Seeing REDD: A Microeconomic Analysis of Carbon Sequestration in Indonesia

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Abstract

Reducing Emissions through Deforestation and Degradation (REDD) is one of the few interventions to mitigate global warming being pursued at a global scale. Its implementation requires knowledge of the willingness to accept land use change contracts and its effectiveness requires its application over large areas. In this paper we use data from Sumatra, Indonesia, to contrast two approaches to the elicitation of the supply curve for carbon sequestration: a reverse uniform auction and a budgetary analysis of opportunity costs. The analysis of the supply curves highlights that individual preferences, namely time and risk preferences, but not the opportunity costs, play a significant role in determining the price villagers are willing to accept land use contracts that promote high carbon sequestration systems. The results also indicate that there are significant gains from trade to be made through the implementation of this program, as the price requested by land users in the setting we study is much lower than current carbon prices. Finally, we analyse possible targeting techniques, concluding that a combination of geographic and self selection targeting would be the most efficient way to implement this policy.

1 Introduction

Throughout the last decade there has been an increased interest, both scientifically and politically, on global warming as a result of greenhouse gas (GHG) emission (Meinshausen et al., 2009). The 2007 report of the United Nations International Panel on Climate Change (IPCC) forecasted an array

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of negative consequences that will occur as a direct result of these changes, including an increase in volatility of weather that will result in hardships to agricultural production (Nath and Behera, 2010) and a rise in global sea level that will lead to the displacement of millions of people (**?**).

The economic consequences of climate change, and the possible mitigation and adaptation policies are the focus of a wide debate, that was recently summarised in World Bank (2010). From these discussions comes a growing consensus that using the forest sector, either by storing carbon or by preventing its release into the atmosphere, is an attractive and perhaps indispensable way of achieving the objective of reducing GHG emissions into the atmosphere, both due to its low cost (Tavoni et al. 2007) and the relative importance of deforestation as the third major source of GHG emission, accounting for approximately 12% of global emissions (Corbera et al. 2010).[1]

The Reducing Emissions from Deforestation (RED) mechanism was first proposed as a supplementary tool for the Clean Development Mechanism (CDM) of the Kyoto Protocol at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP) 11 in Montreal in 2005. Since then, this policy has been actively supported by governments of many developing countries where forests represent a large proportion of land use and where deforestation is historically important. In the case of Indonesia, the country with the second largest rate of deforestation in the period 2000-2005, it is estimated that a 50% reduction in deforestation ac-

[1] Until recently deforestation accounted for an estimated 18% of global emissions. However, the calculation involved incorrect initial measurements and assumptions and it has since been re-calculated.

tivities in that period could be worth between US$2.5 and 4.5 billion per year (Wardojo et al. 2008).

Two other observations reflect the widespread interest in this mechanism. The first, again from Indonesia, is that there were, in early 2010, more than 20 voluntary REDD projects under development, corresponding to a total area of around 30 million hectares of forest (UN-REDD 2010). The diversity of mechanisms for implementation and monitoring exemplify the variety of actors interested in these interventions, with some of the bigger projects being funded by major financing institutions and with a major involvement from the Government of Indonesia.[2] The second observation is about the increasing global interest in such a mechanism. Implementing REDD was one of the few areas where a consensus was reached during the 2009 Copenhagen summit, leading to an increased interest in a discussion of how to define the contracts underlying such transfers for carbon sequestration. This has led to several pilot projects, as mentioned above, and also to the expansion of the type of contracts being considered in this policy that now, under the new designation of REDD+, include reforestation and afforestation in addition to conservation contracts[3].

[2]REDD activities in Indonesia have recently received a significant boost, with the development of the Rimba Raya project, covering nearly 100,000 ha of peat swamp forest in Central Kalimantan, the first with an officially approved auditing process to measure the reductions in emission due to the project. The auditing mechanism is now undergoing third party verification which will enable the calculated carbon reductions to be sold as carbon credits on the voluntary carbon markets. This will increase the value of REDD projects, aiding REDD in surpassing the final hurdle to transform the policy from a public and NGO funded idea, to a private, economically viable investment (Fogarty and Creagh, 2010).

[3]Afforestation refers to the conversion of land that has not recently or ever been classified as a forest into a forested area. Reforestation refers to the conversion of a previously cleared forest back to forest use. The focus on conservation contracts, in which forest owners would receive a payment high enough to deter them from converting forest land

Central to the implementation of this mechanism, in addition to property rights and feasible monitoring and certification methods, is the ability to elicit an accurate willingness to accept (WTA) amount for individual land owners to change their use of land from low carbon sequestration to high carbon sequestration uses, while avoiding adverse selection and possible collusion. This paper addresses this problem by comparing two approaches, a revealed preference approach through a sealed-bid, reverse uniform price auction (Lusk and Shogren 2007), and a budgetary approach, that uses methods similar to those proposed by, for example, Antle and Valdivia (2006) and Immerzeel et al. (2008).

The auction has the comparative advantage that to bid the true reserve price is a weakly dominant strategy for participants, due to the ex-ante definition and advertising of a budget constraint that limits the pool of contracts to a finite number of winners. Any bidder will then have to weigh the value of the payment requested, that is a positive function of the bid, against the probability of winning the contract, which is a decreasing function of the bid. Conversely, the auction also acts as an incentive to not underbid, as this would have negative implications on expected future profits (Lusk and Shogren, 2007)[4]. Auctions have been used in developing countries in the design and implementation of afforestation contracts in Vietnam (Bui

to other uses rapidly ran into the reality of poorly defined property rights in many forests throughout the developing world, with conflicting local and governmental claims over the same resources and the consequent difficulty in clearly defining and enforcing such contracts. Reforestation or afforestation projects are to be established on land that, because cleared, has some recognised property rights (Wunder et al. 2008).

