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Incentive Contracts for Environmental Services and Their Potential in REDD

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Abstract

Implementation arrangements for Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation can be seen as contracts that could address some of the inherent problems with forest carbon credits that often lead to high transaction costs—measuring, monitoring, and verification. Self-enforcing contracts, where it is in the best interest of the environmental service providers to comply with the contracts, may be one way to reduce these costs if providers have incentives to uphold their end of the contract. While the literature on Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation is extensive, there is little information available to guide policy makers or investors on what form such contracts should take. After providing an overview of the current status of Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation and its role as a tool for reducing carbon emissions on an international scale, the paper describes key issues regarding implementation and reviews the literature on contracts from the related area of Payments for Ecosystem Services programs, which face similar challenges. The remainder of the paper reviews various contractual mechanisms from agricultural and forestry related projects that have been proposed or are being used in practice and discusses the various implications associated with their design and implementation.

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Incentive Contracts for Environmental Services and Their Potential in REDD

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Incentive Contracts for Environmental Services and Their Potential in REDD[1]

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I. Introduction

As national and international policymakers continue to consider approaches for addressing climate change, identifying viable mechanisms to reduce greenhouse gas emissions remains vital. Attention has focused in particular on the forestry sector because a significant proportion of carbon emissions worldwide come from deforestation (17% according to IPCC, 2007). Research has shown that reducing emissions from deforestation and forest degradation (REDD) is a potentially effective way to reduce net emissions through increased carbon sequestration. For example, Gullison et al. (2007) estimate that total emissions reductions from reducing deforestation rates by 50 percent by the year 2050, and maintaining those rates for another 50 years, would save the equivalent of worldwide fossil fuel emission for the past six years. Economic assessments also have shown REDD to be a potentially cost-effective way of reducing emissions (IPCC 2007; Jakeman and Fisher 2006; Eliasch 2008; Kindermann et al., 2008). Emissions reductions from forest management activities could amount to an estimated savings in abatement costs of almost US$ 2 trillion worldwide for meeting a global 550 parts per million CO2 concentration limitation relative to relying only on reducing gross emissions of GHGs (Tavoni et al. 2007).

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Along with reducing emissions, there can be environmental and social co-benefits of REDD. Environmental benefits can include improved soil and water quality, protection of biodiversity, and more sustainable forest management. Social benefits from REDD activities can include providing an alternative source of income for the poor in developing countries (Peskett et al. 2008; Angelsen 2008).[2] There is also concern that REDD programs could cause some social damages, however. REDD programs, if successful, could set aside large tracts of forestland and effectively remove the land from access and use by local indigenous communities who have had historical ties to the landscape. In addition, forest areas storing the most carbon will not necessarily include ecologically important forest landscapes. These concerns have been raised in international negotiations over REDD and have important implications for where and when REDD activities may occur globally.

Despite the economic and environmental potential, a number of problems with implementing REDD have been raised in the literature. These include additionality; permanence; leakage; transaction costs; and measuring, monitoring and verification (e.g., Murray et al., 2007). An important issue that has largely been overlooked, however, is the role of contracting. Well-designed contracts are critical for many transactions between buyers and sellers, particularly when the traded goods are complex. In the case of carbon credits, the traded good is very complex. Carbon storage levels are not costlessly, or even easily observable; the level of carbon storage on the landscape is heterogeneous; and carbon storage depends on biological growth processes that vary from year-to-year. All of these factors make carbon storage difficult and costly to measure and monitor. They also raise transactions costs, make contracts harder to design, and reduce the number of transactions that ultimately occur.

[2] The United Nations refers to the potential additional benefits as REDD+ where the '+' implies looking beyond just the prevention of deforestation and forest degradation (UN-REDD Programme).

To date, there has been very little work developing and designing appropriate contracts for carbon credits. In fact, previous forest carbon sequestration initiatives excluded REDD credit generation because of concerns about effectiveness of monitoring and enforcement of carbon credits. In many developing countries, there are important concerns about weak institutional frameworks (e.g., limited ability to enforce contracts), and hurdles associated with contracting with a large number of small, often rural, landholders (Cacho, Marshall, and Milne, 2003; Capoor and Ambrosi, 2008).

These factors also help explain why policy efforts of the last 30-40 years to reduce deforestation appear to have been largely unsuccessful (FAO, 2011). There are many reasons why efforts to curb deforestation are likely to be unsuccessful. Angelsen and Kaimowitz (1999) for example, point out that economic forces provide strong incentives for actors to clear forests and convert land to agriculture. If regulations are in place to limit deforestation, corruption and the difficulties associated with monitoring and preventing illegal land clearing in remote and sparsely populated areas also contribute to deforestation (Brown, 2010). Given these difficulties with the legal enforcement of harvesting and land clearing limitations, a number of authors have suggested the use of incentive-based mechanisms (Capella, 2009). However, incentive-based approaches face similar difficulties when there are limits on the enforceability of contractual arrangements by courts or other third-parties.

Given the many difficulties inherent in making and enforcing contracts in tropical forest regions, and the likely costs associated with regular monitoring and measurement of forests under contract to generate carbon credits, contracts need to give landowners clear incentives to maximize carbon sequestration. Self-enforcing contracts, where it is in the seller's best interest to uphold the contract, could play a key role in successfully implementing carbon sequestration programs, especially wherever external enforcement and third party verification is infeasible or very expensive. Such contracts would require less stringent monitoring and reporting, thus reducing transaction costs and making REDD projects more feasible.

This paper reviews the literature on REDD through the lens of developing contracts that could address some of the inherent problems with forest carbon credits. We start with an overview of the current status of REDD and its role as a tool for reducing carbon emissions on an international scale. The paper then discusses the current state of policy in REDD, including a discussion of current funding mechanisms. The paper describes the key issues in the literature on REDD implementation and reviews literature from the related area of Payments for Ecosystem Services (PES). The PES literature pre-dates intense discussions on REDD, and addresses many of the same issues and concerns. We then examine and review various contractual mechanisms that have been proposed, or are being used in practice, for reducing deforestation.

