# Achieving mitigation and adaptation to climate change through coffee agroforestry: a choice experiment study in Costa Rica

Anais Lamour, Julie Subervie

CEE-M
CENTER FOR ENVIRONMENTAL ECONOMICS - MONTPELLIER

# Achieving Mitigation and Adaptation to Climate Change through Coffee Agroforestry: A Choice Experiment Study in Costa Rica

Anaïs Lamour
&
Julie Subervie

CEE-M Working Paper 2020-09

CEE-M

Abstract

We use primary data from a choice experiment carried out with 207 coffee farmers in Costa Rica, in order to study their willingness to adopt various agroforestry systems under various types of support. We test four adaptation strategies that are based on resistant coffee varieties introduction, timber tree species production and/or shade tree density increase. Revealed preferences suggest that most of the respondents do value the introduction of resistant varieties. They are willing to plant twice the number of trees in their plantations when these are combined with resistant varieties. Conversely, all agroforestry systems requiring timber trees to be planted are chosen significantly less often and on average, their adoption would require a compensation scheme. We moreover find that a large majority of respondents is very responsive to non-monetary rewards, namely a subsidized credit, a free trial of resistant coffee seedlings or technical assistance. We conclude that each of these incentives could be used as an incentive to induce land use changes.

Keywords: Payment for Environmental Services, Non-monetary Incentives, Climate change, Choice Experiment, Coffee, Costa Rica.

# 1 Introduction

Coffee agroforestry appears as the most documented strategy to adapt to warmer, dryer and more variable climate conditions (Lin, 2007, 2010; Siles, Harmand, and Vaast, 2010; Camargo, 2010; De Souza et al., 2012; de Carvalho Gomes et al., 2016; Rahn et al., 2018), while also providing multiple environmental externalities (Hergoualch et al., 2008; Philpott et al., 2008a; Hergoualch et al., 2012; Tully, Lawrence, and Scanlon, 2012; de Jesús Crespo et al., 2016). However, there is a wide variety of agroforestry-based adaptation strategies and little is known about their acceptability by small producers in the real world. Moreover, it remains unclear what types of measures or schemes should be implemented to encourage the adoption of these diverse strategies. This Chapter uses original data collected from a large sample of coffee farmers to evaluate their willingness to adopt various agroforestry systems under various types of support.

Based on the assumption that improving risk management within agroforestry systems could reduce the opportunity cost of adopting the technology, the agroforestry systems studied include resistant coffee varieties and/or timber trees - *a priori* attractive options as part of risk-coping strategies that may better fit within local farming contexts - in addition to a shade tree cover of various densities. Since these adaptive strategies also have the potential to provide environmental externalities, this study assesses coffee farmers' preferences in the framework of an external reward scheme such as a Payment for Environmental Services (PES).

Direct performance-based payments have been initially described as the most cost-effective form of incentive to induce the provision of environmental services such as biodiversity conservation (Ferraro and Kiss, 2002). Nonetheless, in cases where market frictions prevail, indirect interventions which relax constraints may be preferred by both the farmer and the program planner (Groom and Palmer, 2010) and the key innovation would be to make such indirect interventions conditional on the provision of environmental externalities (Cranford and Mourato, 2014). This study investigates the potential of three incentives to trigger a decision to adapt to climate change through agroforestry: the use of a subsidized credit [1], a free trial of resistant coffee seedlings and technical assistance.

Given the agro-ecological heterogeneity of farms and socio-economic heterogeneity of rural households, the net benefits of agroforestry adoption are likely to vary between coffee farms. Both opportunity costs and adoption barriers are often related to specific circumstances. Knowler and Bradshaw (2007) showed that empirical evidence about the specific circumstances for the adoption of conservation agriculture is sparse and therefore it is difficult to highlight the universal conditions of adoption. Building on this literature, Andersson and D'Souza (2014) argued that most of current studies on technological adoption, by relying on standard households survey data, fail at providing useful insights due to the rival interpretations constituting the so named "adoption puzzle". In this context, using contingent valuation

1. In Ecuador, Cranford and Mourato (2014) proposed a credit contract that incorporates an environmental condition - which was the adoption of agroforestry - and found a very large demand for it.

methods to explore individual preferences can be an interesting approach as highlighted in recent studies on adaptation-related technologies for agriculture (Tesfaye and Brouwer, 2012; Ward et al., 2013; Ahmed et al., 2015; Ward et al., 2016; Kassie et al., 2017).

Originally developed to predict demand in traditional markets (Train, 2009), discrete choice methods are now a popular tool for eliciting individual's preferences for environmental attributes. In the context of developing countries, several studies have highlighted the dependence of rural poor households on the services provided by the ecosystems (Vedeld et al., 2004; Atkinson, Bateman, and Mourato, 2012). Following studies conducted in developed countries (Ruto and Garrod, 2009; Espinosa-Goded, Barreiro-Hurlé, and Ruto, 2010; Christensen et al., 2011) and in China (Grosjean and Kontoleon, 2009),a growing body of literature uses these methods to understand preferences of landowners from the developing world not as consumers but as suppliers of environmental externalities, regarding potential designs of PES contracts (Kaczan, Swallow, and Adamowicz, 2013; Cranford and Mourato, 2014; Costedoat et al., 2016). These studies are based on Choice Experiments (CE) during which respondents are asked to select the PES contracts they prefer between various hypothetical alternatives. Recent development of mixed logit models has allowed CE data analysis to incorporate random taste variation, unrestricted substitution patterns and correlation in unobserved factors over time (Train, 2009).

For this case study, a CE approach is uniquely useful to reveal coffee farmers' heterogeneity in making differential profits from both agroforestry systems and rewards. This can help to design technological and institutional innovations tailored to the needs of coffee farmers. We investigate Costa Rican coffee farmers' acceptability for a policy portfolio mixing adaptation technology adoption with the provision of environmental service including mitigation efforts. We carried out a choice experiment with 207 coffee producers in two neighboring cantons in the Los Santos Valley. This relatively homogeneous agro-ecological zone is the main region for coffee farming in term of area, number of producers, production and quality in Costa Rica. In our experiment, the hypothetical PES contracts include a "requirement" (one of four agroforestry systems) as well as four types of "rewards" (a cash payment, a subsidized credit, a free trial of resistant coffee plants and technical assistance) conditional on the compliance with the requirement.

Revealed preferences suggest that most of the respondents do value the introduction of resistant varieties such that they are willing to plant twice the number of trees in their plantations when these are combined with resistant varieties. Conversely, all agroforestry systems requiring timber trees to be planted are significantly less popular and on average, their adoption would require a compensation scheme. This compensation may be explained by the high level of carbon sequestration associated with timber trees. Regarding the respondents' preferences for the various proposed incentives, a large majority of respondents is responsive to a contract offering a cash payment, a subsidized credit, a free trial of resistant coffee seedlings or technical assistance. By showing that farmers were willing to pay for agroforestry systems combining resistant varieties, this study suggests the existence of an unfilled demand for more tolerant plants and highlights the incidence of market frictions in constraining autonomous adaptation to climate change. It also points out the role of such attractive technological packages as PES requirement, in fostering voluntary participation at a possibly lower cost for the program planner. By estimating demand for the subsidized credit, free trial of resistant coffee seedlings and technical assistance, this study also adds to the few studies that empirically investigates interventions to induce land use changes through reducing market constraints.

Following this introduction, Section 2 reviews previous studies on the attributes used in the experiment. Section 3, Section 4 and Section 5 describe the study area, the data collection and the design of the choice experiment, respectively. Then Section 6 presents the econometric models used. Results are explained in Section 7. Section 7 concludes.

# 2 Toward Climate-Smart Coffee Farming

## 2.1 Adaptive practices

As explained in Chapter 2, covering coffee plantations with a layer of shade trees appears as the most documented strategy to adapt to warmer, dryer and more variable climate conditions (Lin, 2007, 2010; Siles, Harmand, and Vaast, 2010; Camargo, 2010; De Souza et al., 2012; de Carvalho Gomes et al., 2016; Rahn et al., 2018). In this Section, we present two other adaptive practices for which evidence have been found about their effectiveness to address some of the needs of coffee farming for incremental adaptation to global changes in Central America: the association of the timber tree Cordia with coffee plants and coffee hybrid varieties introduction. In the last part of this Section, we detail the ability of these practices to provide ecosystem services.

### Cordia timber tree

The association of the timber tree Cordia with coffee plants is in fact a common agroforestry system in traditional coffee farming in Costa Rica (Beer, 1979), Colombia (Venegas Tovar, 1978) and Venezuela (Lamprecht, 1955). Cordia is a widespread specie in tropical America where it can naturally regenerate and grow very rapidly (Pérez Figueroa, 1954). Beer (1979) asserts that coffee farmers can value it as a suitable shade tree also due to its tall straight trunk and compact crown which does not require any pruning operation but provides the leaf litter with a large amount of organic material. Furthermore, Cordia is one of the most popular timber tree in the countries where it occurs naturally, supplying high-quality wood suitable for construction, cabinet work and furniture-making (Greaves and McCarter, 1990), unlike Erythrinas which can provide only firewood. From 1985 to 2005, sale price for Cordia wood increased by 570%, as a result of higher demand in the region (Vaast et al., 2015).

Timber production as an important source of income has been reported in low-altitude coffee farms and attributed to a portfolio diversification strategy (Galloway and Beer, 1997; Rice, 2008; Vaast et al., 2015). Explaining coffee land losses occurred after the 1997-2001 sale price crisis in Turrialba, a low-elevation region in Costa Rica, Bosselmann (2012) evidenced that the sale or consumption of products from shade trees (72% of the sample) had decreased the probability of converting coffee plantation to other uses. Some evidence suggests that in the same region, coffee plantations with both Cordias and Erythrinas can be more profitable than plantations shaded with Erythrinas only (Glover, 1981), even when damages from timber harvest to coffee plants are discounted while coffee yields and coffee prices are high (Somarriba, 1992). Observed Cordia densities in this region and at higher elevations in Colombia cover a range from 50 to 350 trees per hectare of plantation (Beer et al., 1997). For a density of 100 Cordias per hectare, the additional annual revenue from timber sale has been estimated at USD 150-250 per hectare (Vaast et al., 2015). No obvious environmental constraint would prevent the introduction of Cordia in the coffee plantations in Los Santos region, given that the specie is yet found from 0 to 2,000 meters above sea level, reaches its best growth at about a mean annual temperature of 24 °C and mean annual rainfall above 2,000 mm, without being impacted by the pattern of annual rainfall distribution and tolerating very low rainfall levels (Greaves and McCarter, 1990). Moreover, Greaves and McCarter (1990) mentions that Cordia has proven a better resistance to hurricanes and cyclones compared to other timber species.