[4]Because the realisation of such negative profits could increase the probability of default on the contracts (or, at least, of costly litigation about its terms), it is also in the interest of those who are paying for such contracts that bidders do not underbid.

Dung The and Ngoc 2008) and of contracts for soil conservation in Sumatra, Indonesia (Jack et al. 2009). Similarly, there is a large body of work that discusses the use of auctions in the implementation of payments for environmental services in developed countries (see, for example, Stoneham et al.(2003) or Classen et al.(2008)).

Despite their theoretical advantages and the growing experience with their use in the field, auctions are time consuming and expensive to implement, raising questions about the feasibility of basing the implementation of REDD+ on its generalised use. If the WTA elicited through an auction does not differ significantly from the values obtained through simpler approaches, as those based on a budget analysis, the use of the latter could be justified by their relatively lower cost, as suggested by Antle and Valdivia (2006).

(Leimona et al., 2007).

The remaining sections of this paper proceed as follows. The next section presents the setting and the data used in this paper, with reference to the three techniques used in the analysis: a household survey, that paid special attention to the collection of information on the costs and returns associated with current land uses, namely rubber (allowing us to indirectly estimate the opportunity costs of any change in land use); an experimental auction (where WTA specific contracts designed to increase carbon storage is directly elicited) and, simultaneously, a behavioural field experiment designed to elicit information on risk and time preferences. The results of the two approaches used to obtain a value for WTA for land use contracts that promote the change from low to high carbon sequestration (auctions and budgetary estimates) are then presented and contrasted in Section 3, allowing us to conclude that there are significant differences between them: in particular, we show that the values elicited through the auction are substantially lower than the ones based exclusively on a budgetary analysis of current land use.

Although auctions can be defended as the best way to elicit WTA for contracts such as the ones we study here, they are limited in their ability to provide information on the motives behind the bid, in particular which individual bidder characteristics and preferences had an influence on the final bid amount. In Section 4 we use the information collected through the household survey and the behavioural field experiment to analyse the determinants of the bids. In Section 5 we discuss the implications of this work for the functioning of the REDD+ program, in particular matters regarding the targeting of these interventions. We conclude in Section 6.

2 Methodology

In order to understand what determines the willingness to accept for contracts that promote reforestation, one of us (Skidmore) collected original data using a variety of techniques. The first was a time preference experiment and household survey, designed to collect information on household structure, assets and economic activities, with particular attention being paid to the costs and returns of the agricultural activities and, within them, the main cash crop, rubber. Additionally, household heads were invited to an experimental auction for a reforestation contract during which they were also asked to participate in a behavioural field experiment designed to elicit risk preferences. All these methods were used in two villages, Senamat Ulu and Tebeing Tinggi, in the province of Jambi of central Sumatra.

As argued by Gaveau *et al.* (2009), site choice is perhaps the most important factor when considering the capacity of REDD+ to reduce emissions, as some sites are so remote that the decision to introduce a REDD scheme won't have an effect on emissions due inaccessible nature of the site: for payments to be the most effective they should go to land that is under threat and has the ability to sequester high levels of carbon. The two sites were chosen due to their location in areas where local farmers have been encroaching into the native forest, converting land from high to low carbon storage covers, with large and small tracts of forest replaced by palm oil, coffee and, particularly, monoculture rubber plantation[5]. One figure easily illustrates the scale and the importance of this process of land change in the context of CO_2 emissions and climate change. In the neighboring Riau Province, the estimated mean annual CO2 release between the years of 1990-2007, due to deforestation was estimated at 0.22 Gt, the equivalent to 58% of Australia's estimated annual CO_2release (Uryu et al. 2008).

However, there are also differences between the two sites, with one of them (Tebeng Tinggi) located 50km closer to the regional centre than the other. We expected that difference, in a context of high transportation costs such as Central Sumatra, to have profound consequences for livelihood choices and, consequently, for the potential interest in a REDD+ scheme.

The household survey was designed to elicit detailed information on the

[5]The area is also close to the proposed area of the second demonstration site for the Indonesia – Australia Carbon Partnership. The first demonstration site, Rimba Raya, was mentioned in footnote 7 and is located in Kalimantan.

individual's socio-economic conditions as well as capital and labour constraints and information regarding the agricultural plots. [6] Table 1 presents some descriptive statistics for the households whose heads attended the auction.

The risk preference experiment involved a choice between lotteries with different expected payoffs and different variances similar to the approach pioneered by Holt and Laury (2002). A varying amount of red and blue tickets were combined in a lottery, and associated with different pay-offs depending on which option the individual selected for that round. The game is illustrated in table 2 and was designed so that risk neutral individuals would switch between A and B at the fifth choice. In order to minimize the possibility that the choices would not correspond to their preferences, each participant was informed that one of the choices would be arbitrarily selected *ex post* to determine the amount of winnings each individual would receive from the game.

The degree of risk aversion was calculated by observing in which round (if ever) the respondents changed their selection from option A to option B and the associated number of safe choices[7]. The distribution of risk preferences is presented in Table 3

Roughly 45 percent of the respondents are concentrated in the central categories, being classified between slightly risk-loving and slightly risk-averse. Our data shows that the distribution of preferences is more or less

[6] The survey was designed and pre-tested in December 2009, following several meetings with village groups intended to ensure a better understanding of the issues regarding the implementation of such contracts. It was fielded during three weeks in February 2010.

[7] A safe choice is one in which the expected value of the option chosen was greater than the expected value of the opposing option.

evenly spread between risk averse and risk lovers, with each group representing roughly 20 percent of the respondents.