II. Institutional Background for REDD

REDD has gained increasing recognition since its initial introduction onto the agenda of the United Nations Framework Convention on Climate Change (UNFCC) in 1992. In subsequent meetings of the Conference of the Parties (COP), the role of forestry in reducing emissions has gained increasing support, though concerns with ensuring that real and additional reductions in emissions are made remain an issue. In order to assist developing countries in implementing REDD activities, the Forest Carbon Partnership Facility (FCPF) was launched through the World Bank in 2008 to engage countries and direct funds to successfully initiate REDD projects. A number of developing countries now participate in REDD activities, financed by public and private organizations as well as by national governments. While a significant amount of money has been pledged toward REDD activities, the cost of implementing programs on a global scale is high and will require future funding streams, the most promising being the sale of emissions credits on a carbon market. Along with funding issues, a number of projects have already been implemented in different countries, including Indonesia, China, and Brazil, with varying implications for future REDD initiatives. The following section reviews the evolution of REDD and strategies for implementation, along with sources of financing and a sample of REDD activities in developing countries. While much progress has been made in bringing REDD into the current discussion on climate change mitigation, the role of contracts in the negotiation and implementation of projects on both national and sub-national levels has been largely ignored.

Origin and Evolution of REDD: The United Nations Framework Convention on Climate Change (UNFCCC)

The role of avoided deforestation in reducing carbon emissions was recognized in the United Nations Framework Convention on Climate Change (UNFCCC) ratified in 1992, and the subsequent Kyoto Protocol to the UNFCCC. In negotiations over implementation of the Kyoto Protocol, however, most of the effort was placed on activities in developed countries, such as afforestation. Projects focusing on reducing deforestation could have been included in the Clean Development Mechanism (CDM) set out in the Kyoto Protocol, but this mechanism allowed only reforestation and afforestation projects.[3] Projects focusing on avoided deforestation, such as

[3] The Clean Development Mechanism, or CDM, was included in the Kyoto Protocol to provide flexibility to Annex I countries to meet their targeted emission reductions. Through the CDM Annex I countries could meet their emission cap by purchasing certified emission reductions from non-Annex I countries. However, this mechanism has not been very effective (Wara and Victor 2008).

payment for environmental service schemes, are not eligible for participation in the CDM (CDM Rulebook 2010).

REDD was subsequently re-introduced onto the agenda of the UNFCCC in 2005 at the 11th session of the Conference of the Parties (COP), where the COP recognized the importance of REDD as a mitigation strategy for reducing global greenhouse gas (GHG) emissions. In Decision 2/CP.13 from the 13th session in Bali, the COP affirmed the need to take action to reduce emissions from deforestation and forest degradation, and further recognized that "the needs of local and indigenous communities should be addressed when action is taken to reduce emissions from deforestation and forest degradation in developing countries."[4] The COP encouraged capacity building, providing technical assistance through technology transfer, and demonstration activities to improve sustainable forest management (Decision 2/CP.13, Bali Action Plan). At the 15th session of the COP in Copenhagen, participants continued to pledge support for promoting REDD projects and established a REDD mechanism (Copenhagen Accord, 2009), which would enable developing countries to reduce their deforestation rates, while promoting sustainable development through incentive payments for emissions reductions.

While the level of support for reducing emissions from deforestation globally is high, there is recognition that difficult issues regarding measurement and reporting of emissions still need to be addressed. At the 16th session of the COP in Cancun, Mexico (Nov-Dec 2010), in Decision 1/CP.16 negotiators called for countries to create "national strategy" or "action plans" to address forest related emissions (Section C, paragraph 71), along with further research and development in methods for measuring, reporting, and verifying emissions reductions (UNFCCC 2011a). At the moment, it appears that policies to support emission reductions via land use,

[4] Note that within the literature a number of different acronyms are used for the idea of reducing emissions for deforestation and forest degradation. We use REDD throughout this document to refer to all activities related to REDD, including REDD+ activities.

land-use change, and forestry activities (LULUCF) will continue to evolve separately from other market-based mechanisms for reducing emissions (Section III, Part A, paragraphs 38 and 46), though discussions are ongoing regarding the inclusion of additional LULUCF activities in under the CDM (FCCC/SBSTA/2013/L.5). In Durban at the 17th session of the COP, progress was made towards setting emissions and reference levels on a national level (SBSTA 35, 2011). However, little progress has been made regarding future financing streams for REDD. Parties were invited to submit documents with "their views on modalities and procedures for financing results-based actions" surrounding REDD activities, which were to be compiled for a technical paper to be address in Qatar in 2012 (UNFCCC 2011b). No decisions were made in Doha at the 18th session of the COP. During the 19th session of the COP in Warsaw many key decisions were made through the adoption of the Warsaw Framework for REDD+. The framework includes seven decisions covering results-based financing for REDD+, mandatory national forest monitoring systems, reference emission levels set at the international level, reporting on safeguards to ensure transparency, and standards for measuring, reporting and verification of emissions offsets (for details see UNFCCC 2013). The framework was backed by pledges of $280 million in financing from the United States, the United Kingdom, and Norway.

Operationalizing REDD: The World Bank Forest Carbon Partnership Facility

While the discussion about REDD – linking payments for carbon to avoided deforestation – has been driven mainly by the UNFCCC, progress on developing programs to implement this vision has not been limited to UNFCCC process. The Forest Carbon Partnership Facility (FCPF) of the World Bank, for example, was created to implement REDD practices, and began operations in 2008. The FCPF follows in a long line of activities that have been organized by development banks or individual countries to provide financial support and assistance for forest or agricultural carbon sequestration. The FCPF focuses mainly on REDD activities in tropical developing countries. It is funded by sixteen financial contributors, including various countries and environmental organizations, who have pledged an estimated US$447 million. Of this, approximately US$230 million goes toward the Readiness Fund and US$205 million to the Carbon Fund (FCPF, 2012).[5] The Readiness Fund helps prepare countries for REDD by assisting them in developing policies and systems of management, establishing baseline levels, and designing and implementing measurement, reporting, and verification (MRV) systems (FCPF, 2011). The Carbon Fund, which became operational in May 2011, is the main mechanism for payments for verified emissions reductions in REDD countries.

The FCPF currently identifies 37 countries as potential locations for the implementation of REDD activities. Twenty-seven of these countries have submitted Readiness Preparation Proposals (R-PPs), or draft proposals,[6] which outline how the country will achieve the goals of a REDD program including stakeholder participation, budgets, implementation frameworks, and MRV considerations. After the governing body of the FCPF approves an R-PP, the country is then eligible to receive grant money from the Readiness Fund to implement its plans. There is much negotiation in this process.