## Hybrid varieties

Coffee hybrid varieties introduction has good prospect for improving farm resilience to climate-related threats, especially pest and disease issues. Due to their reproductive biology and evolution, Arabica varieties bear low genetic diversity (Lashermes et al., 1993) leading to be vulnerable to most pests and diseases affecting coffee production worldwide (Bertrand et al., 1999). In response to production risk, selective breeding for innovative varieties has led to put on the market several varieties which are high-yield and disease resistant (Silva et al., 2006; Camargo, 2010) and can technically be propagated on an industrial scale (Etienne et al., 2012). Nevertheless, the failed experience of the hybrid variety Catimor in Central America highlighted that such hybrid varieties again face up to the quality imperative of reaching the taste standards of buyers and maintaining local reputation (Bertrand et al., 2003, 2006).

Considering both productivity and quality aspects, Arabica hybrids named F1 from traditional Central American varieties or Catimors, crossed with wild Sudanese-Ethiopian origins have shown promising results. First, they bear some genes of resistance to pests and diseases that are highly prevalent, including the coffee berry disease found only in Africa for the moment (Bertrand et al., 1999). Planted from 750 to 1580 m.a.s.l in current climate conditions, F1 hybrids display yield from 30 to 35% more than traditional Central American varieties in unshaded conditions, and even up to 60% under shade (Bertrand et al., 2011). F1 yield could be also more stable facing environmental stresses (Bertrand et al., 2011). Finally, with regard to the biochemical composition of their beans and taste quality of the processed beverage, Bertrand et al. (2006) found them at least as good as the best traditional varieties from Costa Rica.

### Environmental Services provision

Implementing those farming practices may improve environmental services provision compared to current practices, including carbon capture and storage. Shade trees in coffee plantations can be significant sinks of atmospheric carbon mainly by sequestering carbon in their aboveground biomass, that has been quantified in the literature as around 5.4 and 19.9 tonnes of carbon per hectare for given densities of Erythrinas and timber trees respectively, according to Hergoualch et al. (2012). Consequently, increasing shade tree density has the potential to enhance carbon stocks in coffee plantations, even to a greater extent if timber trees such as Cordia are associated. Accounting for non-$CO_2$ greenhouse gases, the net GHG balance would be improved under large densities of shade trees (Hergoualch et al., 2012), even if leguminous trees such as Erythrinas and Ingas would likely underperform Cordias again, at a given amount of chemical fertilizers and due to their effect on nutrient cycles (Hergoualch et al., 2008). Furthermore, nitrogen losses from fertilizer use through leaching decline with increasing shade tree densities in coffee plantations (Tully, Lawrence, and Scanlon, 2012), hence shade trees could limit contamination of local drinking water supplies and ecosystems (de Jesús Crespo et al., 2016). Again, the assessment of nitrate transfer into local water supplies would likely favour Cordias over Erythrinas (Rosenstock et al., 2014).

As a decrease in the density and in the complexity of the shade cover has been related to a loss of birds and ants richness (Philpott et al., 2008a), shade trees in coffee plantations can contribute to biodiversity conservation, and because of the severe pruning traditionally operated on Erythrinas, an additional shade strata of Cordias would likely preserve more habitats. In addition, the provision of wood products by shaded coffee plantations could reduce the pressure on neighboring forested lands (Vaast et al., 2015) and thus limit anthropogenic disturbances on forests, considering that even in Costa Rica, 13% of the dwellings have walls made of wood and that in the Los Santos coffee region, around 25% of the households still rely on firewood for cooking (INEC, 2011) as well as thousands of seasonal migrants during the harvest season (Bolaños et al., 2008). Lastly, no evidence in the literature refers to improved provision of environmental services by growing hybrid coffee varieties rather than current varieties, except the aforementioned provision of higher coffee yields and potential role in pest and disease control.

## 2.2 Overcoming market failures to support adaptation

Standard economic theory assumes that the decision of whether or not to adopt such adaptive practices depends on the comparison between the utility a farmer expects from the adoption and the expected utilities of the alternative practices. However, market mechanisms may not lead to an optimal decision for either society or for the farmer. On the one hand, since the studied practices if adopted can enhance the available knowledge about their use as well as the provision of aforementioned ecosystem services, the externalities consequent to the public-good nature of these benefits are not well accounted for in the farmer's decision-making, as explained in Chapter 1. As a result, social welfare is not likely to be maximized.

On the second hand, the farmer's decision may reflect the constraints created by local markets imperfections rather than whether or not a farming practice is worthwhile from his/her point of view. In order to meet the conditions of an optimal collective welfare, public intervention may then be required. Economic literature provide relevant findings regarding the public interventions that can adequately address these market inefficiencies issues in developing countries. In this Section, we focus on four instruments likely to support the adoption of the studied adaptive practices: a cash payment (PES-like), in-kind payment (free trial of improved seeds), technical assistance and a subsidized credit facility.

### Cash payment

PES schemes have recently emerged as a Coasean-type solution to align farmers' incentives to provide positive externalities with the demand for the services. They offer a payment to convey private benefits for adopting or maintaining land uses or practices that generate the positive externalities (Engel, Pagiola, and Wunder, 2008; Jack, Kousky, and Sims, 2008). Regarding avoided deforestation, several impact evaluations suggest that PES can induce lower deforestation rates (Honey-Rosés, Baylis, and Ramírez, 2011; Alix-Garcia, Shapiro, and Sims, 2012; Arriagada et al., 2012; Robalino and Pfaff, 2013; Alix-Garcia, Sims, and Yañez-Pagans, 2015; Costedoat et al., 2015; Jayachandran et al., 2017).

Little similar work has been carried out in developing countries on the impact of PES schemes that are conditional on environmental practices in farms. Assessing the impact of such an intervention incentivizing a new tree specie planting, Jack et al. (2015) evidenced that more farmers actually implement the practice in their farm when they are rewarded conditionally on its use.

### In-kind payment

Regarding the provision of local positive externalities similar to pest and disease control, Kremer and Miguel (2007) suggested that a shift from underadoption to a high-adoption equilibrium requires large ongoing subsidies in order to cover for the opportunity cost of adopting rather than free riding on neighbors' control spillovers. Dupas (2014) found that temporary subsidies increase adoption rates among both recipients and their neighbors with a demand highly price-elastic around a zero price, giving credit to free trial periods.

Results in Suri (2011) suggest that addressing constraints on imput market access would alleviate large costs that put a strain on the adoption profitability in remoted areas. By making improved seeds available through door-to-door delivery, Emerick et al. (2016) found that farmers with access to the seeds cultivate more land and displace traditional varieties, they use more fertilizer and improved practices, resulting in increased yields. Studying the impact of a one-time subsidy for fertilizers and improved seeds, Carter, Laajaj, and Yang (2014) found that the voucher receipt induce an increase in short-term adoption and that demand persists over time and generates learning by others.

### Technical assistance

Much public intervention related to input markets consists of agricultural extension services, providing agricultural and farm management knowledge as an input for farmers' activity (Anderson and Feder, 2007). Benefits from agricultural advisory are the greatest in the early stages of a new technology dissemination, when information related to the correct use of the technology is not available such that experimentation costs are the highest and all borne by early adopters. These costs for acquiring information could thus be limited by adequately meeting the demand for learning. Studying the impact of different interventions on the adoption of an improved seed, Emerick and Dar (2017) suggest that simple learning activities can increase the adoption of new but profitable technology. Duflo, Keniston, and Suri (Forthcoming) also evidenced that attending trainings is sufficient to make coffee farmers more likely to implement the practices that are encouraged if the practices are not too labor-intensive. Moreover, strategic delays of adoption would have lower benefits in communities where agricultural extension is not missing so the farmers do not rely on learning from their peers as underlined by Bandiera and Rasul (2006).

### Credit facility

Especially when technology adoption requires large upfront costs, imperfect rural credit markets can prevent farmers from borrowing to invest in a profitable technology. Credit constraints have been found to reduce the adoption of both improved seeds Simtowe, Zeller, and Diagne (2009) and agroforestry systems (Pattanayak et al., 2003; Blackman et al., 2005; Pagiola et al., 2007). Recent studies focused on innovative credit products that are tailored to farmers' needs. Jack (2013a) supported that customizing collateral requirement can reveal a large demand for credit, and Matsumoto, Yamano, and Sserunkuuma (2013); Beaman et al. (2014) found that the availability of a credit product with a repayment schedule adapted to the seasonality of farmers' cash flows can enhance their investments. Moreover, Emerick et al. (2016) evidenced that the adoption of resistant varieties triggers the credit uptake by farmers from existing sources, while increasing production costs through the use of modern input and labor-intensive practices. This result suggests that securing the access to adapted credit products in agriculture could induce that farmers would be able to switch to a high-yield system based on improved input, while the credit supply from existing sources could increase in response to the reduction in production risk.

### Combining interventions

Since technological change involves various market frictions, combining interventions appears as an attractive options for an increased program cost-efficiency by an interplay of effects. Matsumoto, Yamano, and Sserunkuuma (2013) showed that an intervention offering credit sales was more effective on farmers who had received free trials of modern inputs previously. In line with these results, results in Emerick et al. (2016) also signal that once farmers are given access to an improved technology, they tend to take out more loans. Glennerster and Suri (Forthcoming) found that an increase in yields ensues from training coupled to a new variety receipt, whereas farmers who receive the seeds but no the training experienced a small decline in yields.

# 3 The coffee sector in the Los Santos Valley

## 3.1 Agro-climatic characteristics

The study takes place in the Western half of the Los Santos Valley, in Leon Cortes and Tarrazu cantons, Costa Rica. Alongside with Dota canton, the two selected cantons lie on the Pacific side of the Cordillera de Talamanca and share very similar agroclimatic conditions characterized by the influence of the Pacific ocean (relatively low rainfall and a marked dry season) (Coen, 1983), steep slopes and eroded ultisols (Meylan et al., 2013). Arabica coffee is the main crop cultivated, the remaining land uses being extensive pastures or high-altitude forests (de Jesús Crespo et al., 2016), except in Dota canton where around 80% of the area are inside protected areas (SINAC, 2017). Leon Cortes and Tarrazu cantons jointly account for 20% of the national coffee production (Icafé, 2016a). 1,400 small-scale farms has coffee growing on a total of 8,000 hectares of coffee plantations, distributed nearly equally between these two cantons (INEC, 2007).