The other behavioral parameter about which we collected information through field experiments was the private rate of discount. The elicitation of the time preference was done through a game that involved the participants choosing between the option of a specified amount of money now and a different amount of money in the future. There were 6 such options that resulted in a personal time preference rate for each individual depending on which time period they became indifferent between the two values of money. The results are show below in Table 4indicates that around 74 percent of respondents hold a discount rate at or above 0.50, with the percentage of respondents continually decreasing as a function of the discount rate.

In addition to the household survey, a silent auction was carried out in each village, with all the respondents of the household survey invited to participate. Although some household heads chose not to participate, it was not possible to detect any difference between the two groups that is statistically significant at the usual levels of significance[8].

Following standard practice, each individual was given an identification number upon arrival. This was followed by an introduction of the research team and the objectives of the auction. Participants were also encouraged to act as if in a real auction, in particular by keeping their own budget constraints in mind as well as the rules of the auction that were then explained.

[8]To test for differences between the groups, we conducted unpaired t-tests of equality of means for the variables for which we collected information in the household survey. There were no statistically significant differences. The detailed results are omitted but are available from the author upon request.

Participants were told that they would be bidding on reforestation contracts, whereby they would alter their land from its current use (as mentioned above, mostly rubber monoculture), to a fruit-based agroforest system with which the respondents were familiar.[9] The contracts were specified as lasting 10 years and the payments per hectare[10] were to occur in equal, annual instalments, the first of which would accrue upon completion of the land conversion.

A budget constraint of 30 million Indonesian rupiah per year was announced and participants told that the contracts would be awarded to the lowest bidders who fell within the budget. The auction would proceed through a certain number of rounds of bidding (fixed a priori, but not revealed to the participants), with each round lasting 60 seconds, during which participants could change their bid if they wished to. Participants were then encouraged to ask any questions, after which there would be no communication.

At the close of each round, and after all the bids were collected and recorded, we proceeded by identifying which ones fell within the budget constraint after which the identification numbers of the respective bidders were read aloud. This allowed for the participants to understand whether their

[9]The fruit-based agroforest system, once established, requires little in terms of labour and capital inputs, containing a variety of local fruit trees, in combination of natural forest growth. See Swallow et al. (2007) for a more complete description of this system.

[10]Antle et al. (2001) argue that, due to spatial heterogeneity, it is preferable to base contracts on per tonne of carbon rather than per hectare of land when designing such a contract. However, due to the relative spatial homogeneity within each village, we used the per hectare contracts as they are simpler. During pre-testing, it became clear that a discussion of other type of contracts would require lengthy explanations during the period leading up the auction in order to insure that villagers understand the contract and to answer questions regarding the perceived difficulties of any future monitoring process.

bid fell within the finite budget constraint and, eventually, reassess their bid. Due to the limited budget, only around 10% of the participants were awarded contracts at the end of the auction procedure. Each villager who fell within the budget constraint was awarded a uniform price per hectare, determined as the price of the highest bid that fell within the finite budget.

As with any other contract design, the key problem with contracts for Payments for Environmental Services (PES) is the presence of asymmetric information (Ferraro 2008). In this situation each landowner has a private value of the good at hand (in this case, the reforestation project) that is known solely by him/her and has no incentive to reveal it to a potential buyer of such good. Instead, and conditional on signing the contract, s/he will be interested in maximising the amount of information rents that can be extracted from the uniformed buyer (Salani, 1997).

The auction's mechanism added strong incentives for individuals to reveal their reserve price as opposed to an inflated WTA figure. The limited budget constraint combined with a sealed bid mechanism eliminates the possibility of strategic collusion and results in the (weakly) dominant strategy being to undercut other bidders, as long as one's bid remains greater than, or equal to, their reserve price. Additionally, and due to the fact that the contracts are only awarded to participants whose bids fall within the budget constraint, the auction mechanism clearly diminishes the importance of any strategic bias that could occur in the form of protest bids, where individuals will deliberately mislead the experimenter as to their true reserve price, as such bids would risk being outside the set of choices by the auctioneer. Both characteristics of the auction act as a disincentive to strategic bias and result in a weakly dominant strategy of biding their reserve price (Ausubel 2003). We now move to a comparison of the results regarding the supply of reforestation contracts coming from the two approaches mentioned above, the auction and the budgetary analysis based on the data collected through the household survey.

3 The supply of reforestation contracts

3.1 Results from the auction

The supply of land for reforestation contracts, in hectares per USD per tonne of carbon, [11] as elicited through the auction, is graphically presented in figure 1. The median price per hectare is around US$250. When converted into USD per tonne of carbon, this corresponds to a median bid of $3.40, with a standard deviation of $9.89. Given our budget constraint, the auction would lead to the contracting of 1890 tonnes of carbon.

These aggregate values tell us very little with respect to other aspects that may matter for a mechanism such as REDD+, namely its spatial incidence. Although our study is somewhat limited in that analysis, we can separately analyze the supply function in each village. The differences between the two villages are striking: it is evident that bids in Senamat Ulu (the village further away from the urban center) exhibit a noticeably lower mean and median ($3.12 and $1.74 per tonne of carbon, respectively) when

[11] The additional carbon sequestered from this transformation was approximated by the difference in carbon content between the monoculture rubber plantation – the only use of the plots brought to auction – and the carbon content of the agro-forest system, taken from Swallow et al. (2007). The Exchange Rate, at the time of the Auction was $US1=IDR 9450.

contrasted with Tebeng Tinngi ($13.07 and $10.08 per tonne of carbon, respectively). These differences in the price of carbon were matched by an increase in the variability in the amounts bided: in Tebeng Tinngi, the range of bids was $41.82, almost the double of that observed in Senamat Ulu ($22.62). SU and TT had standard deviations of $4.03 and $11.46 respectively. These differences are made even more evident in figure 2.

