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Does Community Forest Collective Action Promote Private Tree Planting?
Evidence from Ethiopia

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Abstract

In community settings in low-income developing countries better forest management depends on collective action (CA), but if CA really offers better incentives than open access, we should observe behavioral differences across CA levels. In this paper we examine one potential farm-level behavioral effect by trying to isolate and understand the effects of community forest CA on households' incentives to invest in trees located on their own farms. Using a household level analytical model, we find that more stringent forest CA should create incentives for private tree planting as a substitute for overusing community forests. We test this hypothesis using detailed measures of highland Ethiopia forest CA attributes taken directly from the rich CA literature and a variety of empirical specifications. Though we are unable to draw firm conclusions due to the nature of our data, we do find robust evidence across specifications that more effective forest collective action causes households to plant more trees on their farms.

Keywords: collective action, Ethiopia, forest management

(JEL Code: Q23, Q12)

1. Introduction

In most low-income developing countries households depend on trees to provide a variety of products that are essential for daily life, including fuelwood, fodder for animals, and building materials. Furthermore, forests provide important "off-site" benefits, including erosion and flood control, but often forests are "common," which creates interdependencies between community members that may result from open access. With open access, as long as resources have value, they will be used in less than ideal ways and almost certainly will be degraded, often to the point where they end up virtually worthless. As Stavins (2011) noted, the so-called "problem of the commons" is at least as important in 2011 as it was in 1911 when Katherine Coman discussed collective action problems in the lead article to the inaugural issue of the *American Economic Review* (Coman, 1911). Eliminating open access through appropriate institutional arrangements is therefore perhaps *the* critical prerequisite to enhanced tree cover in many low-income countries.

Most developing country forests are government owned, but typically those governments do not have the capacity to effectively manage and protect forest resources, especially in low-income countries such as Ethiopia. As a result, state owned forests are often effectively open access (Bluffstone, Robinson, & Purdon, 2015b). To try to reduce the open access due to centralized control of forests, since the early 1980s there has been a worldwide trend in developing countries toward devolution of forests to communities. As a result, community ownership and/or administration are about three times more than private sector ownership, and during the period 1997-2008 collective forest area roughly doubled to 250 million hectares. About 25% of developing country forests are now under some type of collective management (World Bank, 2009; Economist, 2010) and over 15% are *de jure* owned by communities (Rights and Resources Initiative [RRI], 2014).

In community settings forest management depends on collective action (CA) and if CA really offers better incentives than open access, we should observe behavioral differences across the two institutional structures. In this paper we examine one potential farm-level behavioral difference by trying to isolate and understand the effects of community forest CA on households' incentives to invest in trees located on their own farms. Using a household level analytical model, we find that stringent forest CA that eliminates open access should create incentives for private tree planting as a substitute for overusing community forests. We test this hypothesis using detailed measures of highland Ethiopia forest CA attributes taken directly from the rich CA literature and a variety of empirical specifications. Though we are unable to draw firm conclusions due to the nature of our data, we do find robust evidence across specifications that more effective forest collective action causes households to plant more trees on their farms.

The next section discusses the literature related to community forestry CA that we draw on in our empirical analysis and Section 3 overviews deforestation and collective action in Ethiopia. Section 4 presents our analytical framework, which extends that used by Bluffstone, Boscolo, & Molina (2008) and generates testable hypotheses. Section 5 discusses our identification approach and the data we use and Section 6 presents the results. Finally, Section 7 concludes and discusses implications of the findings.

2. Community Forest Collective Action and Household Behavior

In recent years an important literature has emerged that discusses the effects of collective action on economic outcomes in developing countries. In general, this increasingly well-developed literature suggests good things come from such social coordination. For example, Bouma, Bulte, & Soest (2008) combine experimental evidence from a trust game in India with information on households' participation in community management. They find that players that are more cooperative also engage in more pro-social community natural resource management activities. Bluffstone, Dannenberg, Matinsson, Jha, & Bista (2015a) find significant evidence that more cooperative individuals in Nepal – or those who believe their group members cooperate – engage in CA behaviors that support community forests. Gelo & Koch (2014) find that within the context of a program in Ethiopia, better forest CA increases household revenues while reducing dependence on livestock. Gelo & Alemu (2015) find that strengthened community management supports rural livelihoods in Ethiopia. In their work on species diversity in the Tigray region of Ethiopia, Mebrahtu & Gebremedhin (2015) conclude that devolution and collective action increase tree species diversity.

As a small but growing literature is establishing, private tree planting is a potentially important private response to CA (Nepal, Bohara, Berrens, 2007; Bluffstone et al. 2008; Bluffstone et al. 2015b; Mekonnen, 2009). Furthermore, in East Africa as community forests deteriorate, small private plantations are increasingly producing forest products for rural households. In Kenya significant proportions of fuelwood and charcoal come from private lands and in our sample trees planted on households' farms on average make up over 50% of household assets. On-farm trees are a critical part of asset portfolios in highland Ethiopia (Bluffstone, Yusef, Uehara, Bushie & Damite, 2015c).

In recent decades there have been important advances in our understanding of CA and an enormous literature that discusses community member cooperation. This literature suggests that with effective forest CA households must restrict their collections compared with their preferred harvest levels under open access (Baland & Platteau 1999; Bluffstone et al. 2008). A related CA literature discusses desirable aspects of CA and attempts to disaggregate its components. This work suggests that effective CA systems are incentive compatible at the household level when they empower communities, have clear access and extraction rules, fair and graduated sanctions, public participation, clear quotas, and successful monitoring (Ostrom 1990; Agrawal, 2001).

In Ethiopia and indeed in many low-income developing countries CA systems are often subtle, homegrown systems, which may work very well, not at all or anywhere in between. Except for select cases like Nepal, where communities opt into a formal, legal community forestry CA program, CA should therefore be analyzed as a multi-faceted continuum rather than a binomial variable where households do or do not participate (Jodha, 2008; Shyamsundar, 2008; Agarwal, 2010; Bluffstone et al, 2008). This approach represents an important extension of past literature (Edmonds 2002; Heltberg 2001) that viewed CA as dichotomous.

Despite what is an emerging conventional wisdom that CA may in some cases be better than other alternatives, evidence on the effects of community forest CA and its constituents is limited and the subject of empirical research (Ostrom, 2010; Khatri-Chetri, 2008; Adhikari, 2005). The empirical work of Nepal et al. (2007), Bluffstone et al. (2008), Hansen, Luckert, Minae, & Place (2005) and Mekonnen (2009) are directly related to our paper, because of the focus on incentives for planting and managing trees on households' own farms. Nepal et al. (2007) look at a variety of social networks and finds that forest-related institutions spur on-farm tree planting. Other less forest-related groups have limited effects.

Bluffstone et al. (2008) use a methodology similar to that used in this paper to examine whether CA spurs on-farm tree planting in Bolivia. They find that CA at its highest level of aggregation is positively correlated with more and higher quality on-farm trees. Mekonnen (2009) looks at tree planting in Ethiopia and finds that a variety of labor, asset and credit market imperfections affect on-farm tree planting. Hansen et al (2005) highlight the importance of gender and marriage patterns in the tree planting decision. They find that unmarried women are associated with on-farm tree planting in Malawi.

3. Deforestation, Forest Degradation and Collective Action Solutions in Ethiopia

Ethiopia has an estimated closed canopy forest cover of 4.6% compared with an estimated baseline of about 40% in the 16th century (Ethiopian Forestry Action Program [EFAP], 1994; Tumcha, 2004). During the twenty years between 1990 and 2010 the annual deforestation rate averaged 2% per year, with forest area dropping from 15.1 million to 12.3 million hectares (decline of 20%). Above ground forest biomass fell by a much larger 28% during the same period, reflecting not only deforestation, but also degradation of forests (Food and Agriculture Organization [FAO], 2010) by the 83% of 96 million Ethiopians who live in rural areas (Central Intelligence Agency [CIA], 2014).

Causes of deforestation and forest degradation in Ethiopia are the demand for firewood, agricultural land and grazing, pushed by a rapidly growing population. Though in other countries it is common to find companies extracting or destroying forests, in Ethiopia such drivers of forest degradation and loss are less significant relative to other causes. Conversion of forests, woodland and shrub land into agricultural land is the largest driver of deforestation in Ethiopia (Vreugdenhil et al., 2011), but forest loss is greatly aggravated by grazing, fodder collection, and extraction of wood for fuel, charcoal and timber (Bekele, 2011).

