Designing REDD+ Schemes to Address Permanence Concerns:

Empirical Evidence from Kenya

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Summary

Reducing Emissions from Deforestation and Forest Degradation (REDD+) is an important topic in the debate on policies to mitigate climate change. This is the first study to test and compare the environmental impact of different REDD+ payment schemes in the field, and provide some insights on the effectiveness of different policies with respect to the permanence of forest-based emission reductions. This study implements a stated preference experiment of time allocation in the unique setting of the Kasigau Corridor REDD+ Project in Kenya, where charcoaling is a major source of forest degradation. The impact on time allocation is analyzed under the presumption that a hypothetical agricultural policy or an eco-charcoaling policy was introduced. We find that a policy that indexes eco-charcoal payments to charcoalers' opportunity costs is the most effective policy in providing permanence in REDD+: it lowers the amount of labor allocated to charcoaling even at high charcoal prices.

Keywords: REDD, permanence, deforestation, labor, Kenya.

JEL Classification codes: I38, J22, O13, Q18, Q23, Q28, Q56.

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1. INTRODUCTION

Deforestation and forest degradation are responsible for nearly a fifth of global greenhouse gas emissions (Watson et al., 2000; Baumert et al., 2005; IPCC, 2007). Reducing Emissions from Deforestation and Forest Degradation (REDD+) has been proposed as policy measure to prevent or slow deforestation and degradation, and safeguard or increase forest carbon (Börner and Wunder, 2008; Groom and Palmer, 2012). The policy sets a framework for an exchange of benefits, monetary or other, for guarantees to maintain wooded areas that otherwise would be deforested or degraded.

In many cases, the forests at stake were not previously exploited commercially, but owners may have tolerated some degree of subsistence usage through local people. Once enrolled in a REDD+ program, use of the forest by local people, for example for charcoaling, could become a risk to the newly-valuable trees. This situation calls for accompanying measures, which will prevent locals from using the forest in any way that is detrimental to REDD+ goals. However, there are equity concerns that crude fences-and-fines policies to protect REDD+ forests could jeopardize local peoples' livelihoods, and in extreme cases, turn them into 'REDD refugees' (Ghazoul et al., 2010; IUCN, 2010). Ideally, accompanying policies should thus account for restrictions on accustomed forest uses that impair locals' livelihoods (Chhatre and Agrawal, 2009; Palmer and Silber, 2010). In addition, as up to 800 million people worldwide are estimated to be dependent on such forests for their livelihoods (Chomitz et al., 2006; World Resources Institute, 2005), it has been argued that poverty reduction should be incorporated as a 'co-benefit' of REDD+ policy (Brown et al., 2009).

This study contributes to the debate by assessing policies that create alternative livelihood options for people around REDD+ forests. However, when investigating such alternatives, it is important to keep in mind that prices in developing countries are often volatile and households myopic. In the light of growing world food demand, promotion of biofuels, and resulting increases in agricultural commodity prices, the opportunity costs of forest conservation may well increase over time and induce landowners to breach REDD+ contracts (Butler et al., 2009). Creating permanence of forest-based emission reductions under these conditions can be challenging.

Permanence has been a key issue for the design of REDD+ payments (Dutschke and Angelsen, 2008) but it is of equal importance for the design of accompanying policies for people around REDD+ forests. Very few studies exist on how REDD+ scheme design may help promote permanence, and they mostly focus on the allocation of liability between buyers and sellers of REDD credits (Dutschke and Wong, 2003; Dutschke and Angelsen, 2008). Benítez et al. (2006) and Dutschke and Angelsen (2008) propose indexing conservation payments to agricultural commodity prices. However, to the best of our knowledge, no empirical studies exist that test this approach in the field.**1**

In this paper, we compare different policy scenarios that could serve as accompanying measures to REDD+ schemes, and could help ensure permanence. In particular, we consider a cash-crop agricultural policy that aims at diverting labor away from forest use into agricultural production, and a policy that allows for the production of REDD+-friendly eco-charcoal. Under an eco-charcoal policy, a household can collect scrap wood within or around forest grounds and sell it to an eco-charcoal factory. In our setting the destructive activity is charcoaling, and thus the opportunity cost of forest conservation is given by the price of charcoal. We investigate three different modalities of setting the price for scrap wood: (i) a fixed price independent of the charcoal price; (ii) an indexed price, i.e., the price of scrap wood is set equal to a percentage of the charcoal price; and (iii) an indexed price that is a percentage of the charcoal price but also conditional on the level of forest use. While all three eco-charcoal scenarios can be seen as a type of payment for environmental services by some broader definitions, only the third satisfies conditionality in a stricter sense (e.g., Engel et al., 2008).**2**

The comparison of these policies allows us to investigate (i) how effective the proposed policies are in terms of reducing charcoaling, and hence forest degradation. In particular, how does an eco-charcoal policy compare to a cash-crop agricultural policy? (ii) How different payment designs compare to each other, and (iii) what is the most effective policy in providing permanence in REDD+ when the price of charcoal increases. Is a policy that indexes eco-charcoal payments to charcoalers' opportunity costs more effective than a standard policy with fixed payments? To the best of our knowledge, this is the first study that compares the effectiveness of different REDD+ payment schemes in the field, and provides some insights on the effectiveness of different policies with respect to the permanence of forest-based emission reductions.

We begin by theoretically modelling households' labor allocation decisions under the aforementioned policies. We then apply the model to a unique case study: the Kasigau Corridor REDD+ Project in Kenya, which is the first REDD+ project ever to issue carbon credits under an internationally accepted standard (Peters-Stanley et al., 2011). In our case study, the forest owners receive REDD+ payments leaving them content to conserve the trees. However, the forest is flanked by settlings of low-income people who have no formal property rights to the forest, but have exercised customary rights for many years felling trees to produce charcoal.

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[1] Engel et al. (2011) use real options theory to model land users' decisions to convert forest to agriculture in the face of uncertainty in agricultural commodity prices. They use secondary data from Brazil to simulate payment amounts required to induce a 90% probability of permanent emission reductions under three alternative scheme designs: a constant per hectare payment, a payment linked to an agricultural commodity index, and a payment linked to the international carbon market price. The analysis of policy scenarios not linked to opportunity costs also relates to a broader literature on the impacts of alternative income opportunities on damaging activities. For example, Bluffstone (1995) simulates the effect of off-farm labor market conditions on deforestation in Nepal, and finds that off-farm opportunities are important determinants for the equilibrium of forest stock levels. Shively (2001) uses data from the Philippines, and shows that low land irrigation development led to an increase in labor demand, an increase in employment of upland inhabitants, and small but statistically significant reductions in forest clearing rates. Shively and Pagiola (2004) investigate the impact of agricultural intensification on deforestation in the Philippines. They find that off-farm employment opportunities created by irrigation development lead to a reduction in forest clearing. In addition, our analysis relates to the literature comparing integrated conservation and development programs (ICDPs) to more conditional approaches like payments for environmental services (e.g., Ferraro and Kiss, 2002; Ferraro and Simpson, 2002; Muller and Albers, 2004).

[2] In a broader sense, conditionality may still be given in the sense that the payments from the final buyer of verified carbon credits are conditional on the state of the forest. Thus, the level of subsidies for eco-charcoaling that an implementing agency can pay still depends on the state of the forest.

We implement a stated preference experiment of time allocation in different activities (specifically, agriculture, firewood collection, charcoaling, scrap wood collection, and 'other' activities). The sample consists of 1,095 households living adjacent to the Kasigau Corridor REDD+ project. First, we collect information on their current time allocation, and then, under the presumption that the agricultural and eco-charcoal policies were implemented. Charcoal prices were randomly assigned to allow for an investigation of permanence questions. Comparing the status quo labor allocation to that of the policy scenarios allows us to answer our research questions.

Though results could be questioned for being based on hypothetical self-reported time allocation, the use of stated preference experiments has been applied in many areas of economics to test the effects of multiple policy scenarios, an objective that is commonly very difficult to achieve with revealed preference data.**3** Stated preference experiments are also particularly useful to assess the long term impact of policies that cannot be assessed other than by implementing randomized control trials that cover short-to-medium term periods. In addition, an advantage of the estimation procedure applied in this study is that the randomly assigned policies and charcoal prices are independent of household and individual characteristics. This implies that our estimates are not suffering from endogeneity bias. Furthermore, any systematic tendency for respondents to misstate their time allocation is treated as an individual-specific error that is unrelated to prices and policies, thus yielding unbiased results.