Although the supply functions represented in figures 1 and 2 give us a good indication of the willingness to change land use, as promoted under the contracts being auctioned, they lack the ability to explain what factors influence an individual's reserve price. A natural starting point it to search for differences in expected profits between current land use (rubber monoculture) and contracted land use (agro-forestry) as an explanation for willingness to accept such contracts. In addition, and as mentioned above and by others, if largely coincident, such analysis of plot level costs and returns provides a simpler approach, which can be preferred if the implementation costs of auctions such as the ones described in section 2 are too high.

One of such techniques is a simple budgetary analysis, where secondary data is used to elicit a supply function of ecosystem services. [12] This approach contrasts two alternative land uses: monoculture rubber (a) and fruit-based agroforest (b). Each use has a specific value (v) associated with it, $v(p, s, z)$, where p is output price, s is site index and $z = a, b$ the two alternative uses. Assuming that landowners are profit maximisers, monoculture

[12] This technique is similar to the Minimum Data Approach (Antle et al. 2006), however due to the geographic homogenous nature of the sample region a budgetary analysis is more appropriate.

rubber would be grown when:

$$\Psi(p,s) = v(p,s,a) - v(p,s,b) \geq 0 \tag{1}$$

given that $v(p,s,b)$ represents the opportunity costs of current use and $v(p,s,a)$ is the value of current use. - this takes into context the revenue gained from the auction plot, and the costs incurred through production, such as; hired labour, costs of other inputs (seedlings, fertiliser, pesticide, herbicide and fungicide) and temporary or hired capital (non-sunk costs) [13].

The private supply of ecosystem services will equate to zero as long as the value of monoculture rubber is greater than the value of fruit-based agroforest. The budgetary approach elicits a supply curve based on the assumption that land will be converted to agroforest systems at a value of p_b that originates a value that is at least equal to the currently being obtained in this land. This value is adopted as the best estimate of costs and returns assuming limited access to primary data. In a different context, Antle et al (2006) argue that a similar approach leads to results that are roughly the same as those elicited through any revealed preference technique such as a silent auction and justifies these results with the natural assumption that participants will value their plot rationally and that all the costs and returns are being taken into account, implicitly assuming a more or less complete set of markets.

[13]Due to the imperfect labour market and relatively low opportunity cost of labour, it is difficult to assign a quantitative value for each day (or hour) of a farmers labour within their own plot. Another model estimating household labour value equal to the market rate of labour was created. The results did not alter any of the main findings and recommendations of this report. The results of this model are available upon request.

The results obtained with this approach are summarized in the supply curves presented in figure 3 (both villages pooled) and figure 4 (disaggregated across villages). Figure 3 represents the horizontally vertically summed supply curves of both villages. The prices that would need to be paid range from -$4 to $88, with a standard deviation, mean and median of $24.8, $22.3 and $12.4 respectively. [14] The results for the village specific supply curve show a pattern that is similar to the one revealed by the auction mechanism, reflecting the significant differences in revenue and costs between the two villages. Although the two functions have similar ranges ($81.9 and $78.3 per tonne of carbon) and are quite similar in terms of mean ($20.5 and $20.1) and median ($12.9 and $11.3) price of carbon, they differ substantially in the quantity of carbon that can be bought at a specific price. For example, at a price of $20 per tonne, 5345 tonnes can be sequestered in Senamat Ulu (the village that is further away from the urban areas), a value that is approximately 60% higher than the amount that could be sequestered in Tebeng Tinggi (3395 tonnes).

As a first step towards the understanding of whether the two approaches provide similar conclusions regarding the implementation of such land use contracts, we directly compare, in figure 5, the estimates presented in figures 1 and 3. For carbon prices above 1 USD/tonne, the two curves are clearly different: for prices around 20 USD/tonne, for example, the budgetary approach would suggest that we would be able to sequester 8310 tonnes, while the auction suggests that we could sequester an amount that is almost the double of this figure. Clearly, some of the assumptions underlying the bud-

[14] All values are in $US/per tonne of carbon.

getary approach seem too strong to explain the behaviour elicited through revealed preference methods. There are no significant differences in this conclusion once we disaggregate these results across villages (figure 6), although it is worth noticing that the differences between the two approaches are much larger in the more isolated village (Senamat Ulu).

4 Explaining auction bids for contracts on land use changes

The standard approach underlying the definition of REDD+ payments is to assume that the amount to be paid to current land users to reforest their land will equate to the opportunity cost of the resources used, as estimated in the budgetary analysis presented in the previous section. As shown in the previous section, their revealed behaviour can be quite different, with significant consequences regarding the costs of this mechanism, suggesting that some of the assumptions underlying the budgetary approach may not be adequate to explain the behaviour that we observe in the auction.

In order to explain the source of the differences between the two approaches, we estimated the relation between the value of the bid and several individual characteristics, including data usually collected through household surveys and also the behavioural parameters elicited through the field experiments that we ran. Importantly, we include the opportunity costs among the explanatory variables for this decision. If bidding decisions were essentially the same as opportunity costs, then we would expect that this variable would be important in explaining this decision, both in the economic and statistical sense. The estimates are presented in tables 5. In column 1 we restrict the estimation to those variables that are usually collected in household surveys while in column 2 we include, as additional regressors, our measures of preferences towards risk and time.