Virtually all energy used in Ethiopia is biomass (94%) and almost all rural people depend on firewood, dung, and crop residues to cook and heat. Between 2000 and 2010, degradation due to fuelwood consumption claimed an estimated 135 million tons of woody biomass[1] and it is generally believed that unsustainable consumption of fuelwood prevents forests from regenerating. Virtually all land, and therefore from a legal perspective almost all forests, is owned by the government, but the capacity of federal and regional forestry institutions is very weak. *De facto* management (or lack thereof) often falls to communities.

As a result of these weak institutions there is de facto open access in many areas, which likely contributes to degradation and deforestation (Mekonnen & Bluffstone, 2015). Community-based forest CA and associated community forest institutions have therefore recently received significant attention as a potential mechanism to give better incentives for forest management. Legislation, such as the Forest Proclamation of 2007, for example, has made it possible for communities to hold heterogeneous agreements with governments that grant them control over forest areas, as well as various use rights. Rights typically do not include ownership or logging, but focus instead on subsistence products like fuelwood, fodder, and grazing. These agreements are known as participatory forest management (PFM) and have various mechanisms for sharing forest benefits between communities and regional governments. Available evidence suggests that PFM may increase CA, offer improvements in forest management and condition and potentially improve rural livelihoods (Gobeze, Bekele, Lemenih, & Kassa, 2009).

4. Analytical Framework

The purpose of the representative household analytical model presented below is to a) better understand the behavioral processes by which forest CA affects community forest extractions and tree planting effort and b) generate hypotheses related to private, on-farm tree planting that are tested in the remainder of the paper. Consider a representative farming household living in a large village in a low-income country. The village being "large" means that many households access a nearby forest and strategic interactions are not possible.[2] The village is examining the implications of introducing CA regulations that will affect all households. The goal is to curb open access, which is the *status quo*. We assume that once agreed, compliance is perfect.

The household has a unitary decision process and household utility is an increasing concave function of cooked food (F) and other goods (X) that must be purchased (1).

[1] Retrieved from http://www.moa.gov.et/documents/93087/1110213/Ethiopian_MRV_roadmap_v4+(1)%20(1).pdf

[2] Such behavior is sometimes described as "myopic," but this label does not seem appropriate given the constraints.

$$U = U(F, X) \tag{1}$$

Food is produced by households and is a function of environmental and non-environmental household labor inputs (E_E and E_{NE}), community forest quality (Q) and biomass from trees planted on farms (T) that substitute for community forest products (2).

$$F = F(E_E, E_{NE}, Q, T) \tag{2}$$

Environmental labor includes activities such as fuelwood collection, grazing and cutting of fodder for animals. These activities produce fuel for cooking and feed animals that produce meat and dung, which is the main fertilizer in much of the developing world, including Ethiopia. Non-environmental labor consists of agricultural production, as well as household activities like cooking, cleaning, etc. This function is given in (2).[3] Community forest quality (Q) makes environmental labor more productive, i.e.: $\frac{\partial F}{\partial E_E} / \partial Q) > 0$

First derivatives are positive and second derivatives negative due to the existence of short-run-fixed factors such as tools, animals, etc. Community forests do not generate these diminishing returns, because households are "small" collectors of forest products. Labor cross-partial derivatives are assumed to be zero, which means marginal products of any E_i are not affected by any E_h. This approach is taken mainly to reduce dimensionality of the problem, but there is also little reason to believe cross-partials would be non-negative.

Equation 3 is the production function for on-farm tree biomass (T), which is a function of silvicultural and biomass harvesting labor (E_T). This approach focuses attention on labor, which is the main resource allocation issue. E_T includes tree planting, harvesting leaves and wood for fuel, fodder collection, chasing away grazing animals, and guarding against encroachment. The first derivative of $g(E_T)$ is positive and the second derivative negative due to the existence of fixed land. We do not include a land constraint, because households typically plant trees around the perimeters of their agricultural lands and do not devote plots or parts of plots to trees. Tree biomass may also, however, be purchased.

We treat tree biomass as a flow rather than a stock, because eucalyptus is the main tree planted on farms in highland Ethiopia (Bluffstone et al., 2015c). These trees are harvested or coppiced after just 10 years or even earlier, producing valuable products like fuel from oil-rich eucalyptus leaves and branches starting almost immediately.[4]

$$T = g(E_t\} \tag{3}$$

Production occurs subject to the time constraint in (4). All activities are included, as well as off-farm wage labor (E_w), which earns incomes used to purchase X and tree biomass (T). Leisure is omitted, because the labor-leisure tradeoff is not germane to our research questions. This margin of decision-making is also probably not relevant, because the literature suggests there exists substantial surplus labor in highland Ethiopia (Tadesse, 2010).

$$E = E_E + E_{NE} + E_T + E_w \tag{4}$$

Cash is earned from wages at rate w and spent on X and tree biomass. Households are price takers. Due to imperfect financial markets (Yesuf & Bluffstone, 2009) there is no borrowing or saving (5). We do not include a food market, because in the study area in 2005 average cash income was only $86.45 and over 80% of households had total incomes of less than $1.00 per person per day. Few households buy food except in times of extreme need and even fewer sell food.

$$wE_w = P_T T + P_x X \tag{5}$$

Effective CA by its nature utilizes collective action to restrict household deforesting behavior in the name of forest regeneration and boosting rents. Because households' most important variable factor is labor, similar to the method used by Linde-Rahr (2003) we model restrictions as inequality constraints on forest-related labor

[3]This parsimonious arrangement, where we particularly abstract from the details of food production, is done in the interest of focusing on our variables of interest.

[4]In settings where longer-lived species are planted, (1), (2) and (3) should be defined as present values.

supply.[5] Following Heltberg (2001), while forest policies may be group determined, they are given to villagers when they make their day-to-day decisions.

We substitute (3) into (2) and (5). After solving (5) for X we substitute the result into (1) and do the same for (2). The resulting Lagrangian maximized is given in (6). In addition to the time constraint represented by constraint λ1, λ2 and λ3 represent possible policy-generated restrictions on labor supply. The Kuhn-Tucker conditions are that if the constraints bind, the Lagrange multipliers are positive rather than zero. λ2 > 0 therefore says that households are unable to work in the wage labor market as much as they would like. λ3 > 0 indicates restrictions on environmental labor supply imposed by CA.

$$L = U[\{F(E_G, E_{NE}, Q, T) + g(E_T)\}, (\frac{wE_w - P_T g(E_T)}{P_X})] + \lambda_1(E - E_E - E_{NE} - E_T - E_w) \quad (6)$$
$$+ \lambda_2(E_w^* - E_w) + \lambda_3(E_E^* - E_E)$$

Though it is easiest to think of these constraints as extraction time limits, Ethiopian CA constraints may be quantitative (e.g. allowable cutting of fuelwood, maximum days grazing, fees for extraction) or qualitative (e.g. households may take what they need but not more, face social sanctions for over-use, allocations must be fair). All these restrictions are mechanisms for imposing labor constraints.

$$a. \frac{\partial L}{\partial E_E} = \frac{\partial U}{\partial F}\frac{\partial F}{\partial E_E}(Q) - \lambda_1 - \lambda_3 = 0$$
$$b \frac{\partial L}{\partial E_{NE}} = \frac{\partial U}{\partial F}\frac{\partial F}{\partial E_{NE}} - \lambda_1 = 0$$
$$c. \frac{\partial L}{\partial E_T} = \frac{\partial U}{\partial F}\frac{\partial F}{\partial g}\frac{\partial g}{\partial E_T}, - \frac{P_T}{P_X}\frac{\partial g}{\partial E_T} - \lambda_1 = 0$$
$$d. \frac{\partial L}{\partial E_w} = \frac{w}{PX} - \lambda_2 = 0$$
(7)

To derive comparative static results, an explicit form of 7c must be assumed. In rural Ethiopia because markets are thin, food is virtually always produced on-farm and tends not to be purchased or sold. During normal circumstances of autarky there is therefore close to complete separability between X, the purchased good, and food, which is produced by subsistence agriculture. An additive function captures this separability and is therefore used in 7c. Setting 7a=7b=7c gives (8).

$$\frac{\partial U}{\partial F}\frac{\partial F}{\partial E_E}(Q) - \lambda_3 = \frac{\partial g}{\partial E_T}(\frac{\partial U}{\partial F}\frac{\partial F}{\partial g} - \frac{P_T}{P_X}) = \frac{\partial U}{\partial F}\frac{\partial F}{\partial E_{NE}} \quad (8)$$

Assuming $(\frac{\partial U}{\partial F}\frac{\partial F}{\partial g} - \frac{P_T}{P_X}) > 0$, which says that on the margin households find it in their interest to work on their own tree biomass rather than spend time on wage labor and buy those products, we allow λ_3 to increase from zero (i.e. open access), which signifies CA constraints that do not bind, to increasingly positive values representing tightened community-imposed environmental labor constraints.[6] To maintain an optimal labor allocation as λ_3 increases, $\partial g/\partial E_T$ and $\partial g/\partial E_{NE}$ must decline. Given diminishing returns to labor, this adjustment occurs if E_T and E_{NE} increase; labor therefore shifts from labor based on the use of common forests into

[5]This approach is taken merely for convenience. Formulating constraints on forest extractions would be equivalent.