Results meet theoretical expectations, and are robust to different specifications. Our main findings are that while both the agricultural policy and the eco-charcoal policy significantly decrease the amount of time allocated to charcoaling, the implementation of the eco-charcoal policy has a larger effect. In terms of providing permanence, we find that indexing eco-charcoal payments to charcoalers' opportunity costs is the most effective policy, resulting in a significant decrease in time spent charcoaling even at high charcoal prices. On the contrary, when a cash-crop agricultural policy that promotes a little labor-intensive crop is implemented, or the payments are fixed, forest users go back to charcoaling at high charcoal prices.

The paper is organized as follows. Section 2 presents a simple theoretical model; sections 3 and 4 describe the case study, the experimental design, and the data; section 5 presents the econometric model, and section 6 the results. Section 7 concludes, highlighting policy implications, and directions for future research.

2. THEORETICAL MODEL

We develop a static utility maximization model to assess how rural households living close to the forest change their time allocated to charcoaling under different policies. First, a status quo scenario absent of any policies is set up. In a next step, an agricultural policy and eco-charcoal policies with three different pricing regimes are added one at a time. The structure of the model builds on classic household models (Singh et al., 1986) and borrows from a model on labor allocation and forest use by Fisher et al. (2005).

In our model, utility is a well-behaved function of consumption goods (G_i), and household characteristics, (Z). The household can produce and consume a composite agricultural good, (G_A), firewood, (G_F), charcoal, (G_C), and 'other' goods including leisure, (G_O). In the status quo, the household maximizes its utility subject to production functions [1]-[4], household income [7], time constraint [8], and non-negativity constraint [9]:

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[3] Examples of stated preference studies in the development, health, and environmental economics literature include Cropper et al. (2004), Cameron (2005), Kanninnen, (2007), Bosworth et al. (2008), Grosjean and Kontoleon (2009), Bosworth et al. (2010), and Ibanez and Carlsson (2010) among others.

$$\max_{L_i,G_i,X_A} U(G_i,Z) \quad , i = A,F,C,O \quad \text{s.t. [1]-[4], [7]-[9]}$$

where we define

Agricultural products $Q_A = Q_A[L_A, X_A, H_A]$ [1]
Firewood collection $Q_F = Q_F[L_F, D_F]$ [2]
Charcoal collection $Q_C = Q_C[L_C, D_F]$ [3]
Production of other goods $Q_O = Q_O[L_O]$ [4]
Agricultural products including jojoba $Q_{AJ} = Q_{AJ}[L_{AJ}, X_{AJ}, H_A]$ [5]
Scrap wood collection $Q_E = Q_E[L_E, D_F]$ [6]
Household income $Y^{statusquo} = \sum_{i,i=A,F,C,O} p_i Q_i - \sum_{i,i=A,F,C,O} p_i G_i - p_{XA} X_A$, [7]
Time constraint status quo $\bar{L} = \sum_{i,i=A,F,C,O} L_i$ [8]
Non-negativity constraint $G_i, Q_i, L_i, X_A, X_{AJ} \geq 0$ [9]

Agricultural produce [1] is a function of the amount of labor the household invests in agricultural production (L_A), inputs (X_A), and the household's agricultural characteristics such as land holding (H_A). By assumption, agricultural produce is concave in labor $(Q_A'(L_A) > 0,\ Q_A''(L_A) < 0)$ and inputs $(Q_A'(X_A) > 0,\ Q_A''(X_A) < 0)$. The amount of firewood collected by the household [2] is a function of labor in firewood collection (L_F), and forest characteristics (D_F) such as the distance between the household's home and the forest frontier, with $(Q_F'(L_F) > 0,\ Q_F''(L_F) < 0)$. Similarly, charcoal production [3] is a function of labor spent in charcoaling (L_C), and forest characteristics $(Q_C'(L_C) > 0,\ Q_C''(L_C) < 0)$. The group of 'other' goods including leisure and off-farm work [4], for simplicity, is only a function of labor (L_O), $(Q_O'(L_O) > 0,\ Q_O''(L_O) < 0)$. The model will later be extended to allow for scrap wood collection [6], and jojoba cultivation as an additional component of agricultural production [5]. The price of the agricultural produce p_A, the price of agricultural inputs p_{XA}, as well as the prices for firewood p_F, charcoal p_C, and other goods p_O, are assumed to be exogenously given. Eco-charcoal prices are relevant for the policy scenarios and will be introduced later.

Status Quo

In the status quo in absence of any policies, the Lagrangian for the household's maximization problem is given by

$$\psi^{statusquo} = U(G_i,Z) - \lambda^{statusquo}[Y^{statusquo} - p_A Q_A[L_A, X_A, H_A] - p_F Q_F[L_F, D_F] - p_C Q_C[L_C, D_F] - p_O Q_O[L_O] + p_{XA} X_A + \textstyle\sum_i p_i G_i] - \gamma^{statusquo}[\bar{L} - L_A - L_F - L_C - L_O] \quad , i = A,F,C,O \qquad [10]$$

The first order condition for labor in charcoaling in the status quo is

$$\frac{\partial \psi^{statusquo}}{\partial L_C} = \lambda^{statusquo} p_C \frac{\partial Q_C}{\partial L_C} + \gamma^{statusquo} = 0 \qquad [11]$$

At the optimum, the household allocates its labor so that the marginal return to charcoaling is equal to the household's shadow price of labor $\gamma^{statusquo}$. The latter is negative because we assume that the household uses all of its time for the given activities, with leisure included in 'other'. An additional unit of labor would come at the cost of the shadow price since it would need to be hired in.

A central question in the permanence debate is how households change their behavior when the prices for land uses that are competing with forest conservation change. In the specific context of our case study in Kenya, charcoaling is the alternative that is imposing greatest threats on forest conservation. The right hand side of [12] is positive for a positive shadow value of income $(\lambda^{statusquo} > 0)$. This means that in the status quo, households will optimally allocate more labor to charcoaling when the price of charcoal increases.

$$\frac{\partial^2 \Psi^{statusquo}}{\partial L_C \partial p_C} = \lambda^{statusquo} \frac{\partial Q_C}{\partial L_C} \qquad [12]$$

Agricultural Policy

The goal of the agricultural policy is to divert labor from charcoaling to the cultivation of a new crop. The new crop can only be attractive if it is comparatively profitable. Moreover, the crop's requirements in terms of labor-intensive care can be decisive for the effectiveness of such a policy. In our case study, we consider the cultivation of jojoba for which seeds were previously not available. We chose jojoba because this crop is currently under consideration by the conservation company at the case study site in Kenya. They appreciate it as a high-revenue, little labor-intense crop. In the model, the agricultural production function that includes jojoba [5] also includes additional inputs X_{AJ} at price p_{XAJ}. The household's agricultural characteristics are not affected by the introduction of jojoba, and we assume generic agricultural labor to also remain unaltered. In terms of the model, for simplicity, we assume that the introduction of jojoba as additional crop changes the price for the composite agricultural good to p_{AJ}, so that $p_{AJ} > p_A$. The household's objective function is as above, with equation [1] replaced by equation [5].

The Lagrangian for the jojoba scenario is:

$$\Psi^J = U(G_i, Z) - \lambda^J [Y^J - p_{AJ} Q_{AJ}[L_A, X_{AJ}, H_A] - p_F Q_F[L_F, D_F] - p_C Q_C[L_C, D_F] - p_O Q_O[L_O] + p_{XAJ} X_{AJ} + \sum_i p_i G_i] - \gamma^J [\bar{L} - L_A - L_F - L_C - L_O]$$

$$, i = AJ, F, C, O \qquad [13]$$

$$\frac{\partial \Psi^J}{\partial L_C} = \lambda^J p_C \frac{\partial Q_C}{\partial L_C} + \gamma^J = 0 \qquad [14]$$

$$\frac{\partial^2 \Psi^J}{\partial L_C \partial p_C} = \lambda^J \frac{\partial Q_C}{\partial L_C} > 0 \quad \text{, for shadow value of income } \lambda^J > 0 \qquad [15]$$

The first order condition for charcoaling in the jojoba scenario [14] is equal to the decision rule in the status quo scenario [11]. The shadow prices of income and time may, however, differ in the two scenarios. The introduction of jojoba can have an effect on charcoaling through changes in the shadow prices. Condition [15] shows that even with the possibility to produce jojoba, the amount of labor allocated to charcoaling will increase as the charcoal price rises. Whether this increase is equal to or differs from the increase in the status quo scenario cannot be determined with this model and must be tested empirically.