Farms usually exhibit a shaded monoculture pattern characterized by the association of underdiversified tree species, mainly leguminous trees, with highly productive coffee plants that are sustained by an intensive use of chemical inputs (Castro Tanzi et al., 2012; de Jesús Crespo et al., 2016). As displayed in Table 3.1, a very large majority of local farmers grows Caturra and/or Catuai as coffee variety, under the shade of Erythrinas associated with Musaceaes (banana trees). This agroforestry system has been identified as the most intensive system of shaded coffee plantations in Latin America (Philpott et al., 2008a) and is distributed very homogeneously among the study site compared to other coffee regions in Costa Rica. For instance while Cordia is not used at all as shade tree in the study site, this tree can be found frequently in some coffee farms across the country (see Table 3.1).

## 3.2 Institutional features

The entire local coffee production from the study site is classified as Strictly Hard Beans and one processed, obtains high-quality sensory characteristics so similar and renowned that a common geographical indication certification is upcoming (Avelino et al., 2005; La Nación, 2017). In fact, coffee farmers in the study area are strongly organized in cooperatives, namely CoopeTarrazu as the main one and CoopeLlanoBonito, for the processing of harvested coffee cherries and marketing stages. The cooperatives have been successful in accessing specialty market niches for export, still price risk management (Hazell, 2000) and decisions on farming practices (Snider et al., 2017) belong to the farmers who own their land for almost all of them (see Table 3.1). Farmers often choose to deliver their coffee cherries not exclusively to one cooperative, in a context of competition prevailing between local buyers which include also private firms (Wollni and Fischer, 2015). Besides processing and marketing, the cooperatives provide technical assistance by their agronomists, market and price information and input supplies on credit amongst other services (Wollni and Zeller, 2007), to a lesser extent in CoopeLlanoBonito which is limited by its smaller size (Snider et al., 2017).

In spite of the cooperatives services, the lack of access to knowledge and to some goods and services still concerns 11% of the population in this rural area (INEC, 2011). The closest main Costa Rican cities are about two or three hours away by car. About sources of financing, the study area presents the specificity of a low prevalence of formal credit use (see Table 3.1). Since local farmers rely on seasonal loans from strong and competitive coffee buyers, they may have limited access to larger and longer term credit from financial institutions on the other hand (Carranza, Díaz Porras, and Salazar Rivera, 2010). Formal credit market inefficiencies have been salient during coffee crisis, when coffee farmers underwent a wholesale rejection of their loan applications by banks and 3 farms on 4 had to cope by reducing input use, stopping the renovation of their plantations, selling land and/or limiting household expenditures for consumption (Carranza, Díaz Porras, and Salazar Rivera, 2010; Valenciano Salazar, 2010). Based on this knowledge about local institutions, we hypothesize that some of the coffee farmers from the study site are likely to be constrained in their decision relative to technology adoption by imperfect information and inefficiencies on the markets of credit and inputs that are non traditionally used.

## 3.3 Socioeconomic vulnerability

Because farmers from the study site own small but specialized and intensive farms, their profits are risky and burdened with high production costs. Off-farm work opportunities are limited for the coffee farmers, given that most of them have elementary or no academic education (see Table 3.1) and local employment outside of coffee production is dominated by the service sector (INEC, 2011). The very steep and eroded slopes are likely to generate high production costs and low productivity for annual crops (Pfaff et al., 2009; Ferraro and Hanauer, 2011), leading to the current absence of such crops in local coffee farms (INEC, 2007) and to a considerable barrier to climate change adaptation through diversification of farm activities and/or crop switching. Expanding coffee plantations to higher-altitude land is a very limited alternative as well, insofar as remaining on-farm area is dedicated either to livestock production which is one of the rare suitable diversification strategies, or to forest falling under the 1996 Forest Law that forbids landholders to clear it and restricts timber extraction. Using focus groups in October 2014, incremental adaptation of existing coffee plantations appeared as a consensual response to climate change according to the group of stakeholders from the local coffee sector, whereas in another

Costa Rican coffee region with higher pressure from competing land uses, adaptation strategies that were discussed involved more drastic changes in the agroforestry system including crop switching. Therefore, coffee farmers' preferences for farming practices in the study site are likely to be driven by their expectations in coffee incomes in isolation from their beliefs regarding the returns of competing land uses.

### 3.4 Heterogeneity in mesoclimates and socioeconomic backgrounds

Besides this relative homogeneity in farming context, the study site includes major variability in altitude (from 1,300 to 2,000 meters above sea level), slope and slope exposure that ensures covering a broad range of mesoclimates and therefore, differences in coffee farming practices, as found in previous studies (Castro Tanzi et al., 2012; Meylan et al., 2013; de Jesús Crespo et al., 2016; Bhattarai et al., 2017). In their typology of coffee farming systems in a part of Leon Cortes canton included in our study site, Meylan et al. (2013) characterize four groups different in their practices, using a small sample of 32 farmers and in spite of the apparent homogeneity of the agroecological system.

Furthermore, communities across Leon Cortes and Tarrazu cantons comprise a diversity of socioeconomic backgrounds. In Leon Cortes canton, 60% of the population live in rural areas, poverty incidence is relatively high (27.5% of its population living below the national poverty line) and some communities severely lack access to public infrastructure (INEC, 2011). Tarrazu population is mainly urban, with the service sector employing half of the workforce (INEC, 2011) and offering several financial institutions in the main town. Comparing to Leon Cortes, the average coffee farmer from Tarrazu owns two hectares more land, resulting in one additional hectare dedicated to coffee production. Farms of less than one hectare are twice less frequent than in Leon Cortes; still they represent nearly 10% of coffee farms (INEC, 2007). Hence we expect that the preferences of a sample of local coffee farmers will reflect the heterogeneity in individual and/or local characteristics that are difficult to observe and affect the farmers' choices in farming practices.

## 4 Survey and sample

### 4.1 Data collection

The data collection was carried out by the authors from end of February to mid-May 2016. With guidance and active support from four local organizations - including CoopeLlanoBonito and CoopeTarrazu - we visited 14 different communities across both cantons. We set up one group session of interviews by location to which most of identified coffee farmers from the community have been invited by way of a personal visit to their homestead and communication material, through the week before the session. Each session gathered an average of 15 coffee producers, resulting in a sample of 207 respondents (117 from Leon Cortes and 90 from Tarrazu).

We introduced each session with a presentation of the main scientific results about future trends in temperature and rainfall in the Los Santos Valley. In addition, participants have been told about the agronomic rationale behind the three farming practices we defined previously as adaptive practices, as well as some common knowledge informing of their implementation costs. Each respondent filled an individual questionnaire with reading and writing assistance from an enumerator if he/she requested it. The first section of the questionnaire consisted in a survey collecting information about the household's social characteristics, sources of income, credit access and participation in producers' organizations, land ownership and use, as well as the respondent's past experience and current practices in coffee farming.

## 4.2 Respondents characteristics

Column (3) in Table 3.1 displays some descriptive statistics in order to compare the populations of coffee farmers from the study site with the sampled coffee farmers. It shows that the respondents own farms that are very similar in means to the farms in the study site. In addition, we know that half of the sampled farmers had yet experienced to grow some hybrid coffee plants, mostly from Catimor variety. Nevertheless, most of them have dropped it or to still grow it but not as their main variety. The sampled farmers also declared a proxy of their density of Erythrinas in the coffee plantations, providing a mean of 300 and a median of 180 Erythrinas per hectare. We notice that the sample is composed of a smaller proportion of farmers over 60 years old and relatively large farm owners than in the population of the study site. These main differences likely result from selection due to the sampling process: volunteer respondents may have more time available for social events compared to the mean local farmer. Besides, the sampled farmers seem representative of the local population of coffee farmers.

Our questionnaire also included debriefing questions where the respondents were asked to give their opinion on the studied adaptive practices using Likert scales, as well as to rank their 3 main preoccupations regarding the future of coffee production. Figure 2.1 displays the scores aiming at measuring the importance of the seven main preoccupations cited in the literature regarding the future of local coffee farming and ranked by the sampled farmers. Lower rainfall heads the list under the first-past-the-post method, with 25% of the respondents who declared it as their main preoccupation. The subsequent one is the evolution of coffee sale price, followed by temperature increase, gathering 21% and 18% of the votes respectively. All in all half of the sample declared as their main preoccupation one of the three items directly related to climate change, knowing that higher frequency of extreme climate events represents only 7% of the votes. Taking into account the second and third choices of each respondent through a weighted score, a Borda count establishes that pests and diseases are the predominant preoccupation in the overall sample. This item were declared as one of the 3 main preoccupations by 84% of the respondents. Almost the same share of respondents declared at least one item directly related to climate change within their three main preoccupations. As a result, we assume that a majority of coffee farmers grants importance to direct impacts of climate change

Table 2.1: Description of the coffee farmers from Costa Rica, from the study site and from the sample (means)

| | | (1) Costa Rica | (2) Leon Cortés and Tarrazú cantons | (3) Sample |
|---|---|---|---|---|
| Age | <24 years | 2% | 3% | 17% |
| | 25-59 years | 69% | 75% | 73% |
| | >60 years | 29% | 22% | 10% |
| Female head of household | | | 32% | 28% |
| Academic education | None | 8% | 6% | 3% |
| | Primary | 76% | 82% | 75% |
| | Secondary | 10% | 9% | 14% |
| | Higher | 6% | 3% | 8% |
| Household size (members) | | 3,7 | 4,1 | 4,3 |
| Owned area | | 96% | 99% | 98% |
| Farm area | <1 Ha | 19% | 14% | 26% |
| | 1-5 Ha | 50% | 47% | 52% |
| | 5-10 Ha | 15% | 18% | 12% |
| | >10 Ha | 16% | 21% | 10% |
| Farms without credit | | 51% | 84% | 81% |
| Forest area in the farm (Ha) | | 1 | 1,5 | 0,9 |
| Caturra/catuai coffee variety | | 95% | 100% | 99% |
| Erythrina specie as shade trees | | 77% | 91% | 88% |
| Musaceae species as shade trees | | 58% | 78% | 85% |
| Cordia specie as shade trees | | 8% | 0% | 0% |

Notes: Data in columns (1) and (2) have been compiled from INEC (2007), except for the share of female heads of household found in Alpizar, Carlsson, and Naranjo (2011). Shaded percentages indicate noticeably large differences compared to the previous column.

on coffee production in the long run, with the exception of a higher occurrence of climate extreme events. We also expect that the risk of pests and diseases is likely to represent an underlying trade-off upon technology adoption.

Figure 2.2 tends to confirm that coffee farmers' beliefs about climate changes match the predictions. Respondents also declared that they need to adapt coffee farming to climate change. Hence, respondents are assumed to be well-informed about climate trends and to consider their current practices sub-optimal under future climate conditions. Regarding the three adaptive practices we study, all of them met with the approval of most of the respondents, even if the acceptance of associating Cordia trees was not as unanimous as the ones of increasing shade-tree density and introducing hybrid coffee variety. They all appear as options the respondents would be willing to consider as alternatives to their current practices.