[6]Of course if a household is somehow not subject to the CA regime, we expect to observe the household open access equilibrium.

non-environmental (including agricultural) and on-farm tree biomass labor. This result suggests that community CA forest labor constraints increase on-farm tree biomass labor, production and planting. Labor shifts are larger the tighter the constraint.

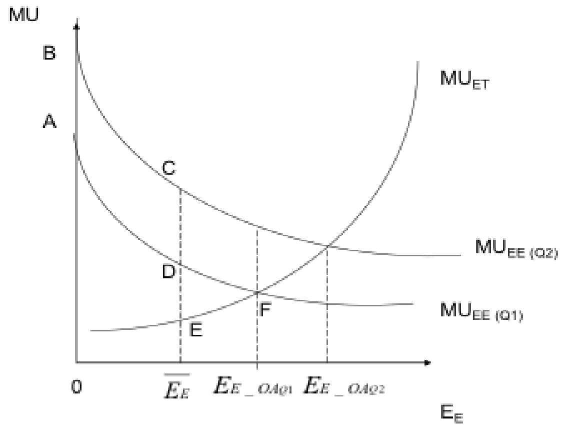

Figure 1. Environmental Labor

Figure 1 presents the situation focusing on E_E and Figure 2 provides the dual with regard to E_T. The horizontal axis is environmental labor and the vertical axis is marginal utility. Because $(\frac{\partial U}{\partial F}\frac{\partial F}{\partial g}-\frac{P_T}{P_X}) > 0$, households trade off environmental labor utilizing community forests against on-farm tree biomass labor and maximize utility as in (8).

We see that without CA restrictions households would choose E_{E_OA1}, which is the open access equilibrium. With binding CA restrictions households are constrained to environmental labor of E_E, which is consistent with a higher MU of environmental labor and lower MU of tree planting labor; with diminishing marginal returns to E_T, tree planting therefore increases due to CA restrictions. Households would like to move labor into forestry activities, but are not permitted to do so; they therefore lose rents of DEF

Over time effective CA allows forests to regenerate and causes community forest quality (Q) to increase. Marginal productivity of E_E increases and MU_{EE} shifts to $MU_{EE(Q2)}$. We see that the desired level of environmental labor increases to E_{E_OAQ2}. Allowing households to respond to increased Q would degrade forests over time, however, reducing Q and shifting $MU_{EE(Q2)}$ back to $MU_{EE\ (Q1)}$. E_{E_OAQ2} is therefore not a bioeconomic equilibrium and long-run labor supply would revert back to E_{E_OAQ1}.

How then do households benefit from CA? In the short-run households lose rents, but in the long run households earn rents in terms of more forest products per hour. As shown in Figure 1, even at $\overline{E_E}$ households would benefit if area ABCD > DEF. Households are therefore better off from CA not because they can reallocate labor to forest dependent activities, but because each unit of (constrained) community forest labor is more productive.

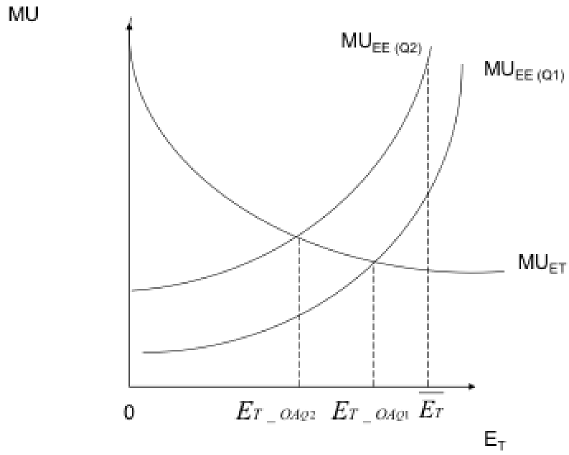

Figure 2. Tree Planting Labor

As shown in Figure 2, a key part of this welfare-improving adjustment comes from changes in E_T. Under open access to common forests, tree-planting labor would be $E_{TE\text{-}OAQ1.}$ Under CA E_E is restricted and labor shifts into on-farm trees and $E_T = E_{T\_\overline{E_E}}$. As community forest quality increases, MU_E_E increases and households would like to reduce their on-farm tree effort even below E_{T_OA1}. This level of effort is not an equilibrium, however, because as E_T falls below $E_{T\_\overline{E_E}}$, Q would decline and create incentives to increase E_T.

Our household analytical model therefore predicts that on-farm tree effort (and tree stocks) is unambiguously increasing in CA stringency. This specific hypothesis is tested in the remainder of the paper. The next section presents our data and identification strategy.

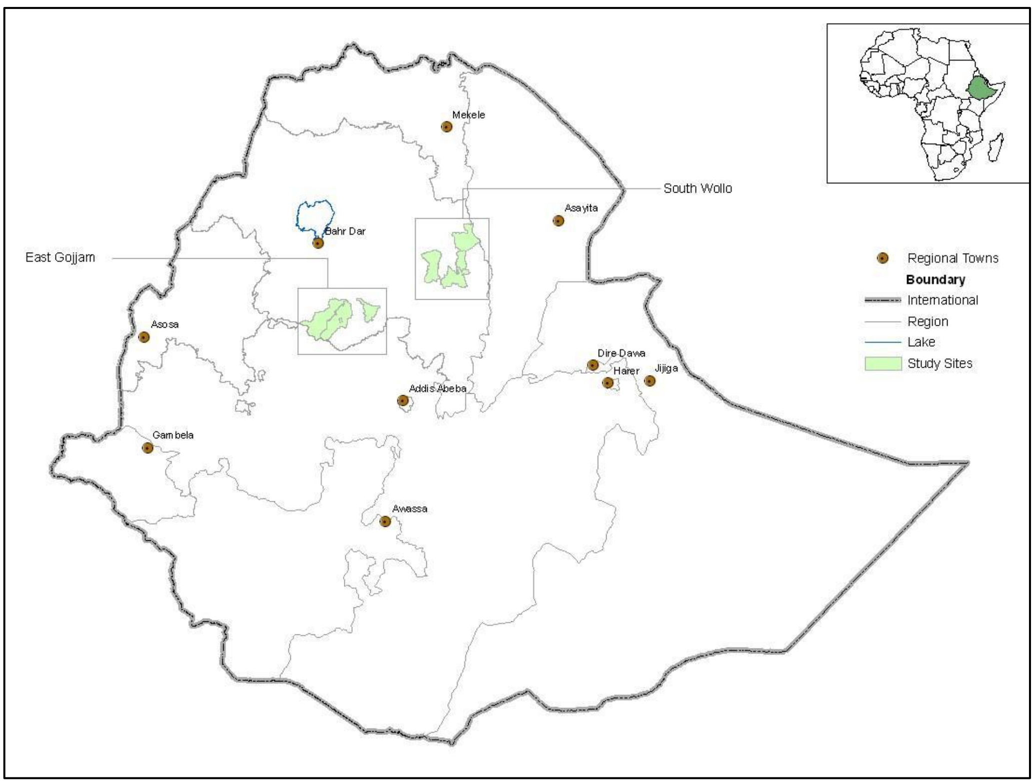

Figure 3. Study Sites in Ethiopia

5. Data and Identification Approach

The key prediction of our analytical model that households experiencing more stringent CA will plant more trees on their farms is tested using cross-section household and community level data collected in 2007. An in-person survey by trained enumerators was conducted in East Gojam and South Wollo zones of the Amhara Regional State. 1167 largely subsistence rural households that rely on mixed crop and livestock farming were surveyed in ten local areas called *kebeles* (often translated as peasant associations). *Kebeles* are chosen to ensure variation in terms of characteristics, such as agro-ecology and tree cover, with households randomly selected within *kebeles*. Figure 3 shows the location of the study sites. Household data are complemented by community information collected from village leaders. Model sample sizes are determined by the need for full-rank matrices.