The choice for Jojoba was exogenously given through the conservation company at the study site. However, other crops, such as more labor-intensive tobacco plants, could also be promoted in an agricultural policy. An interesting question is how the labor requirements of different crops would affect shadow prices and thus charcoaling decisions or in other words, when the charcoal price rises, does the amount of labor allocated to charcoaling increase (as in [15]) to the same extent when the agricultural crop requires a lot of or little labor? To address this question we must specify a functional form for the agricultural production function. Referring to the general status quo, for simplicity assuming that L_A,X_A, and H_A are scalars and imposing a Cobb-Douglas function we have

$$Q_A[L_A,X_A,H_A] = L_A^{\mu} X_A^{\tau} H_A^{1-\mu-\tau} \qquad [16]$$

with μ and τ, respectively, the output elasticities of labor and an input factor. A high value for μ implies a high marginal return to labor and represents a crop that (ceteris paribus) requires comparatively little labor. With [16] given, we can assess how the first order condition of the shadow price of income changes with the output elasticity of labor in crop production:

$$\frac{\partial^2 \psi^{statusquo}}{\partial \lambda^{statusquo}\, \partial \mu} = X_A^{\tau} H_A^{1-\mu-\tau} L_A^{\mu} lnL_A + L_A^{\mu} X_A^{\beta} H_A^{1-\mu-\tau} lnH_A \qquad [17]$$

For values of $L_A > 1$ and $H_A > 1$ the RHS of [17] is positive. In this case, the shadow value of income increases as less labor-intensive crops are chosen. Interestingly, this means that when a little labor-intensive crop is cultivated, the marginal increase of charcoaling, in cause of increasing charcoal prices, is higher than if the crop were labor intensive. The intuition is straight forward: crops that ceteris paribus require only little care are less successful in absorbing labor. However, note that when converging to a corner solution with $L_A < 1$ and $H_A < 1$ the implications are vice versa. For cases of $L_A < 1 \wedge H_A > 1$ or $L_A > 1 \wedge H_A < 1$ the sign of the RHS of [17] is ambiguous.

Eco-charcoal Policies

Eco-charcoal policies are an alternative to agricultural policies. Under this policy, a household has the possibility to collect, for example, dry scrap wood from the forest ground, L_E, and sell it to an eco-charcoal factory. Compared to the status quo, the household now includes scrap wood collection [6] into its utility maximization problem. It can produce and sell but not consume scrap wood. The time constraint is extended to include this activity $(\bar{L} - L_A - L_F - L_C - L_O - L_E = 0)$. Note that the agricultural jojoba policy is not implemented simultaneously. We investigate three different modalities of setting the price for eco-charcoal raw material: (i) a fixed price; (ii) an indexed price; and (iii) an indexed price conditional on the level of forest use.

(i) Fixed price. The first of the three eco-charcoaling scenarios offers a fixed price p_{E_fixed} per unit of scrap wood. The Lagrangian for this scenario is:

$$\psi^{Eco\_fixed} = U(G_i, Z) - \lambda^{Eco\_fixed}\left[y^{Eco\_fixed} - p_A Q_A[L_A, X_A, H_A] - p_F Q_F[L_F, D_F] - p_C Q_C[L_C, D_F] - p_O Q_O[L_O] - p_{Eco\_fixed} Q_E[L_E, D_F] + p_{XA} X_A + \textstyle\sum_i p_i G_i\right] - \gamma^{Eco\_fixed}[\bar{L} - L_A - L_F - L_C - L_O - L_E]$$
$$, i = A, F, C, O \qquad [18]$$

$$\frac{\partial \psi^{Eco\_fixed}}{\partial L_C} = \lambda^{Eco\_fixed} p_C \frac{\partial Q_C}{\partial L_C} + \gamma^{Eco\_fixed} = 0 \qquad [19]$$

$$\frac{\partial^2 \psi^{Eco\_fixed}}{\partial L_C \partial p_C} = \lambda^{Eco\_fixed} \frac{\partial Q_C}{\partial L_C} > 0 \quad \text{, for shadow value of income } \lambda^{Eco\_fixed} > 0 \qquad [20]$$

The decision rule for charcoaling [19] is equivalent to that in the status quo and in the agricultural policy scenario. The shadow values of income and time may, however, differ and lead to diverging optimal amounts of time spent in charcoaling. As in the status quo and agricultural policy scenarios, [20] shows that charcoaling will increase with increasing charcoal prices, under the plausible condition that the shadow value of income is positive.

(ii) Indexed price. In the second scenario, the price for scrap wood is indexed, by factor α, to the price of charcoal, αp_C. The Lagrangian for this scenario is:

$$\psi^{Indexed} = U(G_i, Z) - \lambda^{Indexed}\left[y^{Indexed} - p_A Q_A[L_A, X_A, H_A] - p_F Q_F[L_F, D_F] - p_C Q_C[L_C, D_F] - p_O Q_O[L_O] - \alpha p_C Q_E[L_E, D_F] + p_{XA} X_A + \textstyle\sum_i p_i G_i\right] - \gamma^{Indexed}[\bar{L} - L_A - L_F - L_C - L_O - L_E]$$
$$, i = A, F, C, O \qquad [21]$$

The corresponding first order conditions are

$$\frac{\partial \psi^{Indexed}}{\partial L_C} = \lambda^{Indexed} p_C \frac{\partial Q_C}{\partial L_C} + \gamma^{Indexed} = 0 \qquad [22]$$

$$\frac{\partial^2 \psi^{Indexed}}{\partial L_C \partial p_C} = \lambda^{Indexed} \frac{\partial Q_C}{\partial L_C} > 0 \quad \text{, for shadow value of income } \lambda^{Indexed} > 0 \qquad [23]$$

Indexing the eco-charcoal price to the charcoal price does not change the structure of the decision rule for optimal charcoaling [22]. Again differences are guised in the shadow prices. Condition [23] informs that the indexed eco-charcoal price also does not prevent charcoaling activities from increasing when the charcoal price rises.

(iii) Indexed conditional price. The third pricing policy also indexes the price for scrap wood to the charcoal price but additionally introduces a conditionality clause. Now the price for scrap wood, $\beta p_C + R(p_C, L_C, V_C)$ consists of two parts, the first is a base payment that is indexed to the charcoal price βp_C. The second part is a premium $R(\cdot)$ that is also indexed to the charcoal price but additionally is a function of the household's labor in charcoaling and the labor that other villagers spend in charcoaling V_C, with $R'(L_C) < 0$ and $R'(V_C) < 0$. The household can only decide on the amount of labor that it itself spends in charcoaling. Yet, it has expectations toward the other villagers' behavior. Hence, the premium enters into the household's maximization problem as an expected value of the premium, $E\big(R(p_C, L_C, V_C)\big)$. The expectations are likely to be influenced by the villagers' potential for collective action. The Lagrangian for this scenario is given by

$$\begin{aligned}\psi^{Indexed\_cond} &= U(G_i, Z) - \lambda^{Indexed\_cond}\Big[y^{Indexed\_cond} - p_A Q_A[L_A, X_A, H_A] - p_F Q_F[L_F, D_F] - \\ &p_C Q_C[L_C, D_F] - p_O Q_O[L_O] - \Big(\beta p_C + E\big(R(p_C, L_C, V_C)\big)\Big) Q_E[L_E, D_F] + p_{XA} X_A + \textstyle\sum_i p_i G_i\Big] - \\ &\gamma^{Indexed\_cond}[\bar{L} - L_A - L_F - L_C - L_O - L_E] \\ &, i = A, F, C, O \qquad [24]\end{aligned}$$

$$\frac{\partial \psi^{Indexed\_cond}}{\partial L_C} = \lambda^{Indexed\_cond} p_C \frac{\partial Q_C}{\partial L_C} + \lambda^{Indexed\_cond} \frac{\partial E}{\partial R} \frac{\partial R}{\partial L_C} Q_E[L_E, D_F] + \gamma^{Indexed\_cond} = 0 \qquad [25]$$

$$\frac{\partial^2 \psi^{Indexed\_cond}}{\partial L_C \partial p_C} = \lambda^{Indexed\_cond} \frac{\partial Q_C}{\partial L_C} + \lambda^{Indexed\_cond} Q_E[L_E, D_F] \frac{\partial\left(\frac{\partial E}{\partial R}\frac{\partial R}{\partial L_C}\right)}{\partial p_C} \qquad [26]$$