Figure 2.1: Sampled farmers' preoccupations regarding the future of coffee farming

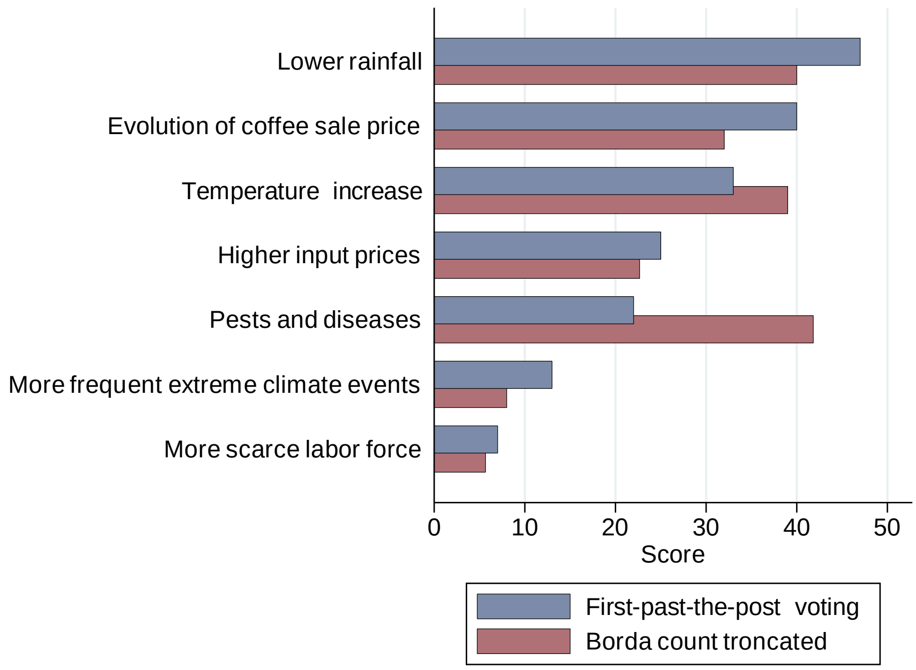
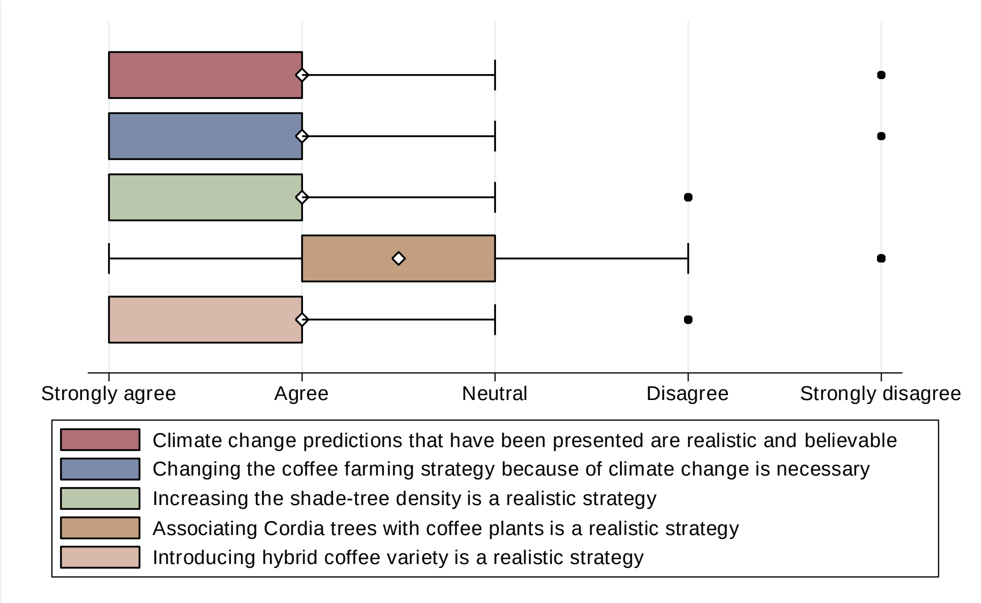


Figure 2.2: Sampled farmers' opinions regarding climate change and the adaptation of coffee farming




# 5 Choice experiment design

A discrete choice experiment was conducted in the second section of the questionnaire. It aims at eliciting respondents' preferences for the adaptive practices we describe in the Section 2, under various hypothetical incentive scheme. Its explanatory statement outlined that a national institution could offer various contracts in which a participant would implement a specific technical requirement in exchange of some rewards; the participant and institution would commit for five years, while the institution would carry out inspections to ensure the enforcement of the contract. The hypothetical contracts offered to the respondents in our CE combine five varying attributes: one attribute settles the technical requirement and four attributes compose the types and levels of the rewards a participant would get. The attributes and levels are displayed in Table 2.2. Table 2.3 gives an example of the choice tasks the respondents performed.

## 5.1 Adaptive strategies attributes

The four strategies from table 2.2 were defined to design an attribute for the technical requirement that is plausible and gradual *a priori*, as well as to limit cognitive burden for the respondents. Thus, we excluded the most unlikely combinations of adaptive practices and forced the hybrid coffee variety to be introduced jointly with at least one another practice in order to provide enhanced carbon capture and storage.

Table 2.2: Hypothetical contract attributes definition

| Attribute variables | Definition | | |
|---|---|---|---|
| One technical requirement amongst: | | | |
| | This attribute mentions one exclusive strategy that a participant would have to implement on his/her coffee plantation (a part or the totality), of four possible required strategies. Each strategy is a combination of 1, 2 or 3 adaptive practices as follow: | | |
| | 1) shade tree density, | 2) shade tree specie | 3) and coffee variety. |
| *Strategy#1* | Double | Current | Current |
| *Strategy#2* | Current | Cordia | Current |
| *Strategy#3* | Double | Current | F1 hybrid |
| *Strategy#4* | Double | Cordia | F1 hybrid |
| From one to four rewards amongst: | | | |
| *Credit facility* | This attribute mentions if a participant would have access to a subsidized credit of 3,000,000 CRC maximum (approx. USD 5,650), per hectare enrolled in the contract (0/1). | | |
| *In-kind payment* | This attribute mentions if a participant would receive 200 F1 hybrid seedlings in the first year of the contract, per hectare enrolled in the contract (0/1). | | |
| *Technical assistance* | This attribute mentions if an agricultural engineer would visit the participants' farms twice during the contract length (0/1). | | |
| *Cash payment* | This attribute sets the amount to be received by a participant, per year and per hectare enrolled in the contract (8 amounts approx. from USD 0 to USD 163). | | |

Note: Shaded texts highlight the adaptive practices we study; current practices were defined as Caturra and/or Catuai for coffee variety, grown under Erythrinas at 200 trees per hectare (see table 3.1).

Current practices were defined as Caturra and/or Catuai for coffee variety, grown under Erythrinas at 200 trees per hectare (see table 3.1).

Doubling shade tree density require a density of 400 trees per hectare if the tree specie is Erythrina (*Strategy#1* and *Strategy#3*), and 100 trees per hectare if it is Cordia (*Strategy#4*). In *Strategy#2* where the density of Cordias is at a current level, only 50 trees are required to meet the shade conditions of a current plantation with 200 Erythrinas, due to the larger foliage of a Cordia. These densities were referred to as the minimum levels a participant would have to implement, without any restriction on other tree species the participant would like to associate in the coffee plantations. F1 hybrids introduction (*Strategy#3* and *Strategy#4*) would require the most drastic change because a participant would have to rehabilitate all coffee plants at once at the beginning of the contract, whereas coffee farmers are used to replace each year only a share of their plants that the farmers select on the grounds of the plants' poor condition. Our concern was to ensure the feasibility of an inspection as the credibility of the enforcement would depend on. In response to the *a priori* high cost of implementation, a participant would be free to engage its coffee plantations either in whole or in part, so the experiment included a question asking the land area the respondent would engage in the preferred contract (see Table 2.3).

## 5.2 Rewards attributes

Regarding the rewards attributes, we chose to study a subsidized credit facility, an in-kind payment, technical assistance and a cash payment, following the hypothesis supported above in this Section according which the coffee farmers from the study site are likely to be constrained in their decision relative to technology adoption by imperfect information and inefficiencies on the markets of credit and inputs that are non traditionally used. We adapted the levels of each reward attribute to the adaptive practices we study.

The *Credit facility* attribute mentions if a participant would have access to a subsidized credit facility of USD 6,000 maximum, per hectare enrolled in the contract. The credit limit corresponds to an estimate of the costs a farmer would handle to renovate one hectare with hybrid seedlings. Respondents have been also informed about its fixed interest rate of 6% which were the Tasa Básica Pasiva [2] during the time of the survey. In addition, the credit facility would not require the subscriber to pledge any collateral or to repay the borrowed amount during the three first years, which correspond to the unproductive period of young coffee plants.

The *In-kind payment* attribute mentions if a participant would receive 200 F1 hybrid seedlings in the first year of the contract, per hectare enrolled in the contract. The hybrid seedlings would be delivered locally and would cover for a mean annual demand for seedlings to progressively replace old and unproductive coffee plants on one hectare.

The *Technical assistance* attribute mentions if an agricultural engineer would visit the participants' farms twice during the contract length, providing personalized support in matters of agricultural issues and contracts paperwork.

Regarding the *Cash payment* attribute, its sets one of 8 amounts which would be received by a participant, per year and per hectare enrolled in the contract (from 0 CRC to 87,500 CRC, approx. from USD 0 to USD 163). The range we used encompasses the cash payments offered to participate in the existing PES scheme covering the coffee sector [3].

2. The Tasa Básica Pasiva of the Central Bank of Costa Rica is a weighted average of the rates applied by financial institutions for saving accounts in CRC. It is used as the base rate for calculating long term loans interest rates in Costa Rica (BCCR, 2008).

3. The FONAFIFO-MINAE *Programa de Pago por Servicios Ambientales* includes a category, namely Coffee Agroforestry Systems, to which coffee farmers with shaded plantations could apply. Each tree would yield around USD 1.7 per tree divided along the 5-year length of the contract, with a upper limit of 250 Cordias and 277 Erythrinas per hectare.