The identification approach is to estimate econometric models explaining tree growing using a variety of methods to assure robust conclusions, allowing for important econometric issues, including that CA may be endogenous, sample selection may exist, dependent variables are truncated at zero and trees are count data. The three key identification concerns are endogeneity, sample selection and omitted variable bias. Our rich data set collected specifically to analyze such issues allows us to specify first stage selection equations and instrument for potentially endogenous variables when necessary. As discussed below, our context also helps obviate the possibility of serious endogeneity bias. Omitted variables due to unobservables affecting both tree planting and our measures of CA are always a possibility, though our approach to measure CA at the household level helps make such problems less likely.

Table 1. Descriptive Statistics on Tree Growing

Variable label	Mean	Std. Dev.	Min	Max
Grows trees	0.82	0.39	0	1
Grows eucalyptus trees	0.70	0.46	0	1
Number of trees grown	241.38	492.58	0	4011
Number of eucalyptus trees grown	196.95	459.84	0	3950

Table 1 shows that 82 percent of households grow trees and on average households have about 241 trees, with a large variation across households. On-farm trees are key household assets and as Bluffstone et al. (2015c) note, on-farm trees on average can make up over 50% of assets. This percentage is much higher than for livestock and represents a majority of assets, because households do not own the agricultural land they use. The government owns all land, though initiatives to certify use rights are gaining momentum (Mekonnen & Bluffstone, 2008). As shown in table 1, about 70% grow eucalyptus, which is the most important tree species, with an average of 197 eucalyptus trees per household.[7]

We measure CF collective action using data on CA attributes collected from household heads averaged across members of the same *kebele*, because all those within a *kebele* are subject to the same CA.[8] We go directly to household heads (e.g. rather than village leaders), because in developing countries on-the-ground realities often correspond poorly with policies, if any exist. This could be for a number of reasons, including leader mis-assessments, attempts to portray local CA in positive lights for enumerators or simple difficulties characterizing CA details.

Our questionnaire focuses on a variety of CA attributes that are standard in the economics of collective action literature, applied to the CF context. These attributes include fairness, clarity of access, monitoring quality and appropriate formal and informal sanctions, which are subjective and subtle aspects that households are likely to perceive much more accurately than leaders.

As discussed in detail in Ostrom (1990:2010), and Ostrom & Gardner (1993) community-based social systems – like those related to CFs – are typically complicated, with often very detailed, if implicit, rules and norms. We know from this economic literature that group membership clarity, benefit sharing rules, fairness, public participation and appropriate sanctions are very important for successful CA (Ostrom, 1990; 2000; 2010; Shyamsundar, 2008; Bluffstone et al, 2008; Agrawal, 2001; Agrawal, Chhatre, & Hardin, 2008). We capture these collective action attributes using the 23 statements and questions presented in Table 2.

[7]Surveys in 2000, 2002, and 2005 of the same households showed that eucalyptus trees were the most important trees in terms of number of households growing and trees grown (see Mekonnen, 2009).

[8]Results using unaveraged respondent values are available from the authors and are very similar to the *kebele* averaged results.

Table 2. CA Survey Questions Definitions and Descriptive Statistics of CA Indices and Associated Survey Questions. All indices$_i$ $\in [0,1]$ as per (9)

FOREST ACCESS INDEX $\bar{X} = 0.33$, σ=0.21 *Does an identifiable system for fuelwood collection exist?[1] * Does an identifiable system for grazing and fodder collection exist?[1] *Is the system that determines who is allowed to gather forest products clear and understandable?[2] * Do you pay for the right to collect fuelwood?[1] * Do you pay for the right to graze or collect fodder? [1]	**FORMAL PENALTIES INDEX** $\bar{X} = 0.52$, $\sigma = 0.33$ * If you took more fuelwood from the forest than you were allowed to take would you be penalized? [2] * If you took more fodder from the forest than you were allowed to take would you be penalized? [2] * Could you lose some or all of your rights to collect forest products if you were caught taking more than your allotment?[2]
FAIRNESS IINDEX $\bar{X} = 0.43$, $\sigma = 0.30$ * Do you feel you and others can take the amount of forest products that is needed, but not more?[2] * Are you get enough forest products to meet your needs, but not more?[2]	**MONITORING INDEX** $\bar{X} = 0.53$, $\sigma = 0.34$ * Do village authorities carefully monitor who takes what products?[2] * Do villagers generally watch who takes forest products?[2] * Are you either formally or informally involved in monitoring community forest lands?[2]
PARTICIPATION & DEMOCRACY INDEX $\bar{X} = 0.49$, $\sigma = 0.29$ * Do you have influence on policies for deciding how much forest products people can take?[2] * Do you help decide who are the managers of the forest?[2] * Do you expect that in the future you will have the opportunity to manage the community forest?[2] Are the managers democratically chosen?[2]	**LABOR INPUT INDEX** $\bar{X} = 0.02$, $\sigma = 0.05$ * Number of days planting community forests[3] * Number of days watering community forests[3] * Number of days thinning community forests[3] * Number of days fertilizing community forests[3]
SOCIAL SANCTION INDEX $\bar{X} = 0.58$, σ= 0.35 * Would other villagers be very unhappy with you if they found that you had taken more than your allotment?[2] * Would you be embarrassed or feel bad if you took more than your allotment of forest products?[2]	**QUOTAS INDEX** $\bar{X} = 0.21$, σ= 0.24 * Are you allocated a fixed allotment of fuelwood per year?[1] * Are you allocated a fixed allotment of fodder and grazing rights per year?[1]

Survey Question Coding:

1 = Yes/No Binomial Variable

2 = Likert Scale 5=definitely, 1=definitely not

3 = Number of Days During Past Month (0, 1, 2, 3,>3 days)

We choose these particular questions and statements based on the well-established criteria for CA institutions (see immediately previously cited literature) and to reflect the nature and tradeoffs associated with forest CA in Ethiopia. The questions were pre-tested by Ethiopian experts and found to be highly relevant for respondents before implementation in the field by trained and experienced enumerators. These attributes are multi-leveled rather than dichotomous, because forest sector CA attributes in Ethiopia and much of the lower-income developing world runs from excellent to terrible and everywhere in between, and has evolved locally in response to circumstances (Bluffstone et al., 2015b; Agrawal et al., 2008; Jodha, 2008). The CA interpreted and reflected in respondent perceptions listed in Table 2 evolved over time based on community circumstances and histories rather than explicit policy.

The questions/statements evaluated by respondents cover the 7 CA design principles/attributes extensively cited in the literature. The first focuses on *access* to forest resources (i.e. who can be a CF group member) and particularly on whether access rules are clear and fair, which was particularly identified by Ostrom (1990) and elsewhere in the literature. The second set focuses on *fairness* of forest product distribution. We also ask respondents to evaluate the degree of forest *monitoring* by respondents and their assessment of other villagers' monitoring contributions. We do not include government monitoring, because monitoring is only done by villagers; formal forest institutions are very weak. Four questions ask about *democratic processes and participation*, particularly regarding management of community forests. Respondents assess *formal sanctions* and *informal sanctions* for those who transgress harvest limits and quotas. The final groups focus on obligations of households, including *limits* on extraction of fuelwood and fodder/grazing and *labor inputs* for forest management.

We emphasize that there is no community forestry "program" in Ethiopia that has the clarity and legal structure that one would find, for example, in Nepal. In Ethiopia the Forest Proclamation of 2007 made it possible for individuals and communities to control forests, but the form of that control and the nature of the CA are multi-dimensional, informal, probably continuous in those dimensions (i.e. from terrible to excellent and everything in between) and often idiosyncratic to each location.

This context is important, because we believe it supports – though perhaps does not guarantee - our attempt to identify the effects of CA on private tree planting. It would not be appropriate, for example, to consider such measures as anything resembling policy "treatments." In Ethiopia there is no sense in which respondents' CA perceptions would reflect communities that "opted" or selected into CA or are somehow a function of forest quality. It is also very unlikely that respondent CA perceptions and private on-farm tree stocks are simultaneously affected by a common exogenous variable that would confound our results; the Ethiopian CA circumstances, which generally evolved over time, and our choice of CA measure help to obviate such important identification problems.