The R-PP includes a REDD Implementation Framework component, which focuses on how the goals of REDD are to be achieved in the country, and through what mechanisms. As stated in the rationale for this component:

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[5] Financial contributors have included: Agence Française de Développement, Australia, British Petroleum, Canada, CDC Climat, Denmark, the European Union, Finland, Germany, Italy, Japan, The Nature Conservancy, the Netherlands, Norway, Spain, Switzerland, the United Kingdom and the United States. From FCPF website: http://www.forestcarbonpartnership.org/fcp/node/12

[6] See the Forest Carbon Partnership website for a list of countries at http://www.forestcarbonpartnership.org/fcp/node/257

> *The success of REDD-plus implementation is likely to be built on stakeholder confidence in the ability of the framework to create sufficient and fair incentives for the strategy options to be implemented.* (R-PP Template and Guidelines, p.40).

The guidelines direct countries to discuss benefit-sharing mechanisms and the distribution of carbon payments if applicable. However, many of the country R-PPs focus more on ownership of carbon stocks and land tenure, and do not explicitly address how they will engage local people and communities in REDD contracts, or how contracts by national authorities with individual landowners, or those who otherwise manage the land, will be structured to ensure compliance and incentive compatibility.

For example, the RR-P for the Central African Republic lists reforestation as one of its REDD strategies and acknowledges the potential challenges this poses with regards to land tenure, and thus the need to compensate land owners (CAR R-PP, 2011). However, a framework for what an actual contract would look like to solidify this strategy is still missing from most of the discussions on implementing REDD at this level. Similarly, Colombia identifies agricultural expansion, infrastructure development, and mining as drivers of deforestation in its R-PP and plans to use PES schemes to establish incentives for local people to limit these activities, but it does not include details about how the contracts will be negotiated or what parties will be involved (Colombia R-PP, 2011).

The guidelines for the R-PP address the need to integrate national monitoring systems with sub-national systems, which may include some combination of remote sensing data and ground-based inventories. However, they do not consider the importance of linking accurate and reliable monitoring on the ground with proper incentives for the community members responsible for the monitoring. Personal and community incentive structures need to be taken into consideration to ensure that those doing the monitoring will not gain from reporting falsely that a forest is intact, while illegally harvesting on the side. Successful implementation of REDD projects in developing countries will likely require multiple levels of contracts on both national and sub-national levels. Eligible countries must first establish contracts with the FCPF to gain access to funds to implement readiness activities, then additional contracts will need to be developed for individual projects between service providers and project managers within the country that are identified in the readiness proposal.

REDD Funding Requirements and Sources

The long-term funding of REDD projects remains largely uncertain, and while reducing deforestation may be less expensive than many other options for reducing carbon dioxide emissions worldwide, it can still be costly. Kindermann et al. (2008) find that the marginal costs of reducing deforestation by 10% globally is about \$3 per ton CO_2, but the marginal costs of a 50% reduction in deforestation is about \$15 per ton CO_2. In total, reducing deforestation by half could cost between \$17 and 40 billion per year (Eliasch 2008; Kindermann et al., 2008; UNEP, 2011). These funds would flow largely from developed countries to developing countries, where much of the sensitive and valued stocks of forests are located. Some countries, such as Brazil or Costa Rica, may develop and implement their own policies for reducing deforestation, including intra-national transfers of funds.

At present, there are essentially no ongoing annual financial streams from countries or the private sector for payments to avoid deforestation. Given budgetary concerns in developed countries, it is unlikely that large new streams of funding will come available from the public sector in the near term. Some countries have provided funds to the World Bank FCPF, or other institutions, but these resources are typically one-time donations, not annual funding. Current levels of official development assistance (ODA) are nowhere near robust enough to reduce large amounts of deforestation. For instance, ODA lies in the range of $500-600 million per year (OECD, 2005), and the majority of funds are already devoted to other, much needed development projects.

Current funding streams even fall short of projected expenses for implementing REDD on a global scale. In a survey of REDD financing and country activities, interim financing expenditure and commitments for REDD activities totaled almost US$2 billion from 2010 to 2012, with US$552 million dedicated to performance-based payments for emissions reductions (Synthesis Report 2010). These expenditures and commitments, however, are significantly less than what most countries estimate they will need financially to reduce deforestation. For example, the Democratic Republic of Congo alone estimates that it will spend US$2 billion from the period 2011-2015 on REDD activities. Brazil will require an estimated US$1.5 billion for implementing a REDD national strategy and supporting capacity building activities over the same period, and has yet to estimate an amount for performance-based payments which will significantly add to the costs (Synthesis Report, 2010).

Currently, there is no global agreement on greenhouse gas emissions beyond 2012, and thus no established long-run funding source, such as through a global cap and trade system with REDD offsets. Even if an agreement were to emerge, Aldy and Stavins (2010) argue that there may not be a single cap and trade system to provide financing for REDD activities. Private funding in principle could be raised through a range of programs, including voluntary initiatives, or national and regional regulatory programs that allow the purchase of carbon credits generated through REDD activities (UNEP 2011). There are already examples of private voluntary initiatives for carbon sequestration, such as the Verified Carbon Standard (VCS) or the efforts of individual NGOs, like The Nature Conservancy, as well some regulatory programs, like the California Air Resources Board.

Up to now, the majority of REDD credits have been sold on voluntary markets. While it is worth noting that efforts to operationalize REDD accounting, such as those by the Verified Carbon Standard, may ultimately enable REDD credits to be included in compliance schemes, that eventuality may still be a long way off. California could be one of the first emissions trading schemes to use REDD credits to meet its compliance standards, once issues with verification standards for emissions credits are satisfied (Diaz et al. 2011). Thus far, the California Air Resources Board (ARB) has closely followed the Climate Action Reserve's Forest Project Protocol regarding these issues. The current protocols used by California allow offsets from improved forest management and avoided conversion, but only for projects located within the United States (Air Resources Board Protocol 2011). However, plans for incorporating international markets are underway (Diaz et al. 2011). In other arenas, progress towards incorporating REDD credits in compliance markets has been stalled. For example, the European Union's emissions trading scheme (ETS) will not discuss allowing REDD into the ETS until after 2020 (Kovacevic, 2011). Thus, in addition to general uncertainty about the strength of climate policy globally, uncertainty about whether REDD credits may be used in carbon markets will remain an important issue.

REDD Activities in Developing Countries

Efforts by the FCPF and other international organizations to prepare countries for REDD implementation have resulted in ongoing forest projects in a number of countries worldwide. In a survey of REDD demonstration and readiness activities, Wertz-Kanounnikoff and Kongphan-Apirak (2009) identify 44 demonstration activities and 65 readiness activities in Asia, Africa, and Latin America. Demonstration activities are focused on potential REDD mechanisms such as promoting sustainable forest management or conservation projects supported by carbon payments. The majority of these activities are in Asia, particularly Indonesia, which has had historically high deforestation rates and accounts for over half of all demonstration projects surveyed. Funding for these projects comes primarily from a mix of bilateral, multilateral, and nongovernmental sources, though private sector funding was an important source for projects in Latin America, particularly in Brazil, where a significant portion of project funds came from American Electric Power, GM, and Bradesco Bank.

