	
On-farm agricultural activities	Income share of on-farm agricultural activities over total income
Off-farm agricultural activities	Income share of off-farm agricultural activities over total income
Off-farm no-agricultural activities	Income share of off-farm non-agricultural activities over total income
Non-agricultural self-employment activities	Income share of non-agricultural self-employment activities over total income
Natural capital	
Land	**1**= < 3 ha, **2** = 3-6 ha , **3** = > 6 ha
Own land	The total amount of arable land owned by the household.
Physical Capital	
Production implement index[d]	Measures the household possession of production implements. The larger the index greater the asset holding
Basic services index[e]	Measures the access of households to basic services. The larger the index greater the access
Human Capital	
Family size	Adult income household members
Education	1=No education, 2=Primary education, 3=Secondary education and higher.
Financial Capital	
Savings	Dummy variable indicating possession or absence of saving
Debt	Dummy variable indicating possession or absence of debt
Social Capital	
Farmer association	Dummy variable indicating membership to rural cooperatives

[a] Includes retirement pensions, remittances from family member resident abroad and *Bono de Desarrollo Humano* (a government cash transfer program)

[b] Other forms of employment include: job as payment for lends, mix between permanent and temporary. Option 4 is selected when the households does not have adult members labor outside of farm

[c,d] Access to productive assets: plow, installations for drying of products, transport of products, and installations for storage of products.

[e] Access to basic services: drinking water, passenger transport, landline, mobile phone, internet, health and education.

Table 3. Fit statistics for models comprising 1 to 5 latent profiles

VARIABLES	PROFILE MODELS				
	1	**2**	**3**	**4**	**5**
Log-likelihood	-2184.49	-2092.56	-2057.25	-2009.68	-1991.5
Global measures-fit (1)					
BIC	4992.12	4855.38	4831.90	4783.89	4794.66
AIC	4606.98	4441.11	4388.51	4311.37	4293.01
CAIC	5111.12	4983.38	4968.90	4929.89	4949.66
Local measures-fit					
max (BVR)	97.794	82.856	42.927	41.893	41.431
Entropy-R2	1	0.9907	0.9541	0.9798	0.9348
Class.Err. (CE)	0	0.0013	0.0166	0.0059	0.0395

BIC: Bayesian Information Criterion
AIC: Akaike's Information Criterion
CAIC: Consistent Akaike's Information Criterion.
BVR: Bivariate Residual.

Table 4. Profiles of livelihood strategies

	PROFILE 1		PROFILE 2		PROFILE 3		PROFILE 4		p-value[a]	R2
	Mixed cocoa varieties & family-labor		*CN-predominant & intensive-labor*		*CN & diversified family-labor*		*CN & diversified-labor*			
Profile Size (%)	37%		31%		17%		15%			
	M	SD	M	SD	M	SD	M	SD		
On-farm family labor	0.67[2]	0.03	0.79[1,3,4]	0.00	0.58[2]	0.00	0.65[2]	0.04	0.015	0.060
Off-farm family labor	0.04[3,4]	0.00	0.02[3,4]	0.00	0.55[1,2]	0.00	0.65[1,2]	0.00	0.000	0.630
On-farm non-family labor	0.03[2,4]	0.00	0.56[1,3]	0.00	0.03[2,4]	0.00	0.52[1,3]	0.00	0.000	0.717
CN	0.28	0.16	0.41	0.16	0.44	0.42	0.41	0.55	0.580	0.026
CCN-51	0.32[3]	0.01	0.24[3]	0.02	0.08[1,2]	0.01	0.16	0.16	0.058	0.059
Transfer income	0.12	0.38	0.08	0.38	0.12	0.41	0.08	0.39	0.690	0.008
Modality of off-farm family employment	3.04[3,4]	0.03	1.43[3,4]	0.04	1.43[1,2]	0.09	1.66[1,2]	0.10	0.000	0.810
1. Permanent employment	0.00	0.00	0.00	0.00	0.57	0.09	0.36	0.09		
2. Temporary employment	0.01	0.01	0.01	0.02	0.42	0.08	0.63	0.09		
3. Other forms employment	0.05	0.03	0.03	0.02	0.00	0.00	0.00	0.00		
4. Does not apply	0.94	0.03	0.96	0.02	0.00	0.02	0.02	0.02		
Modality of on-farm non-family employment	3.05[2,4]	0.03	1.85[1,3]	0.05	3.03[2,4]	0.04	1.83[1,3]	0.07	0.000	0.795
1. Permanent employment	0.00	0.00	0.16	0.05	0.00	0.00	0.18	0.07		
2. Temporary employment	0.00	0.07	0.84	0.05	0.01	0.01	0.82	0.07		
3. Other forms employment	0.06	0.03	0.00	0.00	0.96	0.03	0.00	0.00		
4. Does not correspond	0.94	0.03	0.00	0.01	0.03	0.03	0.00	0.01		