The first and most obvious conclusion from the estimates presented in column 1 is that, once we control for village fixed effects, the variables measuring the opportunity costs of land use change (namely, budgetary value, as defined in the previous section, and plot characteristics) do not seem to matter for the actual bids submitted by our respondents. The second conclusion is that socioeconomic characteristics such as wealth (proxied by buffalo ownership) and length of residence in the village, are statistically significant, yet their coefficient is relatively small, especially when compared with the effect of living closer to markets: for example, it would require almost 20 extra years of permanence (or four extra buffalos, close to the maximum observed in our data) for the bid to overcome the effect of living in Senamat Ulu. There are a number of key reasons as to why the geographic location of the village has such a large effect on the bid amounts. Namely, Senamat Ulu is further distanced from the regional centre of Muara Bungo. This larger distance to the regional centre makes it more expensive to transport crops and commute for non-farm jobs. Additionally, the terrain surrounding Senamat Ulu is much steeper and more difficult to access than Tebeng Tinggi. Secondly, market exposure could be one of the underlying determinants of the variation in the final auction amounts. Tebeng Tinggi is the location for the regional rubber auction, allowing the villages to accurately assess the present day value of their crop on a regular basis. Although we postpone the discussion of targeting until the next section, it is immediately clear that these results raise serious questions about the possibility of more detailed targeting than at geographical level.

This seems to be compounded by the results shown in column 2, where we include our measures of individual preferences. There are two main comments about these results. The first is that the estimates of the effect of other regressors do not change, either in statistical significance or in magnitude, suggesting that behavioural field experiments add information that goes beyond what can be accounted through correlates of such preferences (such as wealth, as measured by ownership of livestock, for example) that are usually collected in household surveys.

The second is that preferences seem to have an important effect on the value of the individual bids. There are two explanations for this effect. The first is that this simply reflects omitted variables (poverty, for example, as discussed in Lawrence (1991)), although that seems hard to accept given that we already control for a wide range of socioeconomic characteristics, including wealth and education. The alternative explanation is that such preferences do matter independently and that they can be rationally linked with lower bids.

For example, given the structure of the contracts, and the schedule of the first payment immediately after the conversion, it makes sense that bidders would prefer the land use contract to other investments with a longer time horizon, namely rubber which was the sole use of the plots brought to the auction. Similarly, a certain payment (such as the one offered by the proposed contracts) is more attractive than a risky one (such as the current land use) for risk-averse bidders, driving the observed result that the higher the levels of risk-aversion the lower the value of the bids.[15] If this interpretation is correct, it can only raise greater difficulties to the targeting of this intervention.

5 Opportunities and challenges to the implementation of REDD+

The previous two sections identified two aspects that seem important when considering the implementation of REDD+: the willingness to accept contracts that promote high carbon land uses (measured in two different ways, the bids submitted to an experimental field auction and a budgetary analysis) and the underlying determinants of this willingness to accept such contracts, as revealed in the experimental auction, in particular the apparent lack of importance of opportunity costs and the central role of individual preferences in determining their bids. These results create both an opportunity for implementing REDD+, in the form of the shape of the supply function, and a challenge, due to the difficulty in selecting who to award such contracts. We discuss them in what follows.

[15] The auction design could have a multiplier affect on a non-risk neutral individual. A more risk seeking individual will be more likely to offer a higher bid (or lower depending on the auction design) in any auction situation (as this will decrease their chance of winning, while increasing their chance of a larger pay-off) than a risk averse individual. Through the experimental design it is difficult to disaggregate the individual effect of taking part in the auction has, as opposed to the singular effect of adopting the reforestation contract.

5.1 Differences in carbon prices and the opportunity for smallholder carbon forestry

The purpose of REDD and other GHG abatement policies is to reduce the amount of carbon in the atmosphere. Generally, in order for a policy to be (politically) effective it must first be economically effective, in other words the cost of REDD (per tonne of carbon abated), must be competitive with other carbon reducing technologies and the voluntary carbon markets. We discuss that relation by focusing on the largest of such markets, that of the European Union (EU).

Assuming that the EU carbon market will rebound to where it was prior to the global financial crisis, the pre-GFC figures of early 2008 can be a good indication of where the European Climate Exchange and the price of carbon is headed in the future.[16] The mean price of carbon between 31/01/2008 and 11/06/2008 was US$37.50 (23.83)(ECX 2010). This can be contrasted to the median price elicited through the silent auction, US$3.40 to suggest that there significant potential gains from trade, even if REDD+ projects are implement in smallholder plots.

Throughout early 2010, and reflecting fluctuations in demand and supply, the price of carbon in the EU voluntary market has fluctuated between US$17.4 and US$12.6.[17]. These prices are due to increase in the near future

[16]The 2010 price may be a less reliable indicator of future prices, given the effects of the global financial crisis and the deflationary pressures that it may have created on the European Climate Exchange.

[17]When considering the future prices of carbon within the EU, it is important to take into to account the current fiscal situation. Europe has significant issues with debt at the in 2009, had a negative 4.2% growth rate across the 27 member countries. Throughout this year it is forecast to have a growth rate of 1%, then continuing on in 2012 with a growth rate of 1.9%. Debt is also an issue, but is currently declining, with the EU27

due to the EU's policy decision to linearly reduce total quantity of carbon allowances from 2013 by a factor of 1.74% (European Commission 2010). This further underlines relative cost effectiveness of this mechanism.

As it is known, one major issue with REDD is the associated cost of implementation and monitoring, that numerous studies internationally currently placed in the range US$4-5 per tonne, although some studies have presented varied estimates.[18]. Close to our study area, a recent study by Cacho et al.(2005) that accounted for an exhaustive list of different types of transaction costs (search, negotiation, verification and certification, implementation, monitoring, enforcement and insurance) suggested that, taken together, and in the context of smallholder carbon forest, such costs would not damage the feasibility of the policy.

That means that, even without assuming that such costs can be expected to decline over the next decade due to the increased availability and affordability of satellite technology, there is still room for potential gains from trade, making this policy an economically viable alternative to carbon reduction. That said, further studies are probably needed before a firm conclusion about the general feasibility of smallholder carbon forestry can be reached and, if transaction costs cannot be easily reduced, the solution may be to contract with those land owners with lower WTA, raising the importance of targeting, a question we discuss next.

current account standing at -34.8 billion. These factors combined have had a deflationary effect on the price of carbon, as EU demand has shrunk, so too has the demand for carbon.