Compared to the first order conditions in the previous scenarios, [24] has an additional term on the RHS, $\lambda^{Indexed\_cond} \frac{\partial E}{\partial R} \frac{\partial R}{\partial L_C} Q_E[L_E, D_F]$. It expresses the marginal decrease in the expected premium for eco-charcoal as consequence of a marginal increase in charcoaling. This effect can help reduce the household's otherwise positive effects of increased charcoaling. We further investigate how the first order condition changes when the price of charcoal increases. In [26] the second term on the RHS indicates that the marginal loss of income from scrap wood collection through charcoaling increases when the charcoal price rises. In other words, the opportunity cost of charcoaling also increases when the charcoal price increases. This effect is special for this conditional scenario and counteracts the problem of non-permanence in emission reductions from charcoaling when charcoal prices increase. Below we assess empirically the degree of the non-permanence problem under the different policy scenarios.

3. CASE STUDY DESCRIPTION

This study focuses on the Kasigau Corridor REDD+ Project in Kenya, which is the first REDD project ever to issue carbon credits under an internationally accepted standard (Peters-Stanley et al., 2011). A peculiarity of this case study is that in the Kasigau Corridor, the forest users are not the landowners. The forest land is split into several community ranches, which are owned by shareholder companies. The shares have historically been distributed among the population living on the more fertile hills that surround the forest, but since then the population increased heavily and many shareholders also migrated to Nairobi or Mombasa. In general, the shareholders do not live close to the forest. The shareholders receive a share of the revenue from the sale of carbon credits, which is high above their opportunity cost, as the area is rather infertile and the forest is of low commercial value for the owners. The amount of land per shareholder varies greatly. The ranch with most shareholders has 2,500 shareholders, while the one with least (which is about ten times smaller) has only one.

Under the REDD+ agreement, the land was leased to a conservation company which is responsible for the entire carbon accreditation and commercialization, as well as protection of the forest. Apart from various indirect measures, the company also introduced rangers who directly control the forest for illegal charcoaling and tree cutting. The focus of this study was laid on the forest users rather than the forest owners, because the former face substantial opportunity costs of forest conservation.

Despite being illegal in Kenya, charcoaling is a widespread practise and the base of many livelihoods, as well as a major cooking fuel in the entire country. Although domestic demand in Kenya has been reduced through the introduction of efficient charcoal stoves (Seidel, 2008), we still considered demand as inelastic, as charcoal is exported through Mombasa harbour and therefore linked to international demand for energy carriers. Therefore policies with the aim to reduce unsustainable charcoaling primarily need to address the supply side. The investigated payment scheme is an indirect payment through the financial support of eco-charcoal factories, which pay local land users for the supply of sustainably harvested raw material, i.e., scrap wood from fast growing shrubs, while at the same time supplying a sustainable substitute for the non-renewable charcoal for the end users. In the Kasigau Corridor charcoal production is the key driver for forest degradation. It also paves the way for deforestation, as the land becomes easier to clear for agriculture once a charcoaler removed all hardwood trees.[4] A pilot eco-charcoal factory has already been set up and is currently producing small amounts of eco-charcoal. In the pilot project, hired workers cut shrubs for daily wage. The project owner made deliberate efforts to hire ex- charcoalers. This setup has several disadvantages when aiming to scale up: (i) the access to shrubs is limited to land owned or leased by the factory operators and public lands; (ii) it could be perceived as unfair since only charcoalers are employed, and even lead to perverse incentives such as starting charcoaling to get a job. For scaling up to a level of production that can substitute a significant amount of charcoal, we assume that access to shrubs on private land is required, and therefore, we analyze a scheme where anybody can sell shrubs at the factory gate.

4. EXPERIMENTAL DESIGN AND DATA DESCRIPTION

4.1. Experimental Design

We implemented a stated preference experiment on time allocation to elicit the behaviour of the forest users under different policies.[5] Each policy is implemented one at the time, and not simultaneously. Our proxy for forest degradation is the time spent making charcoal at the household level. The experiment was conducted together with a conventional socio-economic survey addressed to the household head. The experiment was carried out in person by 14 locally recruited surveyors, and one locally recruited, experienced survey manager. The surveyors went through an intensive five day training course and were given the opportunity to

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[4] The production of eco-charcoal requires equipment costing several thousand USD and is therefore only feasible when done at least at the small factory scale.

[5] We have chosen a stated preference experiment on time allocation rather than for example, a willingness to pay survey as the local economy is strongly cash constrained. The population is therefore more familiar with decisions relating to work time.

give inputs to the survey design. The survey was pre-tested with 50 subjects and adjusted accordingly. The data were collected during two months in spring 2011. Each surveyor worked in the villages proximate to their own home village, making it easier to find access to and gain trust from the subjects. Among other socio-economic data, the surveyors also had to collect the phone numbers of the subjects. The survey manager then checked for half of the questionnaires if the interviews where done properly via phone. The survey manager also did occasional spot checks on the surveyors in the field. This monitoring process was implemented to ensure the quality of the results.

The experiment was conducted with the help of visual aids following Delavandea et al. (2010). In particular, the surveyors carried a bag with a piece of eco-charcoal and some sticks of the raw material to show to the subjects when presenting the scenarios with the eco-charcoal policy. Furthermore, a cardboard circle was presented on which the interviewees could see four drawings, each representing one of the forest-relevant household activities, namely (1) 'farm work' (e.g. cropping, field protection, livestock tending), (2) 'firewood collection', (3) 'charcoaling' and (4) 'other activities' (including charcoal trading). We added 'collection of scrap wood' as a fifth activity in the scenarios with the eco-charcoal policy. To elicit how the individuals allocate their time during a normal week, they were asked to distribute beans on the activity drawings on the circle. Fourteen beans needed to be distributed per individual with each bean representing half a day. The bean game was well accepted by the subjects. We opted for the use of half days as unit during the pre-study field visit since charcoaling is a time-intensive activity. It requires at least half a day to travel into the forest, cut the trees, and prepare the kiln. The surveyors talked the subjects through the week by asking separately for every half day, i.e. 'How do you spend your Monday mornings? Your Monday afternoons? etc.'. We used different colored beans, one color per household member. The household head was asked to choose the time allocation for absent household members. Children under the age of 12 were excluded.

We collected data on time allocation for the status quo, and for six different realistic policy scenarios, two related to the introduction of a new cash crop called 'jojoba' (Simmondsia chinensis), and four related to the introduction of an eco-charcoal factory.set at[6] A detailed description of each policy follows:

(1) Agricultural policy with low price. The value of one acre of jojoba was set at the lower estimate of 150,000 KES / year.[7]

(2) Agricultural policy with high price. The value of one acre of jojoba was set to the higher estimate of 250,000 KES / year.[8]

(3) Fixed price policy for eco-charcoal raw material.[9] The price of raw material was set at 200 KES / unit, independent of the charcoal price (200 KES is approximately equal to a daily labour salary, and thus, roughly represents the current approach of hiring workers).

(4) Indexed price policy for eco-charcoal raw material. The price per kilogram of eco-charcoal raw material was set at 12.5% of the kilogram charcoal price (12.5% was chosen based on a calculation of the conversion efficiency of the raw material with data from the pilot eco-charcoal factory. The factory's objective is to operate revenue neutral by selling eco-charcoal).