[a] From overall Wald test. Super indexes correspond to the profiles from which data is significantly different from at 5% level.

Table 5. Capital asset variables prediction of household profile membership

	a) P1 vs P2, P3 and P4 profiles						b) P2 vs P3 and P4 profiles				Wald	p-value
	P2 *CN-predominant & intensive-labor*		**P3** *CN & diversified family-labor*		**P4** *CN & diversified-labor*		**P3** *CN & diversified family-labor*		**P4** *CN & diversified-labor*			
Capital Asset variables	**β**	**z-value**	**β**	**z-value**	**β**	**z-value**	**β**	**z-value**	**β**	**z-value**		
Land											13.71	0.030
Less than 3 ha.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.		
Between 3 and 6 ha.	-0.09	-0.17	-0.29	-0.48	1.65	2.24	-0.21	-0.32	1.74	2.21		
More than 6 ha	-0.31	-0.34	1.57	1.66	3.38	2.64	1.88	2.31	3.69	2.95		
Land ownership	0.11	1.25	-0.08	-0.83	-0.38	-2.33	-0.19	-2.73	-0.49	-3.13	13.50	0.000
Production implement index	0.46	1.67	-0.02	-0.06	0.85	2.37	-0.48	-1.62	0.39	1.07	8.18	0.040
Basic services index	-0.36	-1.77	-0.24	-0.99	-0.60	-2.77	0.11	0.41	-0.25	-0.99	8.69	0.030
Family size	-0.29	-1.47	0.36	2.36	0.29	1.54	0.65	2.97	0.57	2.12	10.35	0.020
Education											27054.68	0.000
No education	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.		
Primary education	1.47	1.58	54.80	95.32	0.87	0.65	56.73	96.16	-0.60	-0.48		
Secondary education	0.39	0.43	53.48	0.00	-0.32	-0.24	56.49	0.00	-0.72	-0.56		
Savings											9.79	0.020
No	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.		
Yes	0.15	0.25	-0.21	-0.32	1.91	2.90	-0.36	-0.49	1.76	2.16		
Debt											10.05	0.020
No	0.00	.	0.00	.	0.00	.	0	.	0	.		
Yes	0.80	1.75	0.48	0.81	-1.42	-2.02	-0.32	-0.54	-2.22	-2.94		
Farmer association											12.23	0.007
No	0	.	0	.	0	.	0	.	0	.		
Yes	1.57	2.98	-0.22	-0.43	1.12	1.52	-1.78	-2.98	-0.46	-0.57		

Table 6. Income share prediction by livelihood strategy profiles

Income shares	PROFILES								Wald	p-value
	P1 *Mixed cocoa varieties & family-labor*		**P2** *CN-predominant & intensive-labor*		**P3** *CN & diversified family-labor*		**P4** *CN & diversified-labor*			
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**		
On-farm agricultural activities	$0.72^{3,4}$	0.04	$0.79^{3,4}$	0.03	$0.50^{1,2}$	0.06	$0.55^{1,2}$	0.05	24.771	0.000
Off-farm agricultural activities	0.10^{3}	0.02	0.06^{3}	0.02	$0.21^{1,2,4}$	0.05	0.09^{3}	0.02	8.745	0.033
Off-farm no-agricultural activities	0.04^{4}	0.02	$0.03^{3,4}$	0.01	0.14^{2}	0.04	$0.23^{1,2}$	0.05	12.429	0.006
Non-agricultural self-employment activities	0.01^{4}	0.01	0.04	0.01	0.03	0.02	0.06^{1}	0.03	3.073	0.380

^{1,2,3,4}Super indexes correspond to profiles significantly different at 5% level.