Madeira (2009) examined 17 REDD activities underway in Indonesia and found that the majority of site-level interventions followed a concession based model, where prospective landholders gain long-term property rights to an area of forest contracted with the national government, which controls over 98 percent of the forest estate in Indonesia. Unlike REDD projects where an important co-benefit of the project is improved incomes and livelihoods for project participants of limited means, the concession owners of these projects were typically established groups that are well-financed. Only two of the projects focused on mitigation by local actors, which Madeira notes is significant because "…much of the literature hypothesizes that REDD activities will follow the model of PES programs with small-scale resource managers providing the service…" (2009). However, local actors still are an important part of creating and sustaining successful forest conservation projects. All of the concession projects focus on preventing forest conversion because, despite the legal tenure rights of concession holders, local actors often have a significant impact on forestlands. This signifies the need for an integrated approach to forest conservation, which could potentially include secondary contracts between concession holders and local actors for increased community development.

This was the case in China, where secondary contracts were part of the first forest project under the CDM. Gong et al. (2010) examined factors that affected people's willingness to participate in this project in Guangxi province in China, including social capital,[7] property rights, and contractual rules. The project includes 4,000 ha of degraded land to be reforested and an estimated 77,000 tons of CO_2 equivalent to be sequestered over a credit period of 30 years, beginning in 2006. Carbon credit sales make up about 36 percent of total revenue from the project, or US$2 million. The other revenue comes from the sale of timber and pine resin.

The project area is comprised of land bundled from 27 villages, including both individual and communal land holdings. The established share-holding system is made up of local communities and three local forest companies. The revenues are split among the forest companies and local communities.[8] The buyer in the contract is the World Bank's BioCarbon Fund, which signed a contract with one of the local forest companies, acting as the intermediary representing all sellers in the share-holding system. The forest company then signed individual contracts with the other forest companies, village leaders of communal lands, and individual landholders. The buyer pays a single price per tonne of carbon sequestered at the time of credit purchase with no upfront payments.

The project has had mixed results thus far. The researchers estimate that 35 percent of the project land will not be reforested due to high costs, contractual constraints, property rights

[7] Social capital here refers to levels of trust among the village members, the number of interactions that take place with members from outside villages, and the ability of village members to resolve tenure disputes within and among other villages (Gong et al. 2010).
[8] The forest companies were allotted 1000 ha for planting eucalyptus trees and will receive all the revenues from their sales. The communities receive 60% of revenues from carbon credits and 40% of sales from timber and pine resin.

disputes, and low levels of social capital. However, due to the shareholding nature of the contract, some communal-land villages were able to enroll their barren lands and benefit from the program whereas left alone, they would not have reforested the barren lands. Bundling the lands also brought down the transaction costs per tonne of carbon sequestered. Even if not all the lands in the original contract are reforested, the cost per tonne is still less than the price, providing a net profit to the participants and making the project more accessible to poor, small landholder groups.

In Brazil, where deforestation in the Amazon accounts for three quarters of the country's GHG emissions, the government has historically taken a command and control approach to controlling deforestation. However, due to inadequate monitoring and enforcement, deforestation has long continued unchecked, where the main contributors to deforestation in the Amazon are illegal logging and cattle ranching, beyond slash-and-burn agricultural practices by local residents (Hall 2008). Originally, Brazil was reluctant to enroll forestry projects in the CDM due to reservations by the foreign ministry of "internationalization" of the Amazon (Council Task Force, 2001; Fearnside, 2001). However, the government has since warmed to the idea, and PES projects have emerged in Brazil. *Proambiente* was an early example of a program modeled after a PES scheme with the aim of controlling deforestation in Brazil. Payments were made to small-scale farmers for participating in a variety of activities to reduce deforestation and forest degradation, conserve soil, and protect biodiversity. The concept originally developed among rural communities, union groups, and environmental NGOs in 2000, and was then transferred to the Ministry of the Environment in January 2004 with the aim of eventually scaling up *Proambiente* to create a national PES policy (Hall, 2008).

Brazilian President Dilma Rousseff announced a new program, Bolsa Verde that pays poor, rural households for not engaging in deforestation or forest degradation beginning December 2011. Households qualify if they currently make BR$70 (US$ 40) or less per month, and under the program they will receive BR$300 (US$180) every three months. The program is an expansion of Bolsa Floresta, which started in 2007 and is Brazil's first PES program for avoided deforestation (Pereira 2010), with payments to 7,239 families. Bolsa Verde is expected to benefit an estimated 18,000 families in the first stage, and more than 200,000 families may eventually qualify for benefits. Monitoring for compliance will be done via satellite imagery and families found in violation will lose their benefits (Moukaddem, 2011). As of August 2010, a number of other carbon related REDD projects in the Amazon have been identified as well (see May et al., 2010).

Thompson et al. (2013) review six REDD+ projects in the Peruvian Amazon focusing on transaction costs associated with setup, implementation, and monitoring. The projects' time periods ranged from 20 to 45 years, and the types of land enrolled were primarily national reserves and conservation concessions. Participant activities included patrolling the forest area, fire management, and promoting alternative income generation activities. They estimate that the cost of implementing REDD+ in the Peruvian Amazon based on these projects is as much as US$ 68 million per year. However, their results indicate that costs vary substantially depending on the project and have a high degree of uncertainty.

III. Implementing REDD: Issues of Concern

While there has been wide recognition of the importance of REDD and there are many economic and ecological reasons why it should be included as a policy option for reducing global emissions, many issues remain. These include:

- Baseline establishment (Angelsen and Kaimowitz 1999; Eliasch 2008; Chomitz et al. 2006);
- leakage (Gan and McCarl 2007; Saythaye and Andrasko 2007; Schwarze et al. 2002; Sohngen and Brown 2004; Murray et al. 2004);
- additionality of offsets (Angelsen 2008; Wunder et al. 2008); and
- impermanence (Schlamadinger et al. 2007; Wong and Dutschke 2003).

Addressing these issues will require a mix of policy mechanisms that will likely be determined on national and international levels, as well as smaller scale decisions made on a project or even individual basis, which is where contracts play a role in fostering efficient outcomes. Addressing the risk of impermanence and identifying the sources of these risks is of particular importance because the degree of risk has implications for carbon credit prices, with lower prices for higher risk sources. A final concern is the potentially high cost of monitoring, reporting, and verification of carbon credits, which varies depending on the system and size of the area, but may account for a substantial part of the total costs of REDD projects.