(5) Indexed price policy for eco-charcoal raw material with soft conditionality. The minimum price per kilogram of eco-charcoal raw material was set at 10% of the kilogram price of charcoal. Additionally, a premium was introduced. The premium increases by 0.2% of the charcoal price per week up to a maximum of 15% of the charcoal price. If somebody from the village is caught producing illegal bush charcoal in the forest, the premium decreases by 1% of the charcoal price per week.

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[6] These policies, while hypothetical in our experiment, are realistic. A pilot eco-charcoal factory has already been implemented, and field trials with jojoba are running since three years.

[7] 1KES is 0.0117 USD.

[8] The jojoba prices are based on the results of a field trial in the area and current jojoba oil prices.

[9] One unit of eco-charcoal raw material was chosen as 100 kg, which is the average amount that one adult collected in one day during a trial.

(6) Indexed price policy for eco-charcoal raw material with strong conditionality. This is the same as the previous policy, however, if somebody from the village is caught charcoaling or poaching the premium decreases by 2% of the charcoal price per kilogram per week. When these last two policies were presented, subjects were asked to answer three control questions to test if the policies were fully understood.

We randomly assigned two policy scenarios (i.e., two questions) to each household: (i) one scenario on the jojoba agricultural policy, and (ii) one scenario on an eco-charcoal policy. In addition, we randomly assigned five charcoal prices (250, 500, 750, 1000, and 1500 KES) for each policy.[10] We randomized the order of the two scenarios to account for order effects, and we disclosed in advance the choice tasks. Day et al. (2012) find robust evidence of order effects in repeat-response stated preference studies, however, they also find that this effect is significantly mitigated by task training and information provision on the tasks.

4.2. Data Description and Sample Selection

The original design includes 85 villages covering all areas of the Kasigau Corridor REDD+ Project, and 1,095 households randomly selected proportionally to the total village population in each village. We drop 123 observations because two surveyors where found working in an inappropriate manner at a late stage of the survey. This causes a slight underrepresentation of one region (Mwatate). Then, we carry out internal and external consistency checks. We drop five observations because the total time allocation is zero, and 96 observations because the total time did not add up to a full week (i.e., 14 beans). We included several quality control questions to elicit directly or indirectly whether there are charcoalers in the household. For example, a respondent stating directly that the household does not engage in charcoaling should not report that the household used the forest for charcoaling during the last dry season or that the household had income gains from charcoaling. We find only 10 respondents declaring not charcoaling but with positive income from charcoaling. We then drop 31 observations because they did not declare time spent charcoaling while we identified them as charcoalers through the control questions.[11]

After cleaning the data, the final sample used in the analysis consists of 81 villages and 840 households. Since each respondent answered three time allocation questions (status quo plus two policy scenarios) we have three observations per household, that is a panel dataset of 2,520 observations. The survey collected detailed information on household characteristics (e.g., size and composition), forest use (e.g., fuel wood collection, livestock tending, charcoaling, hunting), and household time use in the aforementioned activities: farm work, collection of firewood, charcoaling, collection of scrap wood, and 'other activities.'

Panel A of Table 1 presents the descriptive statistics at the status quo for the whole sample and separately for each treated group. Formal t-tests show the quality of the policy randomization: the null hypothesis that the policy treatment groups are equal for the main variables is not rejected for nearly all the variables presented with the exception of household size for the group corresponding to the indexed price policy with strong conditionality, and for the share of children aged 12-17 for the group corresponding to the indexed price policy with weak conditionality (differences significant at the 5% statistical level). The average household consists of five members, in particular, about 28% are male adults, 25% female adults, 2% elderly, 24% children aged 0-11, and about 11% children aged 12-17.[12] The majority of households own their land (90%) and are small farm-households (about 5 acres on average). An average household spends most of the time per week on farm work and doing 'other activities.' Panel B of Table 1 presents the average time allocation after the policy treatment. Farm work is still the main activity, however, a simple comparison of time allocation at the status quo and after the treatment (Panel A vs. Panel B) seems to convey that the time spent charcoaling decreased, and in particular, that eco-charcoal policies, appear to be more effective than agricultural policies in reducing time spent charcoaling.

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[10] The current average price of charcoal is about 455 KES per bag. 1 bag is equivalent to 35 Kg.

[11] Concerns on sample selection bias could arise. We compared the final 'clean' sample with the original sample, and find that there are no significant differences in the main covariates that will be used later on in the analysis, that is household size, household composition, forest and market distance as well as the time allocation at the status quo. In addition, our findings do not change if we keep or drop these observations. Results available upon request.

[12] Then, there is a remaining 10% of household members that our dataset did not allow us to identify. However, formal t-tests show that the percentage of people belonging to this residual category is not different by treatment group.

Table 1. Descriptive Statistics.

			Treatment Policies											
			Agricultural Policy				Eco-charcoal Policy							
									Indexed Price					
	Full Sample		Low Price		High Price		Fixed Price		No conditionality		Weak conditionality		Strong conditionality	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A - Status Quo														
Charcoaling (weekly half days)	3.912	6.289	3.807	6.408	4.009	6.182	4.146	6.268	4.049	6.205	3.409	6.562	3.974	6.176
Farm work (weekly half days)	10.818	9.076	10.995	9.188	10.653	8.978	11.169	10.168	11.420	10.024	10.790	7.902	9.970	7.890
Fire wood collection (weekly half days)	3.815	4.180	3.844	3.927	3.789	4.408	3.543	3.678	4.332	5.404	4.199	4.183	3.304	3.211
Other activities (weekly half days)	23.588	17.745	24.563	18.447	22.680	17.038	24.484	18.405	24.112	18.057	24.656	18.544	21.404	16.006
Control Variables														
Household size	4.968	2.710	5.069	2.814	4.874	2.608	5.014	2.996	5.156	2.732	5.134	2.591	4.622	2.471
Share of male adults	0.281	0.245	0.282	0.241	0.280	0.249	0.302	0.257	0.276	0.237	0.258	0.219	0.284	0.260
Share of female adults	0.255	0.187	0.253	0.185	0.257	0.190	0.257	0.200	0.265	0.189	0.249	0.165	0.251	0.191
Share of elderly	0.024	0.092	0.021	0.090	0.026	0.093	0.026	0.109	0.022	0.080	0.015	0.060	0.030	0.103
Share of kids 0-11	0.243	0.231	0.244	0.230	0.243	0.232	0.226	0.232	0.238	0.227	0.265	0.226	0.248	0.236
Share of kids 12-17	0.114	0.160	0.119	0.168	0.109	0.153	0.101	0.152	0.121	0.155	0.140	0.183	0.098	0.151
Land owned (Ha)	5.165	4.608	5.145	4.889	5.174	4.335	5.115	4.616	5.177	4.323	5.180	5.205	5.170	4.355
Number of livestock	10.362	12.617	10.373	13.532	10.352	11.716	10.260	14.776	10.034	10.938	10.505	11.940	10.635	12.386
Village forest distance (Km)	5.300	5.293	5.147	4.975	5.423	5.575	5.119	5.005	5.300	5.371	5.179	4.953	5.532	5.761
Village market distance (Km)	21.655	17.272	20.595	16.868	22.641	17.602	20.447	17.518	20.969	16.592	20.770	16.114	24.131	18.363
Panel B - After Policy Treatment														
Charcoaling (weekly half days)	2.515	5.497	3.807	6.955	3.152	5.836	1.863	4.095	1.937	4.722	1.081	3.422	1.335	4.348
Farm work (weekly half days)	10.286	9.054	12.960	10.298	13.411	9.656	7.498	7.540	7.010	6.789	7.435	6.238	7.548	6.947
Fire wood collection (weekly half days)	3.324	4.005	3.847	4.622	3.936	4.989	2.671	2.481	3.083	3.519	2.855	2.575	2.465	2.817
Other activities (weekly half days)	19.489	16.911	22.548	18.590	20.536	17.018	18.534	16.655	17.678	15.194	18.344	16.948	15.570	14.052
Scrap wood Collection (weekly half days)	6.415	9.995	-	-	-	-	12.584	10.348	14.000	11.757	13.263	12.172	11.674	9.112
Sample size	840		405		435		219		205		186		230	

5. ECONOMETRIC MODEL

The effects of permanence and the different policy scenarios on time allocation are assessed by estimating a system of K equations. We can write the k-th equation for household h as follows

$$y_{khq} = \alpha_{0k} + \mathbf{D_{kq}}\boldsymbol{\alpha}_{\mathbf{1k}} + \left(\mathbf{p_{kq}} \times \mathbf{D_{kq}}\right)\boldsymbol{\alpha}_{\mathbf{2k}} + \alpha_{3k} X_{khq} + \varepsilon_{khq} \qquad [27]$$

where the dependent variable is the weekly number of half days spent in each activity k (k = 1, … , K) by household h at the status quo (q = 1) or under a policy scenario (q = 2, … , Q, with q = 2 corresponding to the second policy scenario in our case study, and Q to the last one); vector **D** includes dummy variables equal to 1 for each policy scenario described in the previous section, 0 otherwise;[13] **p** is a vector of relative charcoal prices with respect to the status quo, that is the charcoal price randomly assigned to each household divided by the charcoal price at the status quo; **p**x**D** represents the interaction term between relative charcoal prices and policy dummy variables. In addition, X represents an additional covariate, 'order', to control for the order in which the eco-charcoal policy question was presented: 'order' is equal to 1 if an eco-charcoal policy is presented as first, 0 if second.