Responses to many questions are highly collinear, making it impossible to use all 23 responses in regressions. We therefore aggregate response information into higher-level indices, which address multicollinearity and help us understand which responses are closely related to each other. Our first aggregation method uses (9) to aggregate and weight questionnaire responses. This indexing method is the same one used to compute the human development index and is $\in [0,1]$. A_{ij} is the value of index component i for household j and Min_i and Max_i are the minimum and maximum for component i.

$$Index_{ij} = \sum_{i=1}^{k} (A_{ij} - Min_i)/(Max_i - Min_i) \tag{9}$$

To give a flavor for the stringency of the various CA attributes, Table 2 includes eight indices created using (9), which in general indicate rather loose management. Formal penalties, monitoring and social sanctions have the largest average index values at greater than 0.50. Average *kebele* perceptions of fairness and participation/democracy are similar at over 0.40, but in general forest access details are not well defined, few households have fixed quotas for fuelwood and fodder and almost no households provide regular labor inputs as part of CA.

Taking the average over the 8 *kebele*-level indices presented gives us an equally weighted overall CA index. The mean of this index is 0.39 with standard deviation of 0.20, which suggests rather weak management. This value is similar to that estimated by Bluffstone et al (2008) for the Bolivian Andes (mean overall CA index of 0.31 and standard deviation of 0.15), suggesting possible commonalities across low-income countries.

The second aggregation method uses factor analysis to create linear combinations of CA variables that reconstruct original variables. Resulting factors are orthogonal, which eliminates issues of multicollinearity, and the data dictate which survey responses should be combined and what weights are used. This aggregation method is standard when *a priori* weights are unknown and was used by Chhatre & Agrawal (2009) to aggregate heterogeneous subsistence product extractions into a "forest products" index.

Factor analysis also helps us understand what Ethiopian respondents see as the key components of CA. The equally weighted indices in Table 2 suppose that all 23 questions are equivalent when in fact some may be considered irrelevant by respondents. Factor analysis applies the appropriate weights to responses and creates factors made up of similar responses.

Table A1 in the online appendix presents the factor loadings for the three factors with eigenvalues greater than 1.0, which is a standard criterion for retention (Kabubo-Mariara & Linderhof, 2011). The first factor explains 71% of the total variation, factor two 14% and factor three 10% for a total of 95%. These three orthogonal factors therefore explain virtually all variation in the CA survey responses. Additional details on the factor analysis results are presented in online appendix Table A1.

Our independent variables of interest are the equally-weighted CA index and the three CA factors from the factor analysis. Though we have little reason to suppose that CA is endogenous to the tree planting decision, our observational data do not allow us to explicitly rule it out. We do not assume endogeneity, but instead test using Wu-Hausman F, Durban X^2 and GMM C X^2 tests.[9] When endogeneity may be a problem, we use the fact that CA is mainly determined at the community level, but private on-farm tree planting is strictly a household level

[9] As tree leaves may be an important source of fodder for animals, we test for exogeneity of animal stocks to the tree planting decision. In no models, however, can we reject exogeneity. Animals are therefore treated as exogenous.

decision informed by external circumstances. Indeed, while community variables are likely to be very important for community forest CA, there is little reason to believe they directly affect tree planting on household farms.

We therefore have the potential to identify a class of variables – community level variables – that affect CA, but not on-farm tree planting. If such variables are strongly associated with the potentially endogenous variable (e.g. CA), they can serve as instruments. The specific community variables used as CA instruments in IV models are highly informed by the CA literature and focus on three variables. The first is population density, because more density facilitates interactions and CA, but does not affect tree planting on private plots. The second and third variables come from our survey of community leaders. The first of these is whether forests are actually managed at the local (*Kebele*) level and the second is whether the local forest is identified as a community forest rather than a "government" forest. These variables are valid instruments for CA, because they represent local governance and local ownership, which are two critical aspects of local autonomy that have been identified in the CA literature as critical for CA. To adjust for unobserved local community features that affect local norms and customs, we also include district (i.e. *woreda*) fixed effects.

Our fourth and final excluded exogenous variable takes account that CA is measured at the household level. This variable is the number of years the respondent has lived in the village. It accounts for temporally changing local knowledge and perceptions of CA. Though we recognize that this variable could in principle be correlated with private trees planted, we would argue that we have variables such as respondent age, land area, wealth, etc. that are correlated with stability (i.e. years in village), but much more directly affect private investments in trees.

The IV models are all over-identified. We test over-identification restrictions using Sargan and Basmann tests for 2SLS models and Hansen's J X^2 method for GMM models and confirm all models pass these tests. Weak instruments are tested using F and minimum eigenvalue tests and as shown by the test statistics, it is found that the set of instruments are strong and should not be considered week.

As was already discussed, though 82% of households plant trees, tree planting is not universal. If this decision process involves sample selection, IV models would lead to bias (Heckman, 1979; Linde-Rahr, 2003). We test for sample selection and find evidence at the 5% significance level. We therefore also report Heckman results, but because results are similar to those from models that do not adjust for sample selection we present them in online appendix Table A2. Probit selection equations are estimated using all exogenous covariates.

Without sample selection the standard IV method when data are left-censored is to use IV Tobit, but this is correct only if the process for deciding whether to plant trees is the same as for choosing the number of trees planted. We test this restriction by comparing the IV Tobit with the model of Cragg (1971), which utilizes a Probit for the first stage followed by a truncated regression model. Using likelihood ratio tests, we cannot reject the Tobit as too restrictive. Because the IV Tobit results are virtually identical to those from all other models, however, we do not present the results. IV Tobit results are available from the authors.

Trees planted on household farms are count data variables. We therefore estimate the models using Poisson regression and find based on goodness-of-fit X^2 tests (Prob > X^2 = 0.00 for all models) that the negative binomial is more appropriate. We therefore present negative binomial results.

6. Results

Table A3 in the online appendix presents descriptive statistics for exogenous covariates and excluded exogenous variables along with expected signs and reasons for including. Conditioning variables reflect that households are planting trees on their own farms and the extensive margin in the study area is largely closed. They also reflect the thin, imperfect or non-existent markets in the study area. Variables representing wealth, labor endowments, human capital, proximity to towns and roads, land tenure and information are included as is appropriate for such settings and as is found in a variety of non-separable household models with highly imperfect markets (Jacoby, 1993). Whereas in areas with highly developed markets prices, interest rates, etc. may be relevant, in rural Ethiopia households must rely mainly on their own endowments.

The excluded instruments are mainly community-level variables. These are used to identify the first stage model of the equally-weighted CA index and the three factors when endogeneity tests suggest they should be treated as endogenous variables. As already noted, the instruments are chosen, because they are correlated with CA indices, uncorrelated with tree planting and in accord with the rich literature on CA formation (Ostrom, 1990; Agrawal, 2001) are believed to affect village norms. Mean and median Spearman correlations between excluded exogenous variables and the number of private trees on respondents' own farms are 0.06 and 0.08, confirming virtually complete lack of correlation.

About 20% of households use self-identified improved stoves, with the rest relying on three-stone fires.

Households have an average of 1.15 hectares of land, 3.84 tropical livestock units of animals and family size of 5.5. On average households grow a large number of trees on relatively limited land—land that is also used for producing crops. About 17% of household heads in the sample are female and on average household heads are much less educated (0.81 years) than the most educated household members (5.14 years). This difference reflects major education initiatives since 1995.