Addressing Baselines, Additionality, and Leakage on National and International Scales

We suspect that appropriate policies for setting baselines and addressing leakage are being worked out by national governments in conjunction with international bodies. For instance, there are many well-known methods for setting baselines, such as using historical rates or models to predict future deforestation given country characteristics (Angelsen, 2008). If

REDD credits are to be marketable, the choice of a specific method will need to be agreed upon by the governmental agencies or international institutions that are regulating REDD and the carbon markets. Ensuring additionality will also likely take place on a national level, where baselines could be set and additionality determined based on changes from the baseline, though this likely will require sub-national coordination and accounting to determine which programs should be attributed the credits.

Similarly, individual landowners or managers who engage in carbon projects cannot manage leakage on their own as leakage results from market transactions that are beyond their direct control. Additional leakage may occur beyond a national scale if the cumulative set of projects is large enough to impact international market prices. Wear and Murray (2004) estimated leakage involving forest timber in North America when increased protection of old growth forests reduced timber production in public lands during the 1990s. They found that timber production in the private sector increased through the U.S. and Canada during this time, accounting for an estimated 84 percent of the reduction of timber in public lands. In developing countries, leakage may result from forest conversion shifting from protected to unprotected areas, where the conversion of forest for agriculture is a large contributor to deforestation. Sohngen and Brown (2004) estimated that leakage could be as large as 50% in the Noel Kempf Mercado Climate Action Project in Bolivia. Murray et al. (2004) estimated that leakage due to the implementation of avoided deforestation or afforestation programs in the United States ranged from less than 10 percent to greater than 90 percent. The authors find that the range of leakage depends in part, on the type of forest protection. Set-asides (e.g., removing old growth forests from harvest rotations) tend to have less leakage than avoided deforestation (protecting forest areas that would otherwise be converted to agriculture). The location also influences the degree of leakage, where forest protection in the Pacific Northwest region results in lower levels of leakage compared to protection in the South Central and Great Lakes regions of the United States. While the range of potential leakage is large, overall the results show that leakage in forest carbon projects needs to be taken into account when considering emissions reduction portfolios. Discounting offsets could make up for estimated leakage; however, this increases inefficiencies.

Risks Associated with Impermanence and Related Effects on Carbon Credit Prices

Forests face many risks that can degrade or destroy carbon stocks and thus negate carbon offsets. These risks include drought, fire, bug infestations, snow and ice-storms, invasive species, and human-related disturbances. Cooley et al. (2012) analyze natural risk reversals in forest carbon offsets programs that may be correlated across project types, locations, or relevant threats to permanence, and find that small correlations could potentially lead to significant increases in risk. For example, individual forest projects may have a small positive correlation in reversal risk between projects, but if projects are then aggregated into portfolios, the correlation in reversal risk increases for the whole portfolio. Fat-tailed risks are also important to consider, such as the case with forest fires, where the occurrence of a low probability event, like a record fire, might result in more forest area destroyed in one event, than in the previous hundred. Given that these types of risks are usually not accounted for, Cooley et al. (2012) claim that permanence risks maybe be substantially underestimated. In contrast, Daigneault et al. (2010) showed that landowners who have an incentive to manage their carbon can adapt to forest fire impacts. For instance they show that a doubling of forest fire activity can reduce the value of land by about 26% when there is no value for sequestered carbon, but the value of land declines by only about 2% when carbon is valued.

Anthropogenic risks include changes in land management, theft, and economic risks, such that if more profitable opportunities arise, landowners may renege on their contracts resulting in the release of carbon that was being sequestered in their forestland (Wong and Dutschke, 2008). Given the range of risks that can lead to reversals, policies for permanence need to provide concrete incentives to forest land managers to minimize these risks to the extent practicable. Buyers will offer lower prices to projects with higher reversal risks, preferring to buy less risky credits.

Some of the commonly proposed solutions to address impermanence include buffers, temporary contracts, and discounting the price. Buffers hold a given percentage of project offsets in reserve (i.e., they are not sold), and these reserves are debited or retired from the total reserve in the case of a reversal. Temporary contracts limit the time period of performance for a contract, or focus on renting carbon. Price discounting reduces the value of carbon credits due to perceived risks of reversal. Price discounting would be market driven if liability rules are clearly set and one or the other party must insure its carbon holdings, but some authors have argued for making price discounts explicit. MacKenzie et al. (2010) argue that it is socially efficient to place liability on the sellers when information is incomplete. In each of the solutions above, then, they would recommend shifting liability to sellers.

Several systems have now been placed into practice, and they appear to focus on using buffer systems. The Climate Action Reserve’s (CAR) Forest Project Protocol Version 3.2 (August 2010) provides guidelines and requirements for certifying forest carbon offsets, including how to address issues with establishing baselines, additionality, permanence, and MRV requirements. The California Air Resources Board (ARB) established its own Forest Offset Protocol modeled closely after CAR's Forest Protocol. Both protocols require the longest time commitment of any other carbon standard, where the carbon credits must be verified for 100 years, including continued monitoring and verification of the offsets. Given the extended time commitment for ensuring the offset, there are typically options to purchase insurance in the case of a reversal. To address risks associated with impermanence, forest projects verified under the CAR and ARB are also required to contribute a percentage of offsets to buffer pools, where the percentage depends on the estimated risk of reversal associated with the forest project (FPP, 2010).

Reduced prices have been a frequent result of impermanence risks and MRV uncertainties with prices for forest carbon credits typically lower than prices for other types of carbon credits. Conte and Kotchen (2009), for example, examine factors affecting the variability in voluntary carbon prices based on provider and project characteristics. They find that forestry projects in general sell offsets at lower prices compared to other projects such as biomass methane, hydropower, solar, and wind. This is especially true in developing and least-developed countries, where prices for forest offsets are approximately 39 and 70 percent lower than projects in industrialized nations respectively. Projects requiring third party certification by the Verified Carbon Standard (VCS) are also sold at reduced prices, 19 percent lower than average, where the average offset price ranged from $10 to 25 per tonne CO_2 (2007 dollars). These lower prices reflect uncertainty about the additionality or permanence of the offsets. The authors report that the lower prices for forest related offsets in developing and least developed countries might also be a result of lower opportunity costs, insecure tenure rights, and quality concerns related to the governance and monitoring of the offsets. Improvements in measurement and verification standards by third parties could alleviate some of these concerns. However, such measures will also increase the costs of providing certified offsets.