## 5.3 Design

A full factorial design of the attributes generates 288 ($4 \times 3^2 \times 8$) combinations, each being an alternative contract. We reduced the number of choice tasks submitted to the respondents following an efficient design using Bayesian priors. Based on orthogonality, level balance and minimum overlap, the design also balance the utilities of alternative contracts (Huber and Zwerina, 1996). Because no *a priori* values of the utility-parameters were available, the utility balance relied on priors that correspond to the assumptions that 1) the technical requirement attribute is related to a loss in utility compared to business as usual while getting any reward increases utility, 2) *Strategy#4* induces the greatest loss, following by *Strategy#3*, then *Strategy#2* and lastly *Strategy#1*, the utility loss being linear between them, 3) getting the *Credit facility*, the *Technical assistance* or the *In-kind payment* increases utility to the same extent that the maximum level of the *Cash payment* and 4) the sum of gains in utility induced by the midpoints of the 4 rewards attributes compensates for the loss in utility induced by the midpoint of the technical requirement attribute, such that the overall variation in utility is centered at zero. The uncertainty exhibited by the assumed priors were incorporated through the assumption that all priors have random (uniform) distributions rather than fixed values (Sándor and Wedel, 2001). The Bayesian D-error was approximated using quasi random Monte Carlo draws (Halton). Compared to an orthogonal design, this design improves the reliability of the estimates even using distorted estimates as priors, on the grounds of richer information generated when a choice task brings together 2 similar-utility alternatives in competition (Huber and Zwerina, 1996).

Each choice task included also an opt-out alternative, namely a *status quo* option, to ensure consistency with standard utility theory and thus avoid forced choices (Hanley, Mourato, and Wright, 2008). 2 blocks of 8 choice cards were generated, so that each respondent was asked to choose amongst two hypothetical contracts and a *status quo* option 8 times. Table 2.3 provides a selected choice card we used during the experiment. Illustrative logos were used. Each respondent was randomly assigned to one of the 2 blocks and the order of the choice cards within each block was also randomized between individual questionnaires.

From the 207 CE respondents, 11 skipped one of the eight choice cards they were assigned, or one of their choice cards were not filled in legibly. In addition, 2 respondents only answered to 1 of their choice cards. A total of 4893 observations were collected, being the 3 alternatives of 1631 choice cards.

# 6 Econometric framework and model specification

## 6.1 Mixed logit model

Mixed logit models (MXL), also known as random-parameter logit models, were used for the econometric analysis of the choice experiment. Using a logit specification, they model the probability that a decision-maker chooses one of several given alternatives, which depends on parameters that enter the decision-maker's utility func-

Table 2.3: Example of a choice card

| | Option A | Option B | Option C |
|---|---|---|---|
| *Requirement* | Strategy#2 | Strategy#1 | Neither option A, neither option B |
| *Credit facility* | Yes | Yes | |
| *In-kind payment* | Yes | Yes | |
| *Technical assistance* | Yes | No | |
| *Cash payment* | 37,500 CRC | 37,500 CRC | |
| 1. Which option would you prefer? (tick your choice) | [...] | [...] | [...] |
| 2. If you prefer A or B, how much area would you sign up? | | | |

tion. The utility-parameters hence captures marginal utilities of alternatives' modalities. Specifically, MXL estimate the extent to which decision-makers are heterogeneous in their preferences for alternatives' modalities, by specifying the "mixing" distribution of the utility-parameters over the population (Revelt and Train, 1998). If specified as randomly distributed, a utility-parameter on an alternative-specific explanatory variable gets two estimates: 1) a population mean and 2) a standard deviation of the population around that mean resulting from individual stochastic deviations.

Following Train (1998), the utility that a decision-maker $n$ ($n \in \{1, ..., N\}$) obtains from an alternative $j$ ($j \in \{A, B, C\}$) in a choice situation $T$ is:

$$U_{nj} = \beta_n' x_{nj} + \epsilon_{nj} = b' x_{nj} + \eta_n' x_{nj} + \epsilon_{nj} \tag{2.1}$$

where $x_{nj}$ is a vector of observable explanatory variables that includes alternative-specific variables and individual characteristics, $\beta_n^{'}$ is the corresponding vector of utility-parameters for the decision-maker $n$, and $\varrho_{nj}$ is a random term that represents the unobserved component of utility. $\beta_n^{'}$ can be decomposed as the sum of the vector of population means $b^{'}$ and the vector of his/her individual stochastic deviations $\eta_n^{'}$; it represents that decision-maker's taste.

A continuous density function of unobserved $\beta_n$ which varies over the population of decision-makers can be denoted $f(\beta_n|\theta)$ where $\theta$ refers to the parameters of the distribution of $\beta_n$ (such as its mean and covariance). Under the assumption that $\varrho_{nj}$ is IID extreme value Type 1, the MXL probability that the decision-maker $n$ chooses the alternative $i$ in choice situation $t$ is given by the integral of the logistic probability $L_{ni}(\beta_n)$ over all possible values of $\beta_n$, which is:

$$P_{ni}(\theta) = \int L_{ni}(\beta_n) f(\beta_n|\theta)\,\mathrm{d}\beta_n = \int \frac{\exp^{\beta_n' x_{ni}}}{\sum_{j, j \neq i} \exp^{\beta_n' x_{nj}}} f(\beta_n|\theta)\,\mathrm{d}\beta_n \tag{2.2}$$

Because our CE data has a panel structure with eight choice tasks for each sampled decision-maker, we need the probability of each decision-maker's sequence of choices. $i$ becomes $\mathrm{i} = \{i_1, ..., i_8\}$, a sequence of alternatives, one for each choice situation $t$ ($t \in \{1,...,8\}$). Since we assume that the utility-parameters vary over decision-makers but are stable over the CE duration, resulting in $\varrho_{njt}$ being independent over choice situations, the choice probability of sequence i, $L_{nit}(\beta_n)$, is therefore a product of logistic probabilities, one for each choice task $t$. Once the functional form of $f(.)$ is specified, the probabilities are approximated through simulation for any given value of $\theta$, the maximum simulated likelihood estimator being the value of $\theta$ that maximizes the simulated log-likelihood.

## 6.2 Unobserved heterogeneity and correlation issues

When unobserved heterogeneity is a major threat to the assumption of IID random term of utility in multinomial logit models and thus can occasion spurious test results (Louviere, Hensher, and Swait, 2000; Train, 2009), MXL explicitly captures variance and correlations in unobservable factors through $\eta_n$ entering the stochastic portion of utility which is $\eta_n' x_{njt} + \epsilon_{njt}$ (Revelt and Train, 1998).

First, we expect that there are some individual-specific or context-related factors that are unmeasurable and affect the utility obtained by a given alternative from our CE. In their typology of coffee farming systems in a part of Leon Cortes canton included in our study site, Meylan et al. (2013) characterize four groups different in their practices, using a small sample of 32 farmers and in spite of the apparent homogeneity of the agroecological system. According to other studies conducted in the study site, soil chemical properties of the plantations (Castro Tanzi et al., 2012; Bhattarai et al., 2017), as well as the degree of risk aversion and perceptions of income losses due to unpredictable climate extreme events differ strongly amongst the coffee farmers (Alpizar, Carlsson, and Naranjo, 2011). Their findings mean that some individual and/or local variations that are difficult to observe can be related to the decision-makers' past choices in farming practices (Meylan et al., 2013), as well as to their future choices of adaptation to climate change (Alpizar, Carlsson, and Naranjo, 2011). Hence the expected profitability corresponding to the adaptive strategies in our CE would likely depend on these random variations. As a consequence, there would be correlations in utility over alternatives when modeling the take-up of our CE alternatives with farming practices entering $x_{njt}$, violating the IID assumption in a multinomial logit model.

Because of the panel structure of our data, we also expect that these unobserved factors induce correlated errors across each of the decision-makers' repeated choices as mentioned by Hensher and Green (2003). A multinomial logit model could not again handle these correlations, whereas the modeling of individual heterogeneity $\eta_n$ is present in all alternatives across all choice situations in a MXL. Considering decision-makers' intrinsic motivations regarding an environment valuation, Daniels and Hensher (2000) give some empirical evidence suggesting that in a MXL specification, serial correlation over the choice sequence made by each decision-maker may be negligible or absent.

Another correlation issue is expected in our empirical analysis because our CE alternatives include a set of several payments. Revelt and Train (1998) find that the sampled decision-makers who have large utility-parameters for rebates tend also to have large utility-parameters for attractive financing. Such unobserved effects that are correlated amongst alternatives in a given choice situation can be handled in a MXL, because it allows for full correlation between the utility-parameters of each decision-maker (Hensher and Green, 2003). Scale heterogeneity, which is one source of correlation by which the utility-parameters of all variables are larger in magnitude for certain decision-makers than others, is also accounted for in a MXL with full correlation (Hess and Train, 2017).

In fact, MXL is found to approximate any choice model with any distribution of preferences, to any degree of accuracy depending on the choice of variables and mixing distribution (McFadden and Train, 2000). The following discusses the latter issue, presenting the final variables entering the MXL models we estimate along with the distributional specifications of their utility-parameters.

## 6.3 Empirical specification

The choice situation heterogeneity due to the inclusion of a $Status\ Quo$ alternative is controlled in a nested logit approach, through an additional dummy variable coded 1 when the alternative is a contract and labeled $ASC$, namely alternative-specific constant (Train, 2009). The inclusion of the $ASC$ intercept nevertheless gives rise to an identification problem because it simultaneously causes 1) the intercept being the mean effect of all unobserved factors on the utility of any contract, and 2) each of the dummy alternative-specific variables contrasting its utility-parameter with the intercept. Following Adamowicz, Louviere, and Williams (1994), we use effects-coding rather than dummy-coding to let the alternative-specific variables contrasting their utility-parameter with one of its level and thus avoid confounding their effects with $ASC$, with the exception of the continuous variable *Cash payment*. For each effects-coded variable, the reference level is assigned a value of -1, and the pivot value is zero. For instance, a hypothetical contract with no credit, no in-kind payment and no technical assistance offered has all rewards variables set at a -1 value and a $ASC$ at 1, unlike a $Status\ Quo$ alternative which has a zero value for each of these variables and thus its utility is normalized to zero. Regarding how the 4 mutually exclusive adaptive strategies enter the model, we let their effect to be non-linear in spite of our *a priori* order, using 3 effects-coded variables whose effects are interpreted relatively to the reference level being *Strategy#1*.

Therefore the MXL we estimate are specified such that the utility $U_{njt}$ that the decision-maker $n$ derived from alternative $i$ in choice situation $t$ takes the linear form:

$$\begin{aligned} U_{njt} = {} & \beta_0 ASC_{njt} + \beta_2 Strategy\#2_{njt} + \beta_3 Strategy\#3_{njt} + \beta_4 Strategy\#4_{njt} \\ & + \beta_5 Credit_{njt} + \beta_6 Inkind_{njt} + \beta_7 Assistance_{njt} + \beta_8 Cash_{njt} + \epsilon_{njt} \end{aligned}$$

where all the $\beta$s are random and allowed to be correlated with each other over choice situations. $\beta_0$ to $\beta_8$ are free to take either sign, so they are given a normal distributions with mean and standard deviation that are estimated. The mean for the underlying $\beta_1$ associated to *Strategy*#1 equals to $-(\beta_2 + \beta_3 + \beta_4)$ according to the effects-coding we apply.