Table 3. Dependent Variable is Number of Private Trees on Own Land. IV GMM Estimates

	Equally Weighted CA Index Model	Factor Analysis CA Index Model
Endogenous Variables		
Equally Weighted CA Index	875.7*** (251.0)	
CA Factor 1 (All Questions Included. Roughly Equal Weights)		149.3* (78.37)
CA Factor 2		534.5 (416.6)
CA Factor 3		183.4 (122.0)
Exogenous Covariates		
Wealth Endowments – with imperfect credit markets, own wealth finances trees		
Land size in hectares **(LANDSIZ)**	31.01 (28.59)	-16.25 (49.79)
Corrugated roof (1 if yes) **(CRRGTHS)**	15.05 (31.09)	9.639 (41.13)
Livestock in TLU (tropical livestock units) **(LIVESTOK)**	37.79*** (9.850)	38.44*** (10.53)
Gave loan in last year (1 if yes) **(GIVENLOAN)**	13.79 (66.62)	27.76 (70.86)
Labor Endowments – labor complements trees, but investing in on-farm trees saves labor		
Fraction of boys (6–14 years) **(FRACTIONBOYS)**	229.1* (137.1)	278.7* (151.6)
Fraction of girls (6–14 years) **(FRACTIONGIRLS)**	441.0*** (170.8)	429.7** (178.6)
Fraction of female adults (>14 years) **(FRACTIONFEMAD)**	211.9 (135.5)	337.6* (191.4)
Fraction of male adults (>14 years) **(FRACTIONMALAD)**	88.49 (141.1)	267.8 (230.1)
Family size **(FAMSIZE)**	1.726 (13.55)	20.61 (19.37)
Human Capital – education and experience may complement trees		
Max. years of education of household members **(MAXEDUCHH)**	2.663 (6.144)	-0.554 (6.387)
Gender of head (1 if male) **(HEADSEX)**	16.05 (42.10)	6.520 (44.90)
Age of head in years **(HEADAGE)**	0.996 (1.098)	1.056 (1.145)
Years of education of head **(HEADEDUC)**	9.609 (8.423)	12.22 (8.554)
Market Access – trees may be planted for sale and therefore proximity may increase planting		
Walking distance to town in minutes **(DISTTOWN)**	-0.444 (0.337)	1.025 (1.122)
Walking distance to road in minutes **(DISTROAD)**	0.484 (0.503)	-1.536 (1.558)
Land Tenure – trees are long-term investments and are therefore promoted by tenure security		
Believes the land belongs to household **(OWNSLAND)**	26.25 (33.05)	34.87 (40.48)
Expects to lose land in next 5 years (1 if yes) **(EXPLNSZ5YRS)**	50.93 (41.61)	19.64 (48.57)
Information – tree planting often requires silvacultural and market information to be successful		
TRUSTGOT	23.64 (34.48)	-0.189 (37.72)
NUMDAVISIT	23.73 (16.17)	35.20** (17.94)
FARMERTOFARMER	34.56 (41.09)	55.13 (42.95)
Technological Substitute – improved stove reduces wood consumption and substitutes for trees on-farm		
IMPROVEDSTOVE	45.83 (45.74)	44.15 (46.10)
CONSTANT	-627.6*** (183.8)	-441.6** (197.1)
Observations	1,080	1,080
Goodness of Fit Tests		
R-squared	0.106	0.106
Wald X^2 (22)	93.55 (p = 0.000)***	97.71 (p = 0.000)***
Exogeneity Tests		
GMM C Statistic X^2 (1)	13.776 (p = 0.000) ***	16.5007 (p = 0.0009)***
Overidentifying Restriction Tests		
Hansen's J X^2 (4)	3.929 (p = 0.416)	0.994824 (p = 0.6081)
Weak Instrument Tests		
F Test	F(5, 1053) = 165.86 (p = 0.000) ***	-
Shea's Partial R^2 Factor 1	-	0.26
Shea's Partial R^2 Factor 2	-	0.03
Shea's Partial R^2 Factor 3	-	0.37

Land is owned by the government and the possibility of land redistribution exists. Indeed, land redistribution occurred in the study area in 1997. Some farmers have been issued certificates confirming rights to use land and we find that 44% of households believe land belongs to them. On the other hand, about 19% expect to lose land due to land redistributions within 5 years. We also find about 17% plant trees to increase land tenure security.

Social capital has been found to be an important feature of investments (e.g. see Nyangena, 2011; Kabubo-Mariara & Linderhof, 2011). As Nepal (2007) notes, social capital has a number of implications for tree planting and in our study area we believe the primary effect is through information sharing. Whether households report they trust people in their villages is used to capture social capital and in our sample about 67% of respondents say they trust other villagers. Also related to information is agricultural extension and farmer-to-farmer extension. While on average households are visited by an extension agent once per year, about 36% also benefit from farmer-to-farmer extension.

We estimate a baseline OLS model of on-farm tree stocks. Only in the factor analysis model is a CA variable significant (factor 2). In that model factor 2 is positively associated with trees planted. Significant variables across models include endowments like fraction of boys and girls and livestock holdings, with an additional TLU of livestock (e.g. one cow) increasing on-farm trees by about 41 trees. We do not present these results, because when we test for exogeneity of CA variables we find (as presented in table 6) we can reject exogeneity of CA indices at much better than the 1% significance level. Though communities in no way "opt in" to CA, tests suggest reason to believe that OLS estimates are biased. Based on these test results we present our IV model results.

Table 4. Dependent Variable Number of Private Trees on Own Land. Negative Binomial Model

Endogenous Variables (Predicted Values Used)	Equally Weighted CA Index Model	Factor Analysis CA Index Model
EQUALLY WEIGHTED CA INDEX	4.235** (1.992)	-
CA Factor 1 (All Questions Included. Roughly Equal Weights)	-	0.838 (0.623)
CA Factor 2	-	1.923 (2.819)
CA Factor 3	-	0.391 (1.273)
Exogenous Covariates		
LANDSIZ	0.227** (0.0951)	0.00133 (0.235)
CRRGTHS	0.349** (0.171)	0.285* (0.166)
LIVESTOK	0.0678** (0.0286)	0.0682 (0.0435)
GIVENLOAN	-0.459** (0.207)	-0.207 (0.188)
FRACTIONBOYS	1.583** (0.750)	1.822** (0.827)
FRACTIONGIRLS	2.280*** (0.727)	2.608*** (0.763)
FRACTIONFEMAD	1.048 (0.680)	1.523 (0.967)
FRACTIONMALAD	0.704 (0.630)	1.502 (1.102)
FAMSIZE	-0.0300 (0.0333)	0.0194 (0.0515)
MAXEDUCHH	0.0489*** (0.0149)	0.0441** (0.0201)
HEADSEX	0.152 (0.199)	0.303 (0.256)
HEADAGE	0.00910* (0.00519)	0.00611 (0.00579)
HEADEDUC	0.0269 (0.0315)	0.0262 (0.0312)
DISTTOWN	-0.000886 (0.00214)	0.00300 (0.00695)
DISTROAD	0.00146 (0.00261)	-0.00463 (0.00883)
OWNSLAND	-0.153 (0.229)	0.0773 (0.203)
EXPLNSZ5YRS	-0.0880 (0.151)	0.111 (0.146)
TRUSTGOT	0.000385 (0.150)	0.0175 (0.200)
NUMDAVISIT	0.102 (0.0701)	0.139 (0.0967)
FARMERTOFARMER	0.174 (0.124)	0.237* (0.139)
IMPROVEDSTOVE	0.247* (0.126)	0.122 (0.147)
CONSTANT	0.986 (0.622)	2.007*** (0.691)
Wald X^2	X^2 (22) = 1123 Prob > X^2 = 0.00	X^2 (24) = 1028 Prob > X^2 = 0.00
Goodness of Fit X^2	X^2 (1057) = 52055 Prob > X^2 = 0.00	X^2 (1059) = 519032 Prob > X^2 = 0.00
Observations	1,080	1,080

Robust bootstrapped (1000 Repetition) Standard Errors Adjusted for *Kebele* Clustering, because households in the same villages are likely to have common unobservable characteristics and circumstances. *Kebele* is translated as "peasant association" and includes several village settlements. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A4 in the online appendix presents first-stage CA models. A number of variables are significant. Whether a household gave a loan in the last year, whether respondents believe they own their land, have improved stoves and trust in other villagers are positively correlated with the CA index and factor 1. These results suggest those rich enough to make loans and those who believe they own their land perceive stricter CA. Those who worry they would lose land in the next five years, have more extension visits and corrugated roofs perceive less stringent CA. Excluded exogenous variables, including tenure in village and *kebele* level forest management, which only act on private tree planting through CA, are also positively associated with CA. Robust standard errors are adjusted for *kebele* clustering and three models have R^2 above 0.5.

Unless otherwise noted, robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Clustering is at the *kebele* level, because households in the same villages are likely to have common unobservable characteristics and circumstances. *Kebele* is often translated as "peasant association" and includes several village settlements

Table 3 presents IV results estimated using GMM and we see that the CA index and factor 1 are positively correlated with tree planting. 2SLS and GMM results are very similar for the model with the overall CA index, but in the 2SLS factor analysis models, as was the case for the OLS, only the factor 2 coefficient is positive and significant. Relationships between covariates and tree planting are limited, though in two IV models farmer-to-farmer extension is positively correlated with tree planting and significant at the 1% level.