Since each respondent answered multiple time allocation questions, it is likely that the responses are correlated. In addition, because the respondent has to choose how to allocate his/her time among K activities, our final empirical model is a system of K equations estimated simultaneously. In particular, we employ a random effect seemingly unrelated regression model (Biorn, 2004) where the error term is comprised of two components, both of which are normally distributed: $\varepsilon_{khq} = v_{kh} + \eta_{khq}$ and ε_{khq}~N(0,**V**), where the term ν is an individual-specific error component that remains unchanged within a household over questions, and is independent across households; η is an independent and identically distributed (i.i.d.) error across and within households. This means that ε is a normal vector with zero means and variance-covariance matrix **V**= $\begin{bmatrix} 1 & \cdots & \rho \\ \vdots & \ddots & \vdots \\ \rho & \cdots & 1 \end{bmatrix}$ where ρ represents the correlations between errors.

We then derive the marginal effect of each policy as the difference between the expected time allocation at the status quo (y_{kh1}) and at each policy scenario q with q ≠1 ($y_{khq_{-1}}$), that is

$$E\left[y_{khq_{-1}}\right] - E\left[y_{kh1}\right] = \alpha_{1k} + \alpha_{2k} p_{kq} \qquad [28]$$

Note that equation [28] represents the impact of a policy when the randomly assigned charcoal prices are equal to the status quo charcoal price, i.e., when p_{kq} is equal to one. In the other cases, when the relative price of charcoal p_{kq} is different from one, we can use equation [28] to investigate the effect of permanence, i.e., the impact of the randomly assigned charcoal prices (250, 500, 750, 1000, 1500) on time allocation.

An advantage of this estimation procedure is that the randomly assigned prices and policy scenarios are exogenous, that is they are independent of individual and household characteristics that are included in the error term. This implies that (i) endogeneity problems in estimating $\boldsymbol{\alpha}_1$ and $\boldsymbol{\alpha}_2$ are avoided, (ii) estimates of parameters are unaffected by whether observed individual and household characteristics are included as additional covariates (we report on both versions below), and (iii) any systematic tendency for respondents to misstate their time allocation affects only the constant term.

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[13] Note that **D** is a vector because each respondent answered multiple policy questions, and it is likely that the responses are correlated.

6. RESULTS

A central question of our study is how households change their behavior when the prices for land uses that are competing with forest conservation change. As anticipated, in our case study, charcoaling is the alternative that is imposing greatest threats on forest conservation. In this section, we will then focus on and investigate how households change the amount of time spent charcoaling under different policy scenarios. We will conclude by shortly describing the impact also on the time spent for non-charcoaling activities.

Tables 2 and 3 report, respectively, the coefficient point estimates and marginal effects of policy impacts at the sample mean of the simultaneous equations random effect model [27]. Results meet theoretical expectations, and they are robust to different specifications. In particular, Model 1 presents the simplest specification where time allocation depends only on the policy treatment variables. Model 2 controls for village heterogeneity by including village fixed effects, and Model 3 presents estimates of equation [27] where we included also status quo control variables.

As discussed above, due to the randomization, including control variables for the status quo is not strictly necessary, and should have little effect on the estimates. However, the inclusion of control variables should help absorb any residual variation, and reduce the standard errors. Particular functional forms are chosen to remain within the spirit of previous work in this area (Fafchamps and Quisumbing, 1999; Shively and Fisher, 2004; Fisher et al., 2005; Ito and Kurosaki, 2009). Since we do not observe the shadow cost of labor we control for factors that affect labor supply such as household composition and size (e.g., shares of male and female adults aged 18 to 65, the share of elderly aged 66 and above, and the share of children in the age groups 0-11, and 12-17); hectares of land owned; number of livestock heads; distance to the market and to the forest.

Our results indicate that the inclusion of village fixed effects in Model 2 increases the coefficient point estimates slightly and it does not reduce the statistical significance of the coefficients. In line with our expectations, Model 3 shows that including control variables for the status quo while it adds explanatory power to the regression and helps reduce the standard errors, it has a minimal effect on the coefficient point estimates. Also as expected, the distance of the village from the market, household size and the proportion of men in the household have a significant and positive effect on the time spent charcoaling while the distance of the village from the forest has a negative effect. In addition, the order of presentation of the policy scenarios does not matter at the 1% statistical level in this model.

All three models strongly support the theoretical hypotheses presented in Section 2. The coefficients and marginal effects of policy treatment variables are strongly statistically significant with p-values close to zero in all three models. In particular, Table 3 shows that both agricultural policies and eco-charcoal policies significantly decrease the amount of time allocated to charcoaling. However, the implementation of an eco-charcoal policy has the largest effect, while an agricultural policy with a low jojoba price has the smallest effect. The impact of a fixed price eco-charcoal policy is about five times the impact of a low price agricultural policy, and nearly twice the impact of an agricultural policy with a high jojoba price.

Then, if we compare the effects at different charcoal prices, we find that a policy that indexes eco-charcoal payments to charcoalers' opportunity costs is the most effective policy in providing permanence in REDD+. When an eco-charcoal policy with an indexed price is introduced, we observe a significant decrease in time spent charcoaling even at high charcoal prices. For example, if the price of charcoal is set at 1500 and an indexed price policy with strong conditionality is implemented, then a household spends about one day less per weak charcoaling. On the contrary, if we consider the introduction of a cash-crop agricultural policy such as jojoba, then we find that with respect to the status quo the time spent charcoaling at high charcoal prices increases, specifically, by about half a day if an agricultural policy with a high price for jojoba is introduced. As discussed in the theoretical model, this may be due to the modest amount of labor that jojoba cultivation requires. It fails to absorb labor and divert it away from charcoaling especially when charcoal prices are high. In addition, although the estimated policy coefficients are negative, at high charcoal prices a fixed payments policy does not significantly affect the time spent charcoaling.

Table 2. Policy Impact on Charcoal Time Allocation - Coefficient Point Estimates.