[18]Kindermann, Obersteiner et al. (2006) estimated around $6/tonne, Sathaye, Makundi et al. (2005) estimated around $5/tonne and Greig-Gran (2006) uses $4–$15/ha/year based on PES programs in place in Costa Rica, Mexico, and Ecuador.

5.2 Targeting REDD+ interventions

If auctions prove too expensive to be used in a larger scale and, as we have shown previously, measures of opportunity costs do not provide an accurate measure of the real WTA for land use contracts, one alternative method to improving the efficiency in the allocation of reforestation contracts is targeting REDD+ interventions to those beneficiaries who may be willing to change land use at a cheaper cost. Unfortunately, our results are not very encouraging about the feasibility of this approach.

Targeting has commonly been used to allocate public resources more effectively, most commonly in poverty reduction programs. The experience with such programs led to the development of a variety of techniques such as individual assessment (such as means and proxy-means testing and community assessment), categorical targeting (for example, based on geographical variables) and self-selection that can be used to think about the feasibility of targeted interventions in the case of REDD+ interventions. [19]

Having already analyzed the importance of different characteristics in determining an individual's willingness to accept to enter into a reforestation contract, we could, ideally, use this information in the design of a targeting scheme that could be easily and cost effectively implemented, such as a means or proxy means targeting approach.[20] Unfortunately, we get very

[19] Coady et al. (2004) and Ravallion (2009) provide good reviews of the effectiveness of such techniques.

[20] Pure means testing attempts to elicit a measure on individual or household wealth. However, in practice, within developing countries this can difficult. Firstly, individuals have an incentive to understate their wealth in order to gain the benefits of the program, and secondly, income within developing countries is considered an imperfect measure of welfare, neglecting self produced goods, gifts and remittances. Added to this, income can also be very volatile in developing countries, dependent largely on crop production cycles,

little guidance from the results presented in the previous section because those variables that seemed to matter most, time and risk preferences, are usually unobservable (or are observable at a high cost) and, as such, cannot be used as a category for targeting.

This leaves us with the possibility, supported by our results and by the wider literature (for example Coady *et al.* (2004)), of relying on geographical targeting, exploring the large variations that may exist between villages. Although our results are limited to firmly conclude about the value of such approach, as we only work with data from two villages, the geographical difference is large and significant enough to be suggestive of its importance.

This approach could then be complemented through self selection, which has the advantage of relatively minor administration costs. Similarly to what is done in public works programs, one can imagine that it would be possible to set a standardized criteria (in this case, a price to be offered per hectare of land reforested or per tonne of carbon) that would give incentives for farmers whom have a lower opportunity cost to opt into the policy, and conversely, other farmers who have a higher reserve price, to continue with business as usual. More detailed studies, directly focused on targeting of interventions and with a wider range of conditions, can perhaps provide further guidance to the importance to be given to targeting in the context of implementing REDD+.

and other exogenous factors.

6 Conclusion

Reducing Emissions through Deforestation and Degradation continues to be one of the few internationally agreed upon alternatives for reducing global GHG emissions. In order for this mechanism to be effective, in depth analyzes need to be performed to determine if the underlying assumptions surrounding environmental pricing techniques are consistent with results obtained through revealed preference techniques.

This paper was motivated by the prospect of analyzing different techniques for establishing a price of carbon through REDD. A revealed preference technique was used and accompanied by a detailed household survey. Analysis of the determinants of the bids submitted highlighted that individual preferences, namely time and risk, were major determinants of such values while measures of opportunity costs seemed to play a minor or no role. This conclusion is reinforced by the results of a budgetary analysis, used to estimate a similar supply function for carbon sequestration that proved significantly different from the one obtained through the revealed preference technique. This result throws doubt on the underlying assumption that opportunity cost is the sole determinant of valuation of environmental services, with the villager's opportunity cost and auction price revealing no significant relationship.

The relative price of carbon sequestration was contrasted with international carbon market prices. Even with the relative transaction costs included there still lies significant potential for gains from trade tough policy implementation. Despite further studies needing to be done to accurately quantify these costs, there is little doubt as to the future viability of this mechanism. As such the practicality of targeting this policy was discussed, with the optimal method for implementation in terms of efficiency being a combination of self selection and geographic targeting. The geographic differences in price, both with the revealed preference technique and BA were significant. However, further studies need to be done in order to accurately assess these variances with a larger sample size.

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Table 1: Summary statistics

Variable	Description/Unit	Mean	Standard Deviation
Time Living in Village	years	27.66	17.87
Tebeng Tinggi	= 1 if Tebeng Tinggi, 0 otherwise	0.51	0.5
Senamat Ulu	= 1 if Senamat Ulu, 0 otherwise	0.49	0.5
Household size	Number of people living in household	4.9	1.66
Age	Age of household head (years)	44.99	14.65
Married	= 1 if currently married	0.94	0.24
Education	Education of household head (years)	7.38	4.16
Assets	Value of assets owned (Rp 1000)	12406.47	19602.43
Non-Farm Job	= 1 if individual has a non-farm job	0.07	0.26
Has a Non-Farm Business	= 1 if individual has a non-farm business	0.12	0.32
Area of Plot	Area of auction plot (Ha)	3.19	4.17
Inherited Plot	= 1 if auction plot was inherited	0.16	0.37
Cleared Plot	= 1 if auction plot was cleared from natural forest	0.44	0.5
Purchased Plot	= 1 if auction plot was purchased	0.4	0.49
Plot Revenue	Total revenue from auction plot over the last two cropping seasons (Rp 1000)	17661.32	21619.46
No Document	= 1 if the auction plot has no legal proof of ownership	0.78	0.42
Hired Labour	Wages paid for labor in auction plot over the last two cropping seasons	1375.93	7192
Seedlings	Value of seedlings used in auction plot over the last two cropping seasons (Rp 1000)	1119.3	7308.4
Fertilizer	Value of fertilizer used in auction plot over the last two cropping seasons (Rp 1000)	1551.5	8515.7
Pesticides	Value of pesticides used in auction plot over the last two cropping seasons (Rp 1000)	1404.41	4550.89
Other inputs and costs	Value of other inputs and costs in auction plot over the last two cropping seasons (Rp 1000)	280.09	910.02
Farm Capital	Value of farm capital (Rp 1000)	236.91	836.07
Livestock	Livestock owned in TLU	0.44	0.89
Farm Revenue	Total revenue from all plots over the last two cropping seasons (Rp 1000)	27623.32	54698.28