Table 4 accounts for the count data nature of the dependent variable by estimating the model using a negative binomial regression after testing for and rejecting the Poisson specification (Prob. > X^2= 0.00). We see little difference with previous CA results in the model with the equally weighted CA index positively and significantly correlated with tree planting, but no CA factors correlated with on-farm tree planting. Covariate results are in many cases similar to those of previous models, but more variables are significant than in the continuous models. In particular, those who gave loans had fewer trees, while more educated households with older household heads, more land and livestock, improved stoves and corrugated roofs plant more trees. These findings suggest that wealth and endowments may be important.

7. Conclusion

On-farm trees are a critical source of household wealth in highland Ethiopia and in East Africa a key supplier of tree products like fuelwood. The key research question this paper attempts to answer is whether more effective CA affects on-farm tree planting behavior. We believe this question is of interest not only for understanding whether more private trees can be expected as forest CA improves in the low-income developing world, but also as part of the more general issue of whether more sophisticated social coordination leads to important private outcomes. Relatively little research has focused on this general question in our particular context, though low-income countries across the world have turned to CA to bolster declining forest stocks.

Our theoretical model suggests that if we observe more stringent CA, which has at its core controlling open access through restrictions on harvests, we should also observe more on-farm tree planting. We test this hypothesis using data from the Ethiopian highlands and find that results support the theoretical model and suggest that decisions about numbers of trees to grow are very much influenced by the nature of community forest management. Indeed, in all models the equally weighted CA index is positively and significantly correlated with numbers of trees grown. For the factor analysis, the same was true for factor 1 in all but one model.

Our results are suggestive that better community forest CA may have profound effects on household behaviors. Tree planting on-farm is one example and our findings generally support those of Nepal et al. (2007) and Bluffstone et al. (2008) that CA causes households to invest in on-farm trees. In all models the equally weighted CA index is estimated to promote tree planting and in all but the negative binomial model factor 1 is estimated to increase on-farm tree stocks.

This finding has potentially important implications for climate change initiatives such as REDD+, because it suggests that a possible carbon benefit of more stringent CA could come from on-farm trees. Little is known about such benefits, however. As the relationship between CA and on-farm tree planting is clarified, it is useful to evaluate whether relationships also exist with other technologies that could substitute for forests. Such measures may include commercial fuels and improved agricultural inputs. Of perhaps critical importance is to evaluate under what circumstances constraints imposed by reducing open access increase rural incomes. Evaluating policy instruments that increase rents and assure gains from better management reach all parts of households and societies is also critical.

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Supplementary Information

Table A1. Results of Factor Analysis (Factor Loadings > 0.13 are Highlighted)

Variables Taken Directly from Household Survey	Factor1 (Eigenvalue 7.23; Prop. Expl. 0.71)	Factor2 (Eigenvalue 1.42; Prop. Expl. 0.14)	Factor3 (Eigenvalue 1.04; Prop. Expl. 0.10)
Identifiable system for fuelwood collection exists	0.628	0.203	-0.077
Identifiable system for grazing allocation exists	0.598	0.059	0.058
Clear and understandable system for forest access exists	0.574	0.465	0.077
Pays for the right to collect fuelwood	0.215	-0.056	0.258
Pays for the right to graze	0.198	-0.049	0.305
Access rules are fair	0.536	0.473	0.054
Can take what is needed, but not more	0.443	0.212	-0.005
Has influence over forest policies	0.413	0.232	-0.074
Helps decide on forest management	0.634	0.141	-0.229
Forest managers are democratically chosen	0.723	0.133	-0.243
Fuelwood collection limits exist	0.484	0.229	0.392
Grazing and fodder collection limits exist	0.366	0.054	0.415
Fixed quotas of fuelwood given	0.347	0.130	0.319
Fixed quotas of grazing and fodder collection given	0.430	-0.006	0.297
Forest managers monitor forest	0.715	0.008	-0.278
Villagers monitor forest	0.737	0.007	-0.268
Respondent is involved with monitoring forest	0.645	0.044	-0.223
Would be punished for taking too much fuelwood	0.712	-0.294	-0.061
Would be punished for grazing too much or taking too much fodder	0.647	-0.372	0.141
Could lose some or all forest rights if caught over-harvesting	0.603	-0.372	0.076
Other villagers unhappy if respondent took too much forest products	0.737	-0.375	0.050
Respondent would feel embarrassed if caught taking too much forest products	0.647	-0.460	-0.014
Number of days spent on forest planting and management during past month	0.305	-0.005	0.053

What, therefore, is the meaning of CA in the Ethiopian highlands? Table A1 suggests that respondents view CA as a package made up of diverse components. We see that factor 1, which is most important, loads all variables roughly equally. Factor 2 includes mainly variables that Bluffstone et al (2008) call “institutional characteristics” (e.g. clarity of access, fairness, public participation, democracy) and factor 3 is what they call “management tools,” including clear quotas, penalties and payments for collections.

Factor 1 is by far the most important factor and therefore should be a key focus. All variables have loadings that round up to at least 0.2. Fourteen of 23 variables have loadings greater than 0.5, which suggests that in the Ethiopian highlands “CA” is very broad-based and multi-faceted. Only payments to collect and labor inputs are less relevant aspects of CA.

Table A2. Dependent Variable Number of Private Trees on Own Land. Heckman Selection Model

Endogenous Variables (Predicted Values Used)	Equally Weighted CA Index Model	Factor Analysis CA Index Model
EQUALLY WEIGHTED CA INDEX	1,179***	
	(339.6)	
CA Factor 1 (All Questions Included. Roughly Equal Weights)	-	184.2*
		(109.0)
CA Factor 2	-	396.2
		(640.5)
CA Factor 3	-	56.60
		(143.1)
Exogenous Covariates		
OWNSLAND	32.91	14.14
	(41.13)	(68.69)
LANDSIZ	26.38	12.50
	(34.84)	(81.65)
CRRGTHS	43.10	-68.11
	(42.10)	(86.18)
LIVESTOK	38.18***	64.39***
	(12.22)	(23.20)
GIVENLOAN	-31.05	113.7
	(79.45)	(125.7)
FRACTIONBOYS	291.0	704.5**
	(188.1)	(326.1)
FRACTIONGIRLS	532.5**	654.8*
	(240.9)	(372.0)
FRACTIONFEMAD	326.2*	399.1
	(185.2)	(368.3)
FRACTIONMALAD	173.1	297.1
	(203.0)	(438.9)
FAMSIZE	12.80	45.86
	(18.89)	(33.45)
MAXEDUCHH	-1.754	5.324
	(7.758)	(11.37)
HEADSEX	16.52	-48.92
	(57.63)	(105.5)
HEADAGE	0.954	5.557
	(1.616)	(3.786)
HEADEDUC	15.72	16.14
	(11.11)	(15.17)
DISTTOWN	-0.657	1.313
	(0.417)	(1.769)
DISTROAD	0.529	-1.927
	(0.631)	(2.359)
EXPLNSZ5YRS	35.16	30.49
	(54.66)	(82.47)
TRUSTGOT	8.500	132.7
	(41.01)	(90.29)
NUMDAVISIT	26.90	33.16
	(19.77)	(29.00)
FARMERTOFARMER	37.70	127.2*
	(52.18)	(75.46)
IMPROVEDSTOVE	32.83	70.06
	(53.89)	(72.27)
MILLS LAMBDA	-4.472e+10**	1,282**
	(2.256e+10)	(579.4)
CONSTANT	-812.1***	-1,481**
	(248.5)	(590.7)
Observations	1,080	828
Wald X^2	X^2 (22) = 78.27	X^2 (24) = 45.56
	Prob > X^2 = 0.000	Prob > X^2 = 0.005

Robust, Bootstrapped (1000 Repetition) Standard Errors Adjusted for *Kebele* Clustering, because households in the same villages are likely to have common unobservable characteristics and circumstances. *Kebele* is often translated as "peasant association" and includes several village settlements. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The selection equation is a probit model of whether any tree planting occurred using all exogenous variables as explanatory variables. We find results that are highly consistent with previous findings, with the overall CA index and factor 1 once again positively and significantly related to tree planting. Covariate results are also similar to those of other models.