Kim et al. (2008) examine how the potential impermanence of sequestered carbon would affect the market price of these carbon credits through a permanence discount. To estimate the permanence discount they equalize the effective price of perfect, risk-free credits with impermanent credits and determine what the discount would be under different scenarios. The carbon price path has a large affect on the permanence discount with constant carbon prices over time, the discount is significantly less than when the carbon prices increase at the rate of interest.[9] For forests with longer harvest rotations (85 years) and constant carbon prices, the discount is 5.4 percent, but if the carbon price increases over time, the discount rate increases to 68 percent. For shorter rotations of 20 years with no reforestation, the discount rates increase for both carbon prices, to 52 and 93 percent respectively, largely due to the buyer having to buy back credits after 20 years at full price on the assumption that the forest will be converted to harvest. However, if reforestation takes place after a 20 year harvest period, the discount decreases to 23 and 32 percent respectively. In all cases, the discount is further reduced if energy credits are taken into consideration, where the portion of emitted carbon that is used to generate energy counts as a GHG credit since it replaces other fossil fuel-based energy sources.

The results of these studies have important implications for creating contracts that build in safeguards for permanence. Some risks are unavoidable, as in the case of nature-induced reversals, whereas others may be preventable. Contracts that provide incentives for the landholders to uphold their end of the contract could reduce some of the anthropogenic and economic risks of non-permanence. However, the implications of buffers or discounted prices also need to be taken into consideration. Self-enforcing contracts require a degree of trust

[9] Kim et al. (2008) use an interest rate of 4 percent and assume that the carbon offset is maintained for 100 years.

between the buyers and sellers, so price discounts or buffers, where e.g., two units of carbon stored may only equal one unit to be sold on the market, could send negative signals to sellers indicating a lack of trust, thus reducing the effectiveness of the contract. Gong et al. (2010) recognize the importance of social capital such as strong cultural norms and trust, which may make up for incomplete contracts, such that a lack of full information or trust may result in unfulfilled contracts even if monetary benefits are positive. They conclude that establishing formal institutions, such as property rights, and tailoring contractual arrangements according to the degree of local social capital might improve the success and reach of CDM projects. This remains an important area of future research.

The Costs of Measuring, Reporting, and Verification

Measuring, reporting, and verification (MRV) of carbon will need to be handled both at the national level via policy, and on a contract-by-contract basis. National systems and policies addressing these issues will need to be established, but individual contracts that link sellers of carbon credits to buyers will also need to specify measuring, monitoring, and verification methods. For example, the Climate Action Reserve (CAR) established monitoring and reporting requirements in its Forest Project Protocol (Version 3.2) for projects in the United States. All enrolled projects must submit initial forest inventory reports estimating carbon stocks in the project area. Then, monitoring and reporting primarily consists of updating the forest inventories annually according the project monitoring plan. Forest inventory updates that include carbon stocks also require oversight by a Professional Forester (FPP, 2010).

A major concern for some forest projects is that MRV methods could be very costly. At the project level, estimates indicate that carbon measurement would cost in the range of $1 to $2 per ton CO_2[10] (Antinori and Sathaye, 2007; Antle et al 2003). As Antle et al. (2003) point out, however, larger projects can take advantage of economies of scale, and unique sampling designs, and drive these costs down. Waggoner (2009) reviewed the U.S. Forest Service Forest Inventory and Analysis (FIA) program and found that annual costs for that program are $72 million per year. This amounts to about US$0.24 per hectare, over 300 million hectares of forestland. The annual change in carbon stocks in the U.S. is around 635 million tons of CO_2 sequestered per year, suggesting that measuring costs are in the range of $0.11 per ton CO_2. The FIA program involves on-the-ground measurements and provides the key data used to estimate and officially report annual U.S. carbon sequestration in U.S. forests.

Currently, using satellite or optical data may or may not be more expensive than ground assessment. Remote sensing approaches are still in the research phase, and require substantial on-the-ground verification. Macauley and Sedjo (2011) review cost estimates for measuring and monitoring forests find that high resolution optical monitoring is an estimated US$25 per square kilometer, and more advanced LIDAR monitoring is significantly costlier at approximately US$465 per square kilometer. This implies a range of measuring and monitoring costs from US$0.25 to US$4.65 per hectare. The average hectare of forests in the U.S. has about 183 tons CO_2, so the costs of measurement are less than $0.03 per ton CO_2 using these types of data.

Both on-the-ground sampling and the use of satellite or optical techniques have some uncertainties (Waggoner 2009), and there are costs associated with reducing these uncertainties. Detecting change in forest carbon from year to year, or over a 5 year period, will require repeating measurements over time. One can control the uncertainty in measurement by increasing the sample size, but this is costly. Thus, there will be tradeoffs between the level of

[10] These estimates involve on-the-ground sampling.

uncertainty in carbon contracts and the costs of measurement. These tradeoffs will need to be considered when deciding acceptable levels of accuracy in carbon sequestration contracts.

Contracts with built in incentives for maintaining stocks under a range of future conditions have the potential to significantly reduce monitoring costs. If carbon suppliers, such as local farmers in developing countries, have sufficient incentives to refrain from activities that may violate the contract but generate income such as cutting down trees or other forest degrading activities, less money will have to be spent on monitoring. However there will still be costs associated with measurement and verification if the credits are to be certified and sold on the carbon market.

IV. Payments for Environmental Services (PES)

Many REDD projects are modeled after payment for environmental service (PES) schemes. The idea behind PES is to capture the positive (or negative) externalities of certain environmental activities by having the beneficiaries of these environmental externalities pay those responsible for managing the resources that produce them (Engel, Pagiola, and Wunder, 2008). Since PES projects typically face the same issues as REDD projects, valuable lessons for successful implementation of REDD can be gained from experiences with PES projects around the world, including contract considerations between the buyers and sellers of the environmental service.

Typically, PES programs involve voluntary transactions where a specific environmental service is bought by a buyer from a service provider if and only if the provider fulfills the environmental service agreement. For example, an electric company may be interested in paying landholders in developing countries to change their forest management practices to limit their emissions and increase carbon sequestration so the company can save money by reducing their emissions reductions within their own power plant under a regulated cap, assuming that it is cheaper to pay another group to reduce emissions elsewhere than within the company (Wunder 2005).