Table 2: Risk Preference Experiment

Option A		**Option B**		**Expected Payoff Difference**
1/10 of Rp 25,000	9/10 of Rp 16,000	1/10 of Rp 40,000	9/10 of RP 5,000	8400
2/10 of Rp 25,000	8/10 of Rp 16,000	2/10 of Rp 40,000	8/10 of RP 5,000	5800
3/10 of Rp 25,000	7/10 of Rp 16,000	3/10 of Rp 40,000	7/10 of RP 5,000	3200
4/10 of Rp 25,000	6/10 of Rp 16,000	4/10 of Rp 40,000	6/10 of RP 5,000	600
5/10 of Rp 25,000	5/10 of Rp 16,000	5/10 of Rp 40,000	5/10 of RP 5,000	-2000
6/10 of Rp 25,000	4/10 of Rp 16,000	6/10 of Rp 40,000	4/10 of RP 5,000	-4600
7/10 of Rp 25,000	3/10 of Rp 16,000	7/10 of Rp 40,000	3/10 of RP 5,000	-7200
8/10 of Rp 25,000	2/10 of Rp 16,000	8/10 of Rp 40,000	2/10 of RP 5,000	-9800
9/10 of Rp 25,000	1/10 of Rp 16,000	9/10 of Rp 40,000	1/10 of RP 5,000	-12400

Table 3: Distribution of risk preferences

Number of Safe Choices	**Description**	**Number of Respondents (%)**
0-1	Highly Risk Loving	6 (9.1)
2	Very Risk Loving	7 (10.6)
3	Risk Loving	5 (7.6)
4	Slightly Risk Loving	10 (15.2)
5	Risk Neutral	12 (18.2)
6	Slightly Risk Averse	8 (12.1)
7	Risk Averse	6 (9.1)
8	Very Risk Averse	3 (4.5)
9	Highly Risk Averse	2 (3.0)
10	Agoraphobia	7 (10.6)
Number of observations		66 (100)

Table 4: Distribution of time preferences

Discount Rate	**Number (%)**
0.05	3 (4.55)
0.10	5 (7.58)
0.30	9 (13.64)
0.50	13 (19.70)
1.00	36 (54.55)
Number of Observations	66 (100)

Table 5: Determinants of individual bids

Variable	**1**	**2**
Risk Aversion	-	-1834.034**
Discount Rate	-	-6918.677**
Education (Years)	9.17	177.08
Time living in Village	119.95***	173.3902***
Tebeng Tinggi	5870.10***	6222.424***
No Document	-1970.90	-1773.30
Budgetary Value	-0.12	-0.04
Plot Slope	-526.77	-745.74
Livestock	805.65	-176.32
Buffalo	2890.06***	1683.987*
Non-Farm Business	0.06***	0.064919***
Constant	1731.86	4325.48
Number of Observations	66	66
R – Squared	0.47	0.55
Adj. R – Squared	0.39	0.46