	Model 1			Model 2			Model 3		
Variables	Coeff		Std. Err.	Coeff.		Std. Err.	Coeff.		Std. Err.
Agricultural Policy - Low Price	-1.160	***	0.390	-1.268	***	0.388	-1.278	***	0.387
Relative charcoal price × low_price_ag_policy	0.694	***	0.166	0.638	***	0.163	0.638	***	0.163
Agricultural Policy - High Price	-1.970	***	0.367	-2.268	***	0.367	-2.246	***	0.365
Relative charcoal price × high_price_ag_policy	0.723	***	0.154	0.760	***	0.151	0.753	***	0.151
Fixed Price Eco-charcoal Policy	-3.455	***	0.501	-3.587	***	0.495	-3.605	***	0.493
Relative charcoal price × fixed_price_ eco_policy	0.898	***	0.260	0.880	***	0.255	0.884	***	0.254
Indexed Price - No conditionality	-2.987	***	0.507	-3.198	***	0.502	-3.224	***	0.500
Relative charcoal price × indexed_price_no_cond	0.608	***	0.224	0.604	***	0.220	0.622	***	0.219
Indexed Price - Weak conditionality	-3.104	***	0.590	-3.217	***	0.584	-3.196	***	0.582
Relative charcoal price × indexed_price_weak_cond	0.445	*	0.254	0.360		0.250	0.345		0.249
Indexed Price - Strong conditionality	-2.642	***	0.520	-2.712	***	0.514	-2.719	***	0.512
Relative charcoal price × indexed_price_strong_cond	0.152		0.204	0.075		0.201	0.084		0.200
Covariates									
Order (=1 if eco-charcoal policy first)	4.128	***	0.279	0.765	***	0.291	0.420		0.278
Household size							0.547	***	0.066
Share of male adults							3.088	**	0.948
Share of female adults							0.882		1.103
Share of elderly							-2.035		1.721
Share of kids 0-11							-0.572		0.956
Share of kids 12-17							0.358		1.108
Land owned (Ha)							-0.016		0.033
Number of livestock							0.012		0.012
Village forest distance (Km)							-1.050	***	0.343
Village market distance (Km)							0.337	**	0.170
Village fixed effects	No			Yes			Yes		
R-squared	0.056			0.288			0.344		
Number of observations	2,850			2,850			2,850		
Number of households	840			840			840		

Note: The dependent variable is the household weekly number of half days spent charcoaling. Coefficients are estimated by random effect seemingly unrelated regression model for panel data. * Significant at the 10% level; ** significant at the 5% level; *** Significant at the 1% level.

Table 3. Policy Impact on Charcoal Time - Marginal Effects

	Model 1			Model 2			Model 3		
	Marg. Eff.		Std. Err.	Marg. Eff.		Std. Err.	Marg. Eff.		Std. Err.
Agricultural Policy - *Low* Price	-0.466	*	0.273	-0.630	**	0.275	-0.640	**	0.274
charcoal price 250	-0.708	**	0.309	-0.853	***	0.309	-0.863	***	0.308
charcoal price 500	-0.308		0.254	-0.485	*	0.257	-0.495	*	0.256
charcoal price 750	0.244		0.229	0.023		0.232	0.013		0.231
charcoal price 1000	0.527	**	0.244	0.283		0.247	0.273		0.245
charcoal price 1500	1.346	***	0.363	1.037	***	0.362	1.026	***	0.360
Agricultural Policy - *High* Price	-1.248	***	0.261	-1.508	***	0.264	-1.493	***	0.263
charcoal price 250	-1.503	***	0.294	-1.777	***	0.296	-1.759	***	0.294
charcoal price 500	-1.077	***	0.244	-1.329	***	0.247	-1.314	***	0.246
charcoal price 750	-0.551	**	0.221	-0.775	***	0.224	-0.766	***	0.224
charcoal price 1000	-0.208		0.235	-0.415	*	0.238	-0.409	*	0.237
charcoal price 1500	0.850	**	0.377	0.698	*	0.375	0.694	*	0.373
Fixed Price Eco-charcoal Policy	-2.557	***	0.330	-2.707	***	0.329	-2.722	***	0.328
charcoal price 250	-2.863	***	0.377	-3.007	***	0.375	-3.023	***	0.373
charcoal price 500	-2.343	***	0.308	-2.497	***	0.308	-2.511	***	0.307
charcoal price 750	-1.917	***	0.300	-2.081	***	0.300	-2.092	***	0.299
charcoal price 1000	-1.344	***	0.362	-1.519	***	0.360	-1.528	***	0.358
charcoal price 1500	-0.290		0.592	-0.487		0.583	-0.491		0.581
Indexed Price Eco-charcoal -Policy *No conditionality*	-2.379	***	0.355	-2.595	***	0.353	-2.602	***	0.352
charcoal price 250	-2.584	***	0.399	-2.798	***	0.396	-2.812	***	0.394
charcoal price 500	-2.273	***	0.337	-2.489	***	0.336	-2.493	***	0.334
charcoal price 750	-1.762	***	0.309	-1.981	***	0.309	-1.970	***	0.307
charcoal price 1000	-1.520	***	0.335	-1.741	***	0.333	-1.723	***	0.332
charcoal price 1500	-0.809		0.502	-1.035	**	0.496	-0.996	**	0.494
Indexed Price Eco-charcoal Policy *Weak conditionality*	-2.660	***	0.401	-2.856	***	0.399	-2.850	***	0.397
charcoal price 250	-2.824	***	0.464	-2.990	***	0.461	-2.978	***	0.459
charcoal price 500	-2.538	***	0.363	-2.758	***	0.362	-2.756	***	0.361
charcoal price 750	-2.133	***	0.324	-2.430	***	0.324	-2.442	***	0.323
charcoal price 1000	-1.975	***	0.351	-2.302	***	0.350	-2.319	***	0.349
charcoal price 1500	-1.550	***	0.504	-1.958	***	0.499	-1.989	***	0.497
Indexed Price Eco-charcoal Policy *Strong conditionality*	-2.490	***	0.369	-2.637	***	0.367	-2.635	***	0.365
charcoal price 250	-2.545	***	0.418	-2.664	***	0.415	-2.665	***	0.414
charcoal price 500	-2.448	***	0.337	-2.617	***	0.336	-2.612	***	0.335
charcoal price 750	-2.330	***	0.289	-2.558	***	0.291	-2.547	***	0.290
charcoal price 1000	-2.263	***	0.299	-2.525	***	0.300	-2.510	***	0.299
charcoal price 1500	-2.068	***	0.444	-2.429	***	0.442	-2.402	***	0.440
Village fixed effects	No			Yes			Yes		
Covariates	No			No			Yes		
Number of observations	2,850			2,850			2,850		
Number of households	840			840			840		

Note: The dependent variable is the household weekly number of half days spent charcoaling. Marginal effects are calculated by applying equation [28], and using the coefficients of Table 2. Standard errors are derived by applying the delta method. * Significant at the 10% level; ** significant at the 5% level; *** Significant at the 1% level.

In addition, we find differences between a policy without conditionality and one with conditionality or different types of conditionality (strong/weak) at high charcoal prices. At the high charcoal price scenario (1500) there is a declining trend of charcoaling time as the policy moves from a policy with no conditionality (impact equal to –0.809) to a policy with weak and strong conditionality (impact equal to –1.550 and -2.068, respectively). However, the only statistically significant difference (at 5% level) is between the policy without conditionality and the one with strong conditionality: the effect under the latter is almost double the effect under the policy with no conditionality. The lack of significant effects for the other cases could be linked to the fact that in our context the payment is conditional on collective rather than individual behaviour. As a consequence, the effect of conditionality is likely to depend on monitoring intensity and on the household's expectation of the effective eco-charcoal price it will receive, which depends on others' behaviour as well. If a household believes that others will charcoal illegally it may consider a lower expected eco-charcoal price in the conditional scenario and thus increase own charcoaling. We leave it for future research to test these hypotheses.

Apart from the policies' impacts on charcoaling, the data also reveal very interesting results related to the impact on time spent on farm work, fire wood and 'other activities,' as shown in Table 4.[14] We find, as expected, that the agricultural policies increase the time spent for farm work (by about one day more per week), however, they do not affect the time spent collecting firewood. On the contrary, the eco-charcoal policies have a strong significant (at the 1% statistical level) negative effect on time spent collecting firewood, farming, and in particular, time spent in 'other activities' because more time is allocated to collect eco-charcoal row material.

7. CONCLUSIONS

REDD+ is currently a major topic in the debate on policies to mitigate climate change. Developing mechanisms to ensure permanence and create alternative livelihood options is an important challenge in REDD+ scheme design. This study contributes to the debate in three ways: first, it assesses theoretically and empirically policies that create alternative livelihood options for people around REDD+ forests; second, it is the first study to test and compare in the field different REDD+ payment schemes; and third, it is the first field study to provide some insights on the effectiveness of different policies on the permanence of forest-based emission reductions. We take advantage of a setting where the resource users are not the legal land holders, a situation often observed in developing countries: the Kasigau Corridor REDD+ Project in Kenya, which is the first REDD+ project to issue carbon credits under an internationally accepted standard.