The voluntary aspect of PES programs is based on two assumptions for participation: (1) The expected utility of participating is greater than the expected utility of putting the land toward its next highest value use; and (2) transaction costs are low enough for a positive, net expected utility gain after transaction costs have been deducted (Gong et al. 2010). Gong et al. (2010) further argue that financial incentives alone, such as those reached through a Coasian bargaining process, are not enough to ensure a successful PES forest project, and that social and institutional considerations also need to be taken into consideration. In areas with low levels of trust, Gong et al. (2010) found that participants were not willing to enter into agreements with local forest companies even if it was to their financial benefit.

PES programs have been introduced widely throughout the developed and developing world. Wunder et al. (2008) compare the attributes and outcomes of a sample of prominent PES programs around the world, including funding source, project design, costs, livelihood outcomes, and environmental effectiveness. They find distinctions between user financed programs, where the buyers use the service directly and participation is voluntary for both parties, and government-financed PES programs, where a third party is the buyer and only the provider side is voluntary, as seen in China and the United States. Other distinctions among PES projects are their institutional frameworks including the prevalence of intermediaries who mediate between the service buyers and providers. Contracting with the providers encompasses the majority of the transactions costs, including finding sellers, negotiating contracts, making payments, and monitoring compliance (Paigola and Platais, 2007).

Wunder et al. (2008) looked at payment structures across programs including the amounts paid, payment schedules, and duration of contracts. Payments tend to be lower for programs that do not require extensive physical changes on the land, so the payments only need to be greater than the next highest value of land use, which is typically low for marginal lands. If providers are required to plant trees or change management activities, program costs increase to compensate the provider for planting trees along with the opportunity cost of alternative activities. For example, the PES program in Costa Rica pays on average US$45/ha per year for forest conservation and US$163/ha per year for planting trees. User-financed programs frequently have different levels of payments while government-financed programs typically make uniform payments for administrative ease and/or equity concerns (Wunder et al., 2008). While uniform payments are easier to administer, they are less efficient. The total payout is higher than needed, since it has to be greater than the project with the highest opportunity cost involved in the program. However, if contract providers are able to distinguish between those with high costs and those with low costs, they may be able to create incentives for each group to enter into separate contracts that increase efficiency and reduce costs (see below).

In general, the most difficult criterion to meet when setting up a PES system is conditionality of the contract, where payments are made contingent on the performance of certain activities (Wunder, 2005). In their review, Wunder et al. (2008) find that the conditionality of payments ranges among the programs and usually depends on monitoring. All programs are conditional to some degree, but the payment schemes may be such that enforcement is difficult. For example, in reforestation programs, upfront payments are often required to cover startup costs. Contracts could stipulate that failure to uphold the contract requires repayment, but in reality this is often unenforceable due to high transaction costs, inadequate legal systems, or inability of providers to make repayments. Most programs examined by Wunder et al. (2008) made cash payments, though some included technical assistance and in kind payments such as seedlings. Payments ranged from a low of US$1.50/ha per year in Bolivia, to a high of US$163/ha per year in Costa Rica. The majority of payments were made annually, some after compliance checks. Most of the contracts ranged from one to ten years, but a couple were more than 20 years. All programs used on-site compliance, while some larger programs also used satellite imagery. Sanctions for non-compliance typically included loss of future payments. The authors note that stricter sanctions, such as tying compliance to eligibility for other subsidy programs might reduce monitoring costs if the risks of noncompliance are greater; however, such sanctions might be politically unfavorable or impractical.

One prominent example of a successful PES scheme is the Conservation Reserve Program (CRP) in the United States (see for example, Ribaudo, 1989), which involves rental contracts for agricultural land the use of which could cause environmental damages, or for land that could provide valuable habitat or other environmental services. In the United States, where property rights are well defined, it is relatively easy to find landowners who will enter into the contracts. Typically, these contracts feature benefits to the landowner that exceed opportunity costs, taking into account any penalties associated with early withdrawal. Opportunity costs, however, change with market prices, and can change farmer incentives to maintain land in CRP when contracts come up for renewal. CRP hectares are monitored by local government officials, as well as non-governmental organizations, and contracts include payback clauses, which at least ensure that the government recoups its money if the farmers do not follow through on their obligations.

The success of the CRP program is well documented (e.g., Ribaudo, 1989), but other, similar programs have not achieved the same levels of success. PES programs initiated in some developing countries have not had the same success as the U.S. CRP for various reasons (Pagiola et al., 2002; Grieg-Gran et al. 2005; Wunder 2008) such as insecure property rights or difficulties and high costs associated with measurement, reporting, and verification. The inability to measure outcomes can impede both the demand and supply side, but will have its largest effect on buyers. Buyers are acutely interested in knowing that they have achieved their environmental objectives, and without measurement, they will be reluctant to spend resources, thus limiting demand. The limited ability to measure, monitor and verify forest carbon sequestration or avoided deforestation emissions contracts in developing countries likely explains the limited use of these activities in the Clean Development Mechanism and the subsequent efforts to develop these capacities over the past several years.

Transactions costs also have important implications on the success of PES schemes in developing countries (Ortega-Pacheco, 2010). Transactions costs may be particularly problematic in developing country settings because land-holdings in many countries are often small, and working with large numbers of landowners can be costly (Pfaff et al., 2007; Jindal et al., 2008; Cacho et al., 2003). Some methods for reducing transactions costs have been considered, such as contracting with groups or local communities, who can perform the aggregation, measurement, monitoring, and verification functions more effectively. For example, Seeberg-Elverfeldt et al. (2009) examine the success of using Community Conservation Agreements (CCA) with established community groups in Indonesia. They evaluate the success of these CCAs with regards to “institution, participation, monitoring and enforcement, and the status of the environment.” They find that using existing community institutions can provide initial frameworks for implementing a PES project thus lowering transaction costs, but the degree of community awareness and strength of leadership and social structures is important, and will likely affect the success of a PES scheme. If monitoring and enforcement systems are already in place, costs can be reduced even further.

The literature on PES programs covers a wide range of project types and offers much guidance for implementing REDD projects, regarding payment schemes, transaction costs, program monitoring, intermediaries, and conditionality concerns. Most likely REDD projects will continue to use the knowledge gained from existing PES programs as a basis for structuring programs and addressing common issues and concerns.