Table A3. Descriptive Statistics for Covariates, Expected Sign and Reason for Including in Models of Tree-Growing

Variable label	Mean	Std. Dev.	Min	Max	Expected Sign and Reason for Including
EXOGENOUS COVARIATES					
Wealth Endowments – with imperfect credit markets, own wealth finances trees					
Land size in hectares **(LANDSIZ)**	1.15	1.02	0	6.02	(+) Wealth indicator; complements trees
Corrugated roof (1 if yes) **(CRRGTHS)**	0.77	0.42	0	1	(+) Wealth indicator
Livestock in TLU (tropical livestock units) **(LIVESTOK)**	3.84	3.25	0	31.19	(+) Wealth effect; animals fed by trees
Gave loan in last year (1 if yes) **(GIVENLOAN)**	0.10	0.29	0	1	(+) Indicator of liquidity
Labor Endowments – labor complements trees, but investing in on-farm trees saves labor					
Family size **(FAMSIZE)**	5.48	2.18	1	15	(+/-) Labor complement or substitute
Fraction of boys (6–14 years) **(FRACTIONBOYS)**	0.15	0.15	0	0.67	(+) Higher dependency incents labor saving
Fraction of girls (6–14 years) **(FRACTIONGIRLS)**	0.14	0.15	0	0.75	(+) Higher dependency incents labor saving
Fraction of female adults (>14 years) **(FRACTIONFEMAD)**	0.32	0.19	0	1	(+/-) Labor complement or substitute
Fraction of male adults (>14 years) **(FRACTIONMALAD)**	0.31	0.19	0	1	(+/-) Labor complement or substitute
Human Capital – education and experience may complement trees					
Max. years of education of household members **(MAXEDUCHH)**	5.14	3.71	0	16	(+) Education
Gender of head (1 if male) **(HEADSEX)**	0.83	0.38	0	1	(+/-)
Age of head in years **(HEADAGE)**	51.05	14.87	20	97	(+) Experience
Years of education of head **(HEADEDUC)**	0.81	2.21	0	12	(+) Education
Market Access – trees may be planted for sale and therefore proximity may increase planting					
Walking distance to town in minutes **(DISTTOWN)**	82.76	58.32	0	280	(-) Market access
Walking distance to road in minutes **(DISTROAD)**	38.42	37.25	0	180	(-) Transport costs
Land Tenure – trees are long-term investments and are therefore promoted by tenure security					
Believes the land belongs to household **(OWNSLAND)**	0.44	0.50	0	1	(+)
Expects to lose land in next 5 years (1 if yes) **(EXPLNSZ5YRS)**	0.19	0.39	0	1	(-)
Information – tree planting often requires silvacultural and market information to be successful					
Trusts people in village **(TRUSTGOT)**	0.67	0.47	0	1	(+) Trust encourages information search
Number of visits by extension agent **(NUMDAVISIT)**	0.94	1.32	0	4	(+) Extension agents offer silvacultural info.
Farmer to farmer extension (1 if yes) **(FARMERTOFARMER)**	0.36	0.48	0	1	(+)
Technological Substitute – improved stove reduces wood consumption and substitutes for trees on-farm					
Uses improved stove (1 if yes) **(IMPROVEDSTOVE)**	0.20	0.40	0	1	(-)
EXCLUDED EXOGENOUS VARIABLES – EXPECTED RELATIONSHIP IS WITH CA VARIABLES					
Village-Level Survey					
Woreda* numerical indicator **(WOREDA)**	N/A				? Location fixed effects.
Village Population density **(POPDENSITY)**	2.79	2.21	.55	8.78	(+) Higher population density encourages social coordination
Forests are managed within Kebele **(KEBELEMGT)**	.513	.500	0	1	(+) Lower-level administration of forests reduces transactions costs and increases autonomy.
Community forestry dummy **(COMMUNITYFOREST)**	0.79	0.41	0	1	(+) Forest perceived as community forest imply ownership autonomy making easier to coordinate
Household-Level Survey					
Years Respondent Has Lived in Village	20.66	12.26	0	78	(+) More years in village improves knowledge of norms, increases influence and increases perception of coordination

* Woreda is an administrative district that is roughly comparable to a county.

Table A4. First Stage OLS Regression

Dependent Variables →	**Equally Weighted CA Index**	**CA Factor 1**	**CA Factor 2**	**CA Factor 3**
Exogenous Covariates				
OWNSLAND	0.0219**	0.116***	-0.0460	0.0660**
	(0.00718)	(0.0343)	(0.0339)	(0.0228)
LANDSIZ	-0.0157	-0.0910	0.0957***	-0.0386
	(0.00987)	(0.0504)	(0.0200)	(0.0259)
CRRGTHS	-0.0226**	-0.120***	0.0385	-0.0971**
	(0.00768)	(0.0367)	(0.0462)	(0.0388)
LIVESTOK	0.000773	0.00204	0.0121	-0.00741**
	(0.00126)	(0.00565)	(0.00749)	(0.00281)
GIVENLOAN	0.0335***	0.175***	-0.0323	0.0183
	(0.00778)	(0.0430)	(0.0409)	(0.0398)
FRACTIONBOYS	-0.0181*	-0.0799	-0.0950	0.0219
	(0.00913)	(0.0445)	(0.0711)	(0.0333)
FRACTIONGIRLS	-0.0243**	-0.114**	-0.0635	0.0606
	(0.00971)	(0.0492)	(0.0721)	(0.0599)
FRACTIONFEMAD	-0.0347*	-0.149	-0.213*	0.138
	(0.0171)	(0.0870)	(0.102)	(0.111)
FRACTIONMALAD	-0.0105	-0.0157	-0.305**	0.129
	(0.0251)	(0.119)	(0.106)	(0.0730)
FAMSIZE	0.00587**	0.0317**	-0.0157**	0.0118
	(0.00212)	(0.0107)	(0.00566)	(0.00673)
MAXEDUCHH	0.000419	0.00143	0.00358	-0.000960
	(0.000746)	(0.00335)	(0.00654)	(0.00259)
HEADSEX	0.000355	0.00468	-0.0299	0.0509*
	(0.00598)	(0.0301)	(0.0245)	(0.0260)
HEADAGE	0.000234**	0.00102**	0.00116	-0.000487
	(8.20e-05)	(0.000391)	(0.000727)	(0.000404)
HEADEDUC	0.000435	0.00260	-0.00335	0.00550*
	(0.000420)	(0.00213)	(0.00195)	(0.00282)
DISTTOWN	1.30e-05	0.000316	-0.00221*	-0.00156*
	(0.000124)	(0.000573)	(0.00111)	(0.000721)
DISTROAD	0.000126	0.000155	0.00316**	0.000501
	(0.000227)	(0.00129)	(0.00133)	(0.00120)
EXPLNSZ5YRS	-0.0164**	-0.0873**	0.0275	-0.0395***
	(0.00637)	(0.0319)	(0.0181)	(0.0114)
TRUSTGOT	0.00661***	0.0281**	0.0399**	-0.0114
	(0.00189)	(0.00887)	(0.0154)	(0.00909)
NUMDAVISIT	-0.00894***	-0.0420***	-0.0235**	-0.00375
	(0.00184)	(0.00929)	(0.0103)	(0.00947)
FARMERTOFARMER	-0.00867	-0.0395	-0.0277	-0.0152
	(0.00517)	(0.0247)	(0.0225)	(0.0143)
IMPROVEDSTOVE	0.0121**	0.0612**	-0.00191	-0.0162
	(0.00411)	(0.0223)	(0.0184)	(0.0225)
Excluded Exogenous Variables				
WOREDA	-0.00583	-0.0320	0.00385	-0.0213
	(0.00893)	(0.0476)	(0.0455)	(0.0177)
POPDENSITY	0.0184	0.0944	0.0148	0.0317
	(0.0106)	(0.0537)	(0.0196)	(0.0183)
KEBELEMGT	0.122**	0.586**	0.0975	-0.199
	(0.0429)	(0.219)	(0.189)	(0.154)
YEARS	0.00120***	0.00643***	-0.00225**	0.00339***
	(0.000312)	(0.00160)	(0.000812)	(0.000851)
COMMUNITYFOREST	0.0708	0.384	0.0221	-0.288
	(0.0606)	(0.309)	(0.189)	(0.192)
CONSTANT	0.211**	-0.929**	0.0188	0.342
	(0.0759)	(0.393)	(0.189)	(0.224)
Observations	1,106	1,106	1,106	1,106
R-squared	0.57	0.582	0.373	0.565

Unless otherwise noted, robust standard errors in parentheses ** p<0.01, ** p<0.05, * p<0.1 Clustering is at the *kebele* level, because households in the same villages are likely to have common unobservable characteristics. *Kebele* is often translated as "peasant association" and includes several village settlements.

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