Our case study shows that incentive-based instruments such as an eco-charcoal policy under different payment schemes are more promising than agricultural policies that promote high revenue plants which require little care. In particular, a payment mechanism that links the price of eco-charcoal raw material to the charcoal price significantly lowers the amount of labor allocated to charcoaling even at high charcoal prices. These results are supported by the theoretical findings by Muller and Albers (2004), who find that 'as pure conservation tools, agricultural development projects do not work in all market settings unless the projects contain aspects that alter household preferences' (p. 202) or unless the labor market is missing. On the other side, conservation payments may not work if a market for resources is missing. In addition, Muller and Albers (2004) find that both agricultural policies and conservation payment policies increase welfare in every market setting, and recognize that a portfolio of policies rather than a single policy may be preferable.

However, whether policies to provide alternative livelihood options will be implemented may, to a great extent, depend on their cost-effectiveness. We use the marginal effects of the impact of the eco-charcoal policies from Table 3 (Model 2) to convert the average weekly reduction in charcoaling days into annual CO_2 reductions for the current charcoal price.[15] We find that each eco-charcoal factory would reduce CO_2

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[14] Table 4 presents estimated marginal effects of Model 2, which controls for village heterogeneity by including village fixed effects and no covariates, as we showed that adding covariates has a minimal effect on the coefficient point estimates. Estimated parameters of Model 1 and Model 3 yield to the same findings, and they are available upon request.

[15] For example, we convert the weekly impact of the fixed price eco-charcoal policy into about 19,200 tons of annual CO_2 emissions by multiplying the weekly marginal effect from Table 3 Model 2 (-2.707) by the average bags of

emissions by about 18,000-20,000 tons per year, assuming that there are 1,000 households in close enough proximity to deliver raw material to the factory. Under the current price of 7 Euros per ton of CO_2,[16] it should be cost effective to invest between 128,800 and 142,100 Euros per factory per year into subsidizing eco-charcoal factories in the area.

Finally, before bringing eco-charcoal to such a scale, additional studies are needed (i) to quantify the ecological carrying capacity of the eco-charcoal raw material; (ii) to test whether the effectiveness of the eco-charcoal policies prevails also over longer time periods; (iii) to test whether there are general equilibrium effects that we could not capture in our study such as the possibility that increasing returns to agriculture through agricultural policy could lead to more land being deforested, or improved income and labor opportunities drawing more people into the area; and (iv) to test the presence of leakage, i.e., the possibility that the damaging activity (charcoaling) will be relocated elsewhere to satisfy energy demands. We speculate that while the mere reduction of charcoaling as a consequence of an agricultural policy may induce leakage, eco-charcoaling is likely to be superior in that it provides a sustainable alternative energy source, however, this should be object of future research. Last but not least, additional studies are needed to test whether the effectiveness of indexed payments policies that are conditional on forest degradation depends on monitoring intensity and households' expectation of the effective eco-charcoal price they will receive. The latter in turn depends on other households' behavior regarding deforestation. Households from communities with better collective action potential might expect a higher price and reduce charcoaling more. We leave it for future research to test these hypotheses.

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charcoal produced in a day (0.78), by the CO_2 emissions produced by one bag of charcoal (that is 175 Kg: 1 bag of charcoal is equivalent to 35 Kg and 1 Kg of charcoal produces 5 Kg of CO_2, Pennise et al., 2001) by 52 weeks. Similarly, we calculate the annual CO_2 reductions from an indexed eco-charcoal policy without conditionality (about 18,400 tons), from an indexed eco-charcoal policy with weak conditionality (20,300 tons), and with strong conditionality (18,700 tons).

[16] According to Tullet Prebon VER Monitor at the 17th of February 2012 price for REDD CCBS VCUs.

Table 4. Policy Impact on Time Spent for Farm Work, Firewood Collection and 'Other Activities' - Marginal Effects.

	Farm Work		Firewood Collection		Other Activities	
	Marg. Eff.	Std. Err.	Marg. Eff.	Std. Err.	Marg. Eff.	Std. Err.
Agricultural Policy - *Low* Price	2.345 ***	0.352	0.190	0.171	-1.701 ***	0.364
charcoal price 250	2.487 ***	0.396	0.256	0.192	-1.604 ***	0.410
charcoal price 500	2.253 ***	0.328	0.147	0.159	-1.765 ***	0.340
charcoal price 750	1.930 ***	0.297	-0.004	0.144	-1.987 ***	0.308
charcoal price 1000	1.764 ***	0.316	-0.081	0.153	-2.101 ***	0.327
charcoal price 1500	1.285 ***	0.463	-0.305	0.225	-2.430 ***	0.480
Agricultural Policy - *High* Price	3.050 ***	0.337	0.203	0.164	-1.966 ***	0.349
charcoal price 250	3.166 ***	0.378	0.230	0.184	-1.876 ***	0.391
charcoal price 500	2.972 ***	0.316	0.185	0.153	-2.026 ***	0.327
charcoal price 750	2.733 ***	0.287	0.129	0.139	-2.213 ***	0.297
charcoal price 1000	2.577 ***	0.304	0.093	0.148	-2.334 ***	0.314
charcoal price 1500	2.096 ***	0.479	-0.020	0.233	-2.708 ***	0.496
Fixed Price Eco-charcoal Policy	-3.080 ***	0.421	-0.957 ***	0.205	-5.339 ***	0.436
charcoal price 250	-2.837 ***	0.480	-0.931 ***	0.233	-4.934 ***	0.497
charcoal price 500	-3.250 ***	0.394	-0.975 ***	0.191	-5.623 ***	0.408
charcoal price 750	-3.588 ***	0.384	-1.011 ***	0.186	-6.186 ***	0.397
charcoal price 1000	-4.044 ***	0.460	-1.059 ***	0.224	-6.946 ***	0.477
charcoal price 1500	-4.882 ***	0.746	-1.147 ***	0.363	-8.341 ***	0.773
Indexed Price Eco-charcoal -Policy						
No conditionality	-3.709 ***	0.452	-0.974 ***	0.220	-6.772 ***	0.468
charcoal price 250	-3.405 ***	0.507	-0.899 ***	0.246	-6.903 ***	0.524
charcoal price 500	-3.868 ***	0.429	-1.012 ***	0.208	-6.705 ***	0.444
charcoal price 750	-4.629 ***	0.394	-1.197 ***	0.192	-6.380 ***	0.408
charcoal price 1000	-4.989 ***	0.426	-1.284 ***	0.207	-6.227 ***	0.440
charcoal price 1500	-6.047 ***	0.635	-1.541 ***	0.308	-5.775 ***	0.656
Indexed Price Eco-charcoal Policy						
Weak conditionality	-2.902 ***	0.510	-1.014 ***	0.248	-5.352 ***	0.528
charcoal price 250	-2.648 ***	0.589	-0.957 ***	0.286	-5.053 ***	0.608
charcoal price 500	-3.091 ***	0.463	-1.056 ***	0.225	-5.573 ***	0.479
charcoal price 750	-3.716 ***	0.414	-1.196 ***	0.201	-6.307 ***	0.429
charcoal price 1000	-3.961 ***	0.448	-1.251 ***	0.218	-6.594 ***	0.464
charcoal price 1500	-4.618 ***	0.638	-1.398 ***	0.310	-7.365 ***	0.660
Indexed Price Eco-charcoal Policy						
Strong conditionality	-2.235 ***	0.469	-0.981 ***	0.228	-5.075 ***	0.484
charcoal price 250	-2.176 ***	0.531	-0.990 ***	0.258	-4.803 ***	0.548
charcoal price 500	-2.279 ***	0.430	-0.974 ***	0.209	-5.280 ***	0.444
charcoal price 750	-2.407 ***	0.372	-0.956 ***	0.180	-5.868 ***	0.384
charcoal price 1000	-2.478 ***	0.384	-0.945 ***	0.186	-6.196 ***	0.397
charcoal price 1500	-2.687 ***	0.565	-0.915 ***	0.274	-7.160 ***	0.584

Note: The dependent variable is the household weekly number of half days spent on each activity. Marginal effects are calculated by applying equation [28], and estimating Model 2, which includes village fixed effects and no covariates. The number of households is 840 and the number of observations is 2,850. Standard errors are derived by applying the delta method. * Significant at the 10% level; ** significant at the 5% level; *** Significant at the 1% level.

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