# 7 Model results

Table 2.4: Mixel logit model estimates of discrete choice regarding each alternative

| | MXL 1 | | | |
|---|---|---|---|---|
| Attributes | Mean (S.E.) | | St.Dev. (S.E.) | |
| *Strategy#1* = Double shade | 0.325 | [a] | - | |
| | - | | - | |
| *Strategy#2* = Cordia | -0.306 | * | 1.040 | *** |
| | (0.180) | | (0.249) | |
| *Strategy#3* = Double shade + Hybrid | 0.396 | ** | 1.457 | *** |
| | (0.209) | | (0.290) | |
| *Strategy#4* = Double shade + Hybrid + Cordia | -0.515 | *** | 1.171 | *** |
| | (0.193) | | (0.319) | |
| *Credit facility* | 0.555 | *** | 0.816 | *** |
| | (0.107) | | (0.147) | |
| *In-kind payment* | 0.220) | *** | 0.362) | ** |
| | (0.080) | | (0.189) | |
| *Technical assistance* | 0.302 | *** | 0.397 | *** |
| | (0.115) | | (0.140) | |
| *Cash payment* (scaled by 1/1,000 CRC) | 0.013 | *** | 0.022 | *** |
| | (0.004] | | (0.004) | |
| *ASC (intercept)* | 0.994 | *** | 4.216 | *** |
| | (0.384) | | (0.453) | |
| N observations | 4893 | | | |
| Simulated log likelihood | -1264 | | | |
| Wald $\chi^2$ | 63.27 | *** | | |
| BIC | 2901 | | | |
| AIC | 2615 | | | |

Note: All variables but Cash payment are effects coded. 2000 Halton draws. Correlated random parameters. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a]: *Strategy#1* coefficient has been obtained by identification as $\beta_1 = -(\beta_2+\beta_3+\beta_4)$.

Results from a mixed logit model are presented in Table 2.4. The model includes the CE attribute variables and estimates their effects on the probability of an alternative to be chosen. It is specified as justified in Section 5. Similar results are obtained from other mixed logit models with marginal modifications in the specification and displayed for comparison in Appendix 2.1 and in Appendix 2.2.

## 7.1 Preference regarding adaptive strategies

Regarding the mean effects of the adaptive strategies we study, the results presented in Table 2.4 indicate that *Strategy#2* and *Strategy#4* significantly decrease the probability of a take-up, whereas *Strategy#3* significantly increases it, compared to *Strategy#1*. The mean utility-parameter of *Strategy#1* is positive, revealing that its effect is not associated with a lower take-up in the CE. When the reference level is switched as in the models in Appendix 2.2, results show that *Strategy#1* does not significantly change the mean choice probability. Furthermore, *Strategy#4* discourages an alternative choice significantly more than *Strategy#2* (see Appendix 2.2). The revealed differences in the expected utilities thus define the preference relations of the mean respondent for the adaptive strategies as *Strategy#3* $\succ$ *Strategy#1* $\succ$ *Strategy#2* $\succ$ *Strategy#4*.

Nevertheless, this preference relations correspond to the mean respondent, whereas the standard deviations are all significant and large, revealing very high heterogeneity in the estimated utility-parameters amongst respondents. From the model in Table 2.4, we observe that a large number of respondents have an opposite sign on their utility-parameters compared to the ones of the mean respondent, with 38% of the sample who associate a loss in expected utility from *Strategy#3* compared to *Strategy#1*, while 29% prefer *Strategy#2* rather than *Strategy#1*, and 27% prefer *Strategy#4* rather than *Strategy#1*.

Besides, the covariance matrices of the models in Appendix 2.2 include some relevant coefficients demonstrating that individual preferences for different attributes are correlated, and explaining the differences in estimates between the model in Table 2.4 and the restricted model with zero correlations in Appendix 2.1 (MXL 1.2). The correlation between the utility-parameters of *Strategy#1* and the *ASC* intercept is significant and large while being the only coefficient between adaptive strategies and *ASC* that is negative. It reflects that the more a respondent is inclined to choose the *Status Quo* option over any contract alternative, the more likely he/she expects a large gain in utility from *Strategy#1*. The opposite occurs on the preferences for *Strategy#3* and the *ASC* intercept, with a significant but positive correlation of their utility-parameters. This result indicates that a respondent who has a propensity to choose any contract alternative over the *Status Quo* option, expects a large gain in utility from *Strategy#3*. Furthermore, the covariance coefficients are significant and negative between the utility-parameters of *Strategy#1* and *Strategy#3* as well as between the ones of *Strategy#1* and *Strategy#4*. Accordingly, the respondents who have a strong taste for *Strategy#1* not only prefer the *Status Quo* option over any contract alternative, they also tend to associate a large loss in expected utility to both *Strategy#3* and *Strategy#4*. Knowing that all adaptive strategies are combining the same 3 practices, an underlying individual taste (or distaste) for hybrid introduction, which is the common requirement of *Strategy#3* and *Strategy#4* that is not shared with *Strategy#1*, may then drive both preferences for *Strategy#3* and *Strategy#4*, with *Strategy#1* mediating the relationship. Regarding the 2 other adaptive practices, we observe that the covariance coefficient between *Strategy#2* and *Strategy#4* is positive but not significant. Thus it does not capture any particular taste for Cordia tree association. Similarly there is no salient taste for increasing the shade tree density which is a practice shared by *Strategy#1*, *Strategy#3* and *Strategy#4*.

## 7.2 Preference regarding rewards

The results show significant and positive utility-parameters estimated for the subsidized-credit facility, the in-kind payment, the technical assistance and the cash payment. Each reward increases the mean probability of a take-up compared to the same alternative without it offered, meaning that each one of them is related to a gain in expected utility so that it has the potential to compensate for a proportional loss. With the exception of the continuous cash payment, the mean preferences for the rewards can be ordered as *Credit facility* ≥ *Technical assistance* ≥ *In-kind payment*.

As for the adaptive strategies, the gains in expected utility associated with the rewards are very heterogeneous amongst respondents, with all standard deviations being significant and large. Unlike the mean respondent, the share of the sample who has a negative utility-parameter for *Credit facility* is 18%, 14% for *In-Kind payment*, 15% for *Technical assistance* and finally, 14% of the sample prefer not to have any cash payment rather than to be offered one. Such a distaste for a reward attribute can be found in other articles. For instance, several Ugandan female coffee farmers in the study by Meemken, Veettil, and Qaim (2017) value as a loss in utility an attribute offering them a credit. Studying the preferences of a sample of Tanzanian farmers, Kaczan, Swallow, and Adamowicz (2013) evidenced that for 21% of them, the mean utility-parameter is zero for an in-kind payment. In the study by Kuhfuss, Preget, and Thoyer (2014), 24% of the sampled French farmers have a negative mean utility-parameter for technical assistance and do not value a cash payment as a gain in utility. Espinosa-Goded, Barreiro-Hurlé, and Ruto (2010) found that 27% of their sample of Spanish farmers has a negative utility-parameter for a cash payment, and 15% of them dislike an attribute offering them more flexibility.

Regarding the covariance matrices in Appendix 2.2, we observe no significant coefficient between rewards utility-parameters. Hence it appears that there is no salient taste pattern in the sample that would make the distributions of the utility-parameters of two different rewards attributes correlated with each other. Accordingly, the fact that some respondents have a negative utility-parameter for one reward attribute does not imply that they are likely to have negative utility-parameters for another reward attribute. If we consider that higher values would be attached to a reward by farmers who are subject to the market constraint targeted, this therefore suggests that the potential market constraints among respondents are randomly distributed. Besides, some significant correlations between the utility-parameters of the rewards attributes and the ones of the adaptive strategies are worth mentioning. The utility-parameters of *Credit facility* are significantly and positively correlated with the utility-parameters of *Strategy#3*. Hence the stronger a respondent's taste for the subsidized-credit facility is, the larger gain from *Strategy#3* he/she expects. Conversely, there may be a negative correlation between the taste for the subsidized-credit facility and the utility-parameters of *Strategy#2*, due to a negative coefficient of which the significance appears to be sensitive to specification. Similar lack of robustness is found on the always positive coefficient between *In-kind payment* and *Strategy#3*.

## 7.3 Preference regarding Status Quo alternative

The mean utility-parameter of the $ASC$ intercept is significant and positive in Table 2.4. The mean estimates for $ASC$ captures the effect on the take-up of all the factors making an hypothetical contract with no attribute different from the *Status Quo* option. In Table 2.4 all rewards variables are effects-coded with the exception of *Cash payment*. In such specification, the adopter of a hypothetical contract with no reward suffer losses in expected utility that are equal to $-(\beta_5 + \beta_6 + \beta_7)$. It is worth noting that the mean value of the utility-parameters for $ASC$ is very close to $(\beta_5 + \beta_6 + \beta_7)$ and become not significantly different from zero when the reward attributes are dummy-coded (see MXL 1.3 in Appendix 2.1). This suggests that the positive effect of $ASC$ only corrects for losses in expected utility due to the coding scheme. We can thus conclude that the mean expected utility of an hypothetical contract with no attribute is not significantly different from the expected utility obtained under the *Status Quo* option. Put differently, there is no Status Quo bias detected for the mean respondent.

Results also show that the standard deviation of the utility-parameters of $ASC$ is significant and very large. Indeed around half of the respondents associate a gain in expected utility to a hypothetical contract with no attribute compared to the *Status Quo* option, whereas the other half value more the *Status Quo* option than the hypothetical contract with no attribute. Also this result is not intuitive, it is quite standard in CE studies using a PES framework (Kaczan, Swallow, and Adamowicz, 2013; Jaeck and Lifran, 2014; Villanueva et al., 2015; Kuhfuss et al., 2016; Costedoat et al., 2016; Jaung et al., 2016; Meemken, Veettil, and Qaim, 2017).

This result can be explained in several ways. First, the CE method is based on hypothetical choice situations so that it could be subject to the yes-saying and/or social desirability bias which would lead the respondents to over-declare some contracts preferred over the *Status Quo* option, to an extent that would be heterogeneous amongst individuals.