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

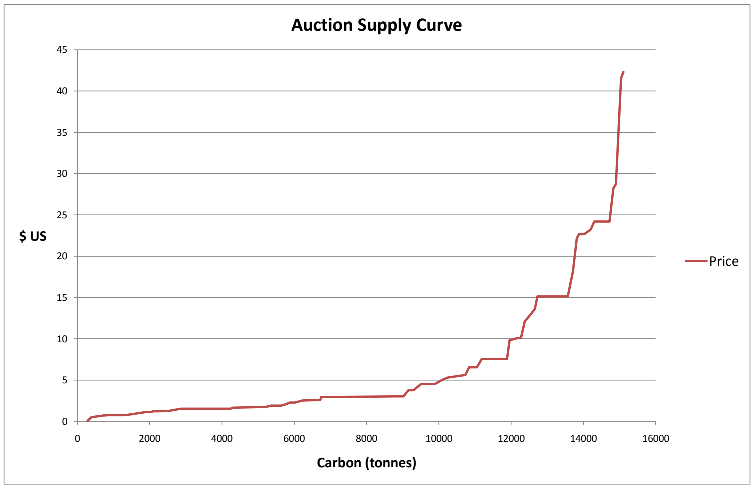

Figure 1: The supply curve: auction

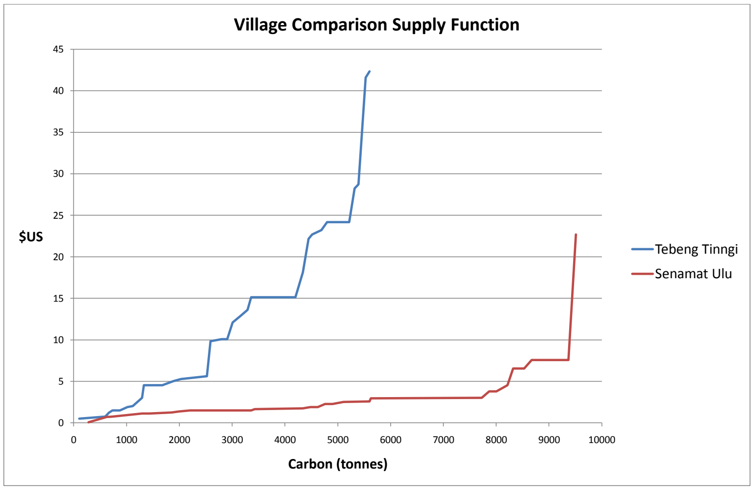

Figure 2: The supply curve: auction, by village

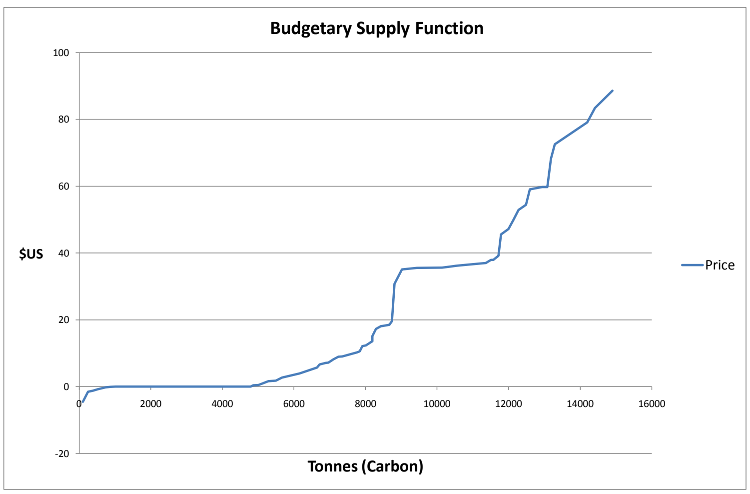

Figure 3: The supply curve: budgetary analysis

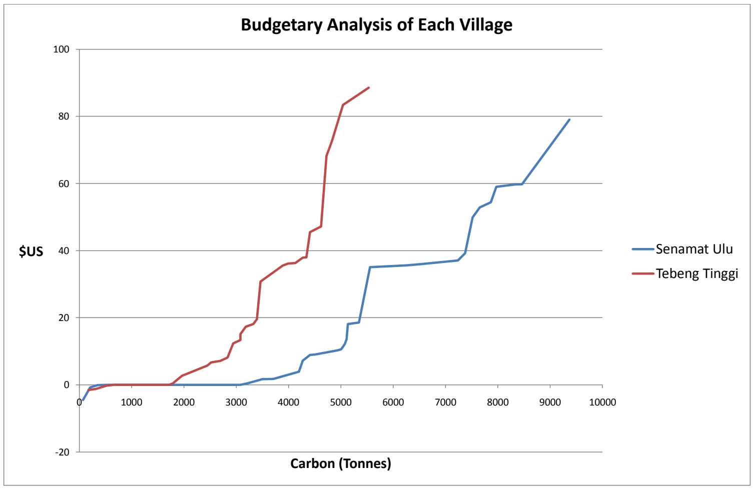

Figure 4: The supply curve: budgetary analysis, by village

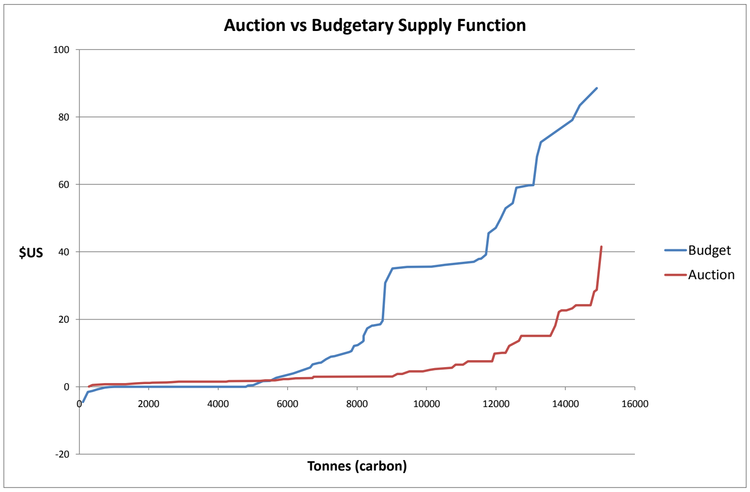

Figure 5: The supply curve: contrasting auction and budgetary analysis

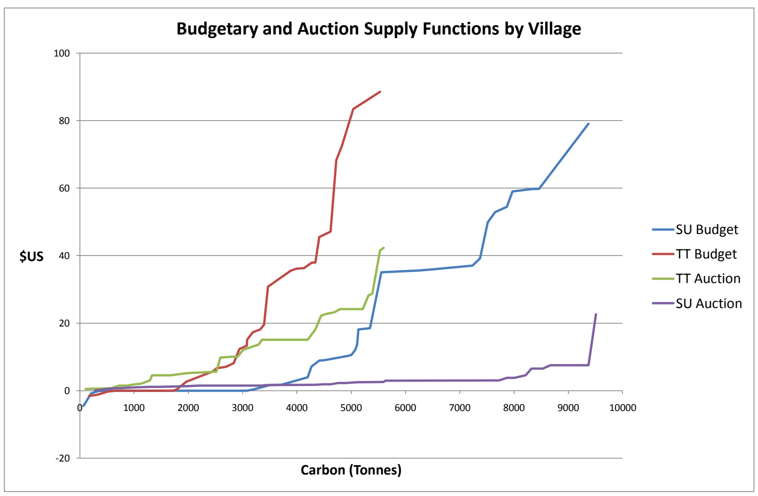

Figure 6: The supply curve: contrasting auction and budgetary analysis, by village