Second, a positive effect of $ASC$ could also arise from a demand for attributes that are fixed over the alternatives and not offered on the local market such that the *Status Quo* option reflects a second-best equilibrium (Tesfaye and Brouwer, 2012; Cranford and Mourato, 2014). This is unlikely to be observed in our CE because the fixed attributes we used to frame the CE did not include any valuable good or service consistently offered in every contracts. Nevertheless, knowing that i) for the mean respondent the expected utility of a hypothetical contract with no attribute is similar to the expected utility procured by the *Status Quo* option, while ii) *Strategy#3* is associated with a net gain in expected utility iii) which is, in addition, positively correlated to the respondents' distaste for the *Status Quo* option, the model estimates lead to the conclusion that a hypothetical contract requiring the implementation of *Strategy#3* without any reward would be preferred by the mean respondent over the *Status Quo*. Accordingly, *Strategy#3* appears as a more profitable option than his/her

*Status Quo*. This result signals an unfilled demand for it and thus an inefficiency in local input market to provide the hybrid seedlings, such that farmers may fail to reach their potential.

Third, it may indicate that each respondent has anchored its *Status Quo* option with its current farming practices rather than with the farming practices that are optimal on a longer term [4]. On the same line, the utility-parameter for $ASC$ may capture the difference in expected utility of each respondent's current practices against a common characteristics over the hypothetical contracts, namely the adaptation to global changes through agroforestry. A positive utility-parameter may thus signal that the respondent value his/her current practices as outperformed by any adaptive strategy, indicating a need to shift from current practices to an adaptive strategy, no matter which one of the four suggested in the CE.

## 7.4 Welfare changes associated with attributes

Given the utilitarian interpretation of the $\beta$s, the ratio of two $\beta$s is simply the marginal rate of substitution of one attribute for the other. The ratio of the parameter of an attribute over the parameter associated with *Cash payment* is therefore a measure of the marginal change in welfare of that attribute expressed as a monetary value, and usually called marginal willingness-to-pay (MWTP). Positive values indicates that the respondents value the attribute enough to trade an amount of money off for it, whereas negative values signal that the respondents would not willingly accept the attribute without some form of incentive. The simplest and most common approach to calculate MWTP is to rely on the mean on the random parameters. Using all of the information associated with the random parameter is preferable, such simulations can however generate larger confidence intervals. Due to the coding scheme of all attribute variables but *Cash payment*, the estimates obtained have to be doubled to get the whole MWTP, no matter the method used. Results from both methods are presented in Table 2.5.

The MWTP estimates indicate that respondents are willing to pay on average 75,837 CRC (USD 143) per hectare and per year to adopt *Strategy#3*. Conversely, they do not consider that *Strategy#2* would improve their welfare, such that its adoption requires a financial support of 46,740 CRC (USD 88) per hectare and per year on average. *Strategy#4* is much more unfavorable, with a MWTP at -78,718 CRC (USD -148) on average. Respondents are estimated to be willing to pay on average 84,926 CRC (USD 160) for the credit facility, 33,624 CRC (USD 63) for the free trial of resistant coffee seedlings, and 46,176 CRC (USD 87) for technical assistance, per hectare and per year. These amounts are all very large and could cover for the support required for *Strategy#2* and *Strategy#4* to be adopted.

---

4. A choice between an hypothetical contract and the *Status Quo* option is suppose to be driven by the difference in expected utility for a time horizon covering at least the 5 years of the contract duration and even longer if the respondents take into account the durable effect of the technical requirement on a perennial plantation.

Table 2.5: Mean marginal willingness to pay for attributes (in CRC)

| | MWTP[a] | [95% C.I.] | Simulated MWTP[b] | [95% C.I.] |
|---|---|---|---|---|
| *Strategy#2* | -46,740 | [-107,439; 13,958] | -46,740 | [-141,692; 9,273] |
| *Strategy#3* | 75,837 | [-3,861; 155,535] | 75,837 | [11,702; 218,626] |
| *Strategy#4* | -78,718 | [-128,920; -28,516] | -78,718 | [-149,660; -26,848] |
| *Credit facility* | 84,926 | [30,525; 139,327] | 84,926 | [45,989; 196,973] |
| *In-kind payment* | 33,624 | [6,983; 60,265] | 33,624 | [9,806; 78,444] |
| *Technical assistance* | 46,176 | [14,206; 78,145] | 46,176 | [14,579; 91,831] |

[a]: Estimated via Delta method.
[b]: Estimated via Krinsky-Robb method, 10,000 replications.

# 8 Conclusion

In this Chapter, we used primary data from a choice experiment carried out with 207 coffee farmers in Costa Rica, in order to study their willingness to adopt various agroforestry systems under various types of support. Based on the assumption that improving risk management within agroforestry systems could reduce the opportunity cost of adopting the technology, the agroforestry systems studied included resistant coffee varieties and/or timber trees, *a priori* attractive options as part of risk-coping strategies that may better fit within local farming contexts. Revealed preferences suggest that most of the respondents do value the introduction of resistant varieties. In particular, they are willing to plant twice the number of trees in their plantations when these are combined with resistant varieties. The farmers were found to be willing to adopt this agroforestry-based system. Conversely, all agroforestry systems requiring timber trees to be planted are chosen significantly less often and on average, their adoption would require a compensation scheme. This compensation may be explained by the high level of carbon sequestration associated with timber trees. Our result therefore suggest that the choice of the technological package to be promoted is a central point for the cost-efficiency of climate change policies based on incentives.

Concomitantly, the study investigated the potential of three incentives to trigger a decision to adapt to climate change through agroforestry: the use of a subsidized credit, a free trial of resistant coffee seedlings and technical assistance. The results moreover showed that a large majority of respondents attach large monetary values to a contract offering a cash payment, a subsidized credit, a free trial of resistant coffee plants or technical assistance. Results also indicate that respondents who display a strong taste for the agroforestry system that combines resistant varieties also tend to be very responsive to the credit offer. This suggests that the adoption of such systems may therefore require enhanced access to financing. We did not however find any correlation patterns between the preferences for the three incentives. Since a farmer with a strong preference for one reward will not systematically be included in the subset of farmers attaching a high value to another type of incentive, a larger pool of PES participants would be expected under an intervention that combines several types of incentives.

# Appendices

## 2.1 Sensitivity to alternative MXL specifications

| | | MXL 1.1 | MXL 1.2 | MXL 1.3 | MXL1.4 | MXL 1 |
|---|---|---|---|---|---|---|
| Mean | *Strategy#1* | 0.290[A] | 0.133[A] | 0.404[A] | 0.325[A] | 0.325[A] |
| | | - | - | - | - | - |
| | *Strategy#2* | -0.299* | -0.178 | -0.321* | -0.306* | -0.306* |
| | | (0.168) | (0.160) | (0.177) | (0.174) | (0.180) |
| | *Strategy#3* | 0.431** | 0.342** | 0.457** | 0.496** | 0.496** |
| | | (0.180) | (0.162) | (0.186) | (0.201) | (0.209) |
| | *Strategy#4* | -0.422** | -0.297* | -0.541*** | -0.515*** | -0.515*** |
| | | (0.185) | (0.163) | (0.195) | (0.190) | (0.193) |
| | *Credit facility* | 0.483** | 0.545*** | 1.060*** | 0.555*** | 0.555*** |
| | | (0.096) | (0.087) | (0.207) | (0.099) | (0.107) |
| | *In-kind payment* | 0.206*** | 0.231*** | 0.428*** | 0.220*** | 0.220*** |
| | | (0.074) | (0.069) | (0.162) | (0.077) | (0.080) |
| | *Technical assistance* | 0.271*** | 0.272*** | 0.661*** | 0.302*** | 0.302*** |
| | | (0.100) | (0.088) | (0.220) | (0.107) | (0.115) |
| | *Cash payment* | 0.111*** | 0.011*** | 0.014*** | 0.013*** | 0.013*** |
| | | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) |
| | ASC (intercept) | 1.041** | 1.153*** | -0.318 | 0.994** | 0.994*** |
| | | (0.431) | (0.418) | (0.463) | (0.398) | (0.384) |
| St.Dev. | *Strategy#2* | 1.049*** | 1.062*** | 1.021*** | 1.047*** | 1.040*** |
| | | (0.200) | (0.197) | (0.240) | (0.248) | (0.249) |
| | *Strategy#3* | 1.334*** | 1.307*** | 1.369*** | 1.529*** | 1.457*** |
| | | (0.264) | (0.224) | (0.332) | (0.318) | (0.290) |
| | *Strategy#4* | 0.997*** | 1.111*** | 1.130*** | 1.107*** | 1.171*** |
| | | (0.198) | (0.204) | (0.248) | (0.270) | (0.319) |
| | *Credit facility* | 0.694*** | 0.736*** | 1.527*** | 0.810*** | 0.816*** |
| | | (0.124) | (0.110) | (0.242) | (0.116) | (0.147) |
| | *In-kind payment* | 0.304** | 0.358*** | 0.761*** | 0.388*** | 0.362** |
| | | (0.123) | (0.131) | (0.230) | (0.121) | (0.189) |
| | *Technical assistance* | 0.318** | 0.316* | 1.017*** | 0.470*** | 0.397*** |
| | | (0.158) | (0.170) | (0.338) | (0.156) | (0.140) |
| | *Cash payment* | - | 0.018*** | 0.019*** | 0.024*** | 0.022*** |
| | | - | (0.004) | (0.004) | (0.004) | (0.004) |
| | ASC (intercept) | 4.122*** | 4.216*** | 4.471*** | 4.693*** | 4.216*** |
| | | (0.452) | (0.453) | (0.684) | (0.567) | (0.453) |
| | N observations | 4893 | 4893 | 4893 | 4893 | 4893 |
| | Simulated log likelihood | -1270 | -1281 | -1264 | -1264 | -1264 |
| | Wald $\chi^2$ (LR $\chi^2$ in MXL 1.4) | 59.42*** | 69.60*** | 63.00*** | 877.93*** | 63.27*** |
| | BIC | 2847 | 2699 | 2902 | 2901 | 2901 |
| | AIC | 2613 | 2595 | 2616 | 2615 | 2615 |
| | Fixed parameters | *Cash payment* | None | None | None | None |
| | All parameters correlated | Yes | No | Yes | Yes | Yes |
| | Reward attributes coding | Effects | Effects | Dummies | Effects | Effects |
| | Robust S.E. correction | Yes | Yes | Yes | No | Yes |

Note: 2000 Halton draws. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[A]: *Strategy#1* coefficient has been obtained by identification as $\beta_1 = -(\beta_2 + \beta_3 + \beta_4)$.

## 2.2 Sensitivity to the reference level for Technical requirement

| | | MXL 1 | MXL 2 | MXL 3 | MXL 4 |
|---|---|---|---|---|---|
| Mean | *Strategy#1* | 0.325[A] | 0.286 | 0.299 | 0.281 |
| | | - | (0.236) | (0.246) | (0.249) |
| | *Strategy#2* | -0.306* | -0.312[A] | -0.309* | -0.320* |
| | | (0.180) | - | (0.182) | (0.188) |
| | *Strategy#3* | 0.496** | 0.514*** | 0.500[A] | 0.505** |
| | | (0.209) | (0.200) | - | (0.207) |
| | *Strategy#4* | -0.515*** | -0.486** | -0.490** | -0.466[A] |
| | | (0.193) | (0.201) | (0.210) | - |
| | *Credit facility* | 0.555*** | 0.525*** | 0.519*** | 0.513*** |
| | | (0.107) | (0.102) | (0.115) | (0.097) |
| | *In-kind payment* | 0.220*** | 0.214*** | 0.222*** | 0.217*** |
| | | (0.080) | (0.075) | (0.086) | (0.077) |
| | *Technical assistance* | 0.302*** | 0.297*** | 0.297** | 0.293*** |
| | | (0.115) | (0.110) | (0.130) | (0.110) |
| | *Cash payment* | 0.013*** | 0.013*** | 0.013*** | 0.013*** |
| | | (0.004) | (0.004) | (0.004) | (0.004) |
| | *ASC (intercept)* | 0.994*** | 1.114*** | 1.049** | 1.164*** |
| | | (0.384) | (0.407) | (0.472) | (0.452) |
| St.Dev. | *Strategy#1* | - | 1.888*** | 1.945*** | 1.886*** |
| | | - | (0.407) | (0.448) | (0.363) |
| | *Strategy#2* | 1.040*** | - | 0.944*** | 1.021*** |
| | | (0.249) | - | (0.269) | (0.231) |
| | *Strategy#3* | 1.457*** | 1.417*** | - | 1.443*** |
| | | (0.290) | (0.297) | - | (0.296) |
| | *Strategy#4* | 1.171*** | 1.061*** | 1.188*** | - |
| | | (0.319) | (0.335) | (0.299) | - |
| | *Credit facility* | 0.816*** | 0.756*** | 0.796*** | 0.742*** |
| | | (0.147) | (0.112) | (0.157) | (0.126) |
| | *In-kind payment* | 0.362** | 0.350*** | 0.317** | 0.347*** |
| | | (0.189) | (0.112) | (0.153) | (0.117) |
| | *Technical assistance* | 0.397*** | 0.411*** | 0.401** | 0.412*** |
| | | (0.140) | (0.126) | (0.166) | (0.150) |
| | *Cash payment* | 0.022*** | 0.021*** | 0.023*** | 0.022*** |
| | | (0.004) | (0.004) | (0.006) | (0.005) |
| | ASC (intercept) | 4.216*** | 4.660*** | 4.525*** | 4.609*** |
| | | (0.453) | (0.548) | (0.557) | (0.550) |
| | N observations | 4893 | 4893 | 4893 | 4893 |
| | Simulated log likelihood | -1264 | -1264 | -1265 | -1265 |
| | Wald $\chi^2$ | 63.27*** | 60.89*** | 41.60*** | 64.79*** |
| | BIC | 2901 | 2901 | 2903 | 2902 |
| | AIC | 2615 | 2615 | 2618 | 2616 |
| | Reference level for Technical requirement attribute | Strategy#1 | Strategy#2 | Strategy#3 | Strategy#4 |

Note: All variables but Cash payment are effects coded. 2000 Halton draws. Correlated random parameters. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
[A]: the reference level coefficient has been obtained by identification as $\beta_1 = -(\beta_2 + \beta_3 + \beta_4)$ for instance for *Strategy#1* coefficient in MXL 1.

Covariance matrices from Mixed logit models in the previous table

| MXL 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Strategy#1* | *Strategy#3* | *Strategy#4* | *Credit facility* | *In-kind payment* | *Technical assistance* | *Cash payment* | *ASC* |
| *Strategy#1* | 3.566** | | | | | | | |
| | (1.537) | | | | | | | |
| *Strategy#3* | -1.344* | 2.009** | | | | | | |
| | (0.708) | (0.842) | | | | | | |
| *Strategy#4* | -1.442* | -0.008 | 1.126 | | | | | |
| | (0.870) | (0.442) | (0.710) | | | | | |
| *Credit facility* | -0.373 | 0.777*** | -0.082 | 0.571*** | | | | |
| | (0.308) | (0.246) | (0.198) | (0.178) | | | | |
| *In-kind payment* | -0.110 | 0.286* | 0.021 | -0.006 | 0.122 | | | |
| | (0.199) | (0.171) | (0.137) | (0.082) | (0.078) | | | |
| *Technical assistance* | -0.231 | 0.260 | 0.049 | 0.100 | 0.060 | 0.169 | | |
| | (0.247) | (0.216) | (0.139) | (0.092 | | (0.052) | (0.103) | |
| *Cash payment* | 0.015 | -0.007 | -0.004 | -0.003 | 0.001 | 0.004 | 0.000** | |
| | (0.013) | (0.008) | (0.007) | (0.004) | (0.003) | (0.003) | (0.000) | |
| *ASC* | -4.660** | 2.234* | 1.185 | 0.911 | 0.213 | 0.288 | -0.028 | 21.711 *** |
| | (2.063) | (1.294) | (1.409) | (0.624) | (0.452) | (0.626) | (0.626) | (5.106) |

| | MXL 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Strategy#1* | *Strategy#2* | *Strategy#4* | *Credit facility* | *In-kind payment* | *Technical assistance* | *Cash payment* | *ASC* |
| *Strategy#1* | 3.784** | | | | | | | |
| | (1.742) | | | | | | | |
| *Strategy#2* | -0.709 | | 0.892* | | | | | |
| | (0.542) | (0.507) | | | | | | |
| *Strategy#4* | -1.799* | 0.457 | | 1.410** | | | | |
| | (1.052) | (0.349) | (0.710) | | | | | |
| *Credit facility* | -0.212 | -0.431* | 0.052 | 0.633** | | | | |
| | (0.460) | (0.226) | (0.264) | (0.249) | | | | |
| *In-kind payment* | -0.215 | -0.094 | 0.017 | -0.038 | 0.100 | | | |
| | (0.252) | (0.125) | (0.234) | (0.094) | (0.097) | | | |
| *Technical assistance* | -0.233 | -0.080 | -0.014 | 0.122 | 0.018 | 0.161 | | |
| | (0.267) | (0.151) | (0.160) | (0.147) | (0.076) | (0.133) | | |
| *Cash payment* | 0.017 | -0.007 | -0.010 | -0.004 | 0.001 | 0.004 | 0.001* | |
| | (0.017) | (0.005) | (0.009) | (0.006) | (0.004) | (0.003) | (0.000) | |
| *ASC* | -4.709** | 1.259 | 1.564 | 0.844 | 0.088 | 0.144 | -0.035 | 20.476 *** |
| | (2.377) | (1.273) | (1.706) | (0.727) | (0.457) | (0.591) | (0.032) | (5.044) |

| | MXL 4 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Strategy#1* | *Strategy#2* | *Strategy#3* | *Credit facility* | *In-kind payment* | *Technical assistance* | *Cash payment* | *ASC* |
| *Strategy#1* | 3.557*** | | | | | | | |
| | (1.370) | | | | | | | |
| *Strategy#2* | -0.619 | 1.043** | | | | | | |
| | (0.567) | (0.473) | | | | | | |
| *Strategy#3* | -1.428* | -0.754 | 3.083** | | | | | |
| | (0.742) | (0.516) | (0.854) | | | | | |
| *Credit facility* | -0.358 | -0.344 | 0.787*** | 0.551*** | | | | |
| | (0.356) | (0.213) | (0.288) | (0.187) | | | | |
| *In-kind payment* | -0.066 | -0.167 | 0.251 | -0.010 | 0.120 | | | |
| | (0.193) | (0.120) | (0.208) | (0.090) | (0.081) | | | |
| *Technical assistance* | -0.169 | 0.013 | 0.184 | 0.090 | 0.067 | 0.170 | | |
| | (0.271) | (0.138) | (0.208) | (0.101) | (0.073) | (0.124) | | |
| *Cash payment* | 0.155 | -0.003 | -0.010 | 0.120 | 0.002 | 0.005 | 0.000** | |
| | (0.013) | (0.004) | (0.010) | (0.081) | (0.003) | (0.003) | 0.000 | |
| *ASC* | -4.456** | 1.099 | 2.348* | 0.826 | 0.127 | 0.261 | -0.028 | 21.245*** |
| | (2.045) | (1.243) | (1.214) | (0.642) | (0.464) | (0.611) | (0.028) | (5.068) |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

# CEE-M Working Papers[1] - 2020

| | |
|---|---|
| WP 2020 - 01 | Francisco Cabo & **Mabel Tidball**<br>« Cooperation in a dynamic setting with asymmetric environmental valuation and responsibility » |
| WP 2020 - 02 | **Mathias Berthod**<br>« Commitment and efficiency-inducing tax and subsidy scheme in the development of a clean technology » |
| WP 2020 - 03 | Manon Authelet, **Julie Subervie**, Patrick Meyfroidt, Nigel Asquith & Driss Ezzine-de-Blas<br>« Economic, Pro-social and Pro-environmental Factors Influencing Participation in an Incentive-based Conservation Program in Bolivia » |
| WP 2020 - 04 | Lesly Cassin  Paolo Melindi Ghidi & **Fabien Prieur**<br>« Confronting climate change: Adaptation vs. migration strategies in Small Island Developing States » |
| WP 2020 - 05 | Victor Champonnois, & **Katrin Erdlenbruch**<br>« Willingness of households to reduce  ood risk in southern France » |
| WP 2020 - 06 | Sophie Clot, **Gilles Grolleau** & **Lisette Ibanez**<br>« The Reference Point Bias in Judging Cheaters » |
| WP 2020 - 07 | Jean-Marc Blazy, **Julie Subervie**, Jacky Paul, François Causeret, Loic Guindé, Sarah Moulla, Alban Thomas & Jorge Sierra<br>« Ex ante assessment of the cost-effectiveness of Agri-Environmental Schemes promoting compost use to sequester carbon in soils in Guadeloupe» |
| WP 2020 - 08 | Sophie Clot, Gilles grolleau & **Lisette Ibanez**<br>« Projection bias in environmental attitudes and behavioral intentions » |
| WP 2020-09 | **Annaïs Lamour** & **Julie Subervie**<br>« Achieving Mitigation and Adaptation to Climate Change through Coffee Agroforestry: A Choice Experiment Study in Costa Rica » |

[1] **CEE-M Working Papers / Contact** : laurent.garnier@inra.fr

- RePEc https://ideas.repec.org/s/hal/wpceem.html
- HAL https://halshs.archives-ouvertes.fr/CEE-M-WP/