V. Contract Design for Environmental Services

Thus far, the REDD literature has focused on assessing the overall costs of projects, and outlining the challenges of forest carbon sequestration projects in developing countries. These challenges include the transaction costs associated with setting up contracts; showing additionality; ensuring permanence; and measuring, monitoring and enforcement. The importance of proper incentives in forest carbon trading projects has been recognized, but little research has been done that identifies frameworks for creating contracts that build in such incentives. Similarly, in the PES literature, contracts between buyers and service providers are often assumed and until recently, there has been little research or guidance regarding the structure of the actual contracts. As REDD has become a more prominent tool for reducing emissions, greater attention has been given to developing and structuring guidelines for contracts and research on incentive compatible contract design has increased.

Lessons from Agricultural-based Contracts

Earlier research on environmental contracts focused mostly on agricultural programs. Wu and Babcock (1996) looked at contracts for environmental goods in U.S. agriculture and acknowledged that if the actions of farmers are not easily observed, enforcement costs may be prohibitive. Other research has provided mixed results about what type of contact structure is most efficient for sequestering carbon, and tradeoffs need to be addressed when designing these contracts. One trade off in particular is the desire for changes in land management versus maximizing the quantity of carbon sequestered under the contract. Van Kooten (2008) argues that due to high transaction costs associated with measuring, verifying, and reporting credits from sequestering carbon in biological sinks, emphasis should be shifted away from the quantity of reductions and instead, the activity itself should be the focus, such as tree planting or implementing no-till cultivation. In this case, the contract would stipulate the length of time the activity is to be carried out, as well as penalties for discontinuing contracted activities. Such contracts would reduce the measurement and reporting costs, though there would still be transaction costs associated with contract negotiations and so forth.

Antle et al. (2003) came to the opposite conclusion in their study of contracts in the agricultural sector. They examined two types of soil carbon sequestration contracts where the contract is based on per-hectare of land enrolled or per-tonne of sequestered carbon. They compared the efficiency of the two types of contracts based on costs and estimated amount of carbon sequestered. Per-hectare contracts required costs associated with changes in land management and resulted in less carbon being sequestered compared to the per-tonne contracts, which required measurement costs, but proved more efficient than the former. They also looked at the impact of spatial heterogeneity in terms of bio-physical and economic conditions and found that increased spatial heterogeneity increases both efficiency gains and measurement costs of the per-tonne contracts. These findings can similarly be applied to contracts in the forestry sector.

Recently, Tesfaye and Brouwer (2012) examined factors affecting households' willingness to enter into contractual agreements for improved soil conservation in Ethiopia. Farmers were offered loans to invest in soil conservation measures which in return provide public benefits such as flood protection and reduced downstream sedimentation, while increasing agricultural yields and providing sustainable income for the farmers. As part of the contract, farmers get land certificates, securing their right to the land for the duration of the contract period which ranges from one to ten years. The authors use a choice experiment where farmers chose from a menu of contracts with different attributes including contract duration, monthly repayments, soil conservation activities, and contract provider. The aim was to identify what conditions on incentives need to be satisfied in order for farmers to accept the contracts; these are commonly referred to as participation constraints. The results of the choice analysis indicate that farmers prefer entering into contracts with local government organizations as opposed to regional government, and that they prefer longer contracts accompanied by more extension services. Even though over half of the farmers interviewed currently had a land-use certificate, this contract attribute was the most highly valued, likely due to general insecurities for land tenure and fears of land redistribution. Regarding farmer characteristics, the results supported the hypothesis that the farmers most likely to participate were ones with the greatest soil erosion problems who were not currently investing in erosion control measures. With regards to income, poor households without previous access to credit were less likely to enter into contracts compared to wealthier households.

While some of the results from this study can inform general environmental contracts, they do not fully generalize to most forest-related PES programs because the soil conservation contracts involved loans which the farmers must repay; thus problems with adverse selection were minimized since rational farmers would not enter into the contract if they did not receive positive net benefits from engaging in soil conservation measures after repaying the loan. In comparison, the majority of carbon-related PES schemes include an upfront payment with subsequent payments for changing forest activities, so households may be inclined to enter into contracts for activities they would have done regardless or even claim the upfront payment, then revert to previous land use practices if contracts are weakly enforced.

Forest-Related Contracts

As REDD programs move beyond the planning stages to implementation, contract development becomes an increasingly important issue, and as a result there has been a noticeable increase in the literature and resources available for implementing forest contracts. For example, the Katoomba Group is an international working group that was launched by Forest Trends in 1999 with the goal of "advancing markets and payments for ecosystem services" (Katoomba Group 2011). Their services include legal advice and toolkits for developing contracts for PES programs, and sample contracts are offered on their website. The contacts can be tailored to conservation services or carbon sequestration, which typically require third party verification. Sample contracts include a schedule of an initial payment at the time of signing, and then subsequent, increasing payments over a specified time frame (e.g. every six months), where payments are contingent on verification by the buyer and sellers (Seller Aggregator 2009).

Sandker et al. (2010) model different scenarios for potential REDD contracts in Ghana, where the probability of forest conversion to cocoa plantations is high. The scenarios include business as usual, payments for avoided deforestation of old-growth forests, and payments for avoided deforestation of all forests. The scenario focusing on old-growth forest is the most attractive to farmers, where the contract is for a 20-year period and REDD payments amount to US$ 2.50 per tonne CO_2 reduced.[11] The contract involves a large upfront payment, which makes the REDD project more appealing for some farmers initially, since cocoa revenues would not be realized for 8 years. In the simulation, Sandker et al. (2010) find that farmers would renege on their contract after 5 years, and start converting land to cocoa at that time. To prevent farmers from breaking the contract, a carbon price of US$ 55-60 per tonne CO_2 would be required. Given this price, the authors then recommend that payments to farmers extend beyond the 20-year period to keep the forest area intact. However, they also acknowledge that the high variability in prices for agricultural commodities in tropical countries makes it difficult to predict the performance of long-term contracts, which are required for most REDD projects.

Jindal et al. (2008) examined forest carbon sequestration programs in Africa and recognized the importance of "developing effective contractual arrangements with farmers" as part of a successful forest carbon sequestration project. Some key contractual aspects include who to pay (landowners, local government, intermediaries, etc.) and what the payment method and schedule should look like (cash vs. in kind and up front vs. periodic payments). Social and

[11] This is based on a carbon price of US$ 10/tonne CO2 and transaction costs accounting for 75% of the carbon payment.

cultural factors should also be taken into consideration, including the need for farmers to understand the long-term nature of the contract, where small landholders often live and farm at a subsistence level and may not be accustomed to thinking in the long-term with regards to forest management (Jindal et al., 2008). The International Small Group and Tree Planting Program (TIST), a voluntary carbon sequestration project, addresses the problem of long-term contracts by allowing the amount of land under contract to change, and making payments conditional on the number of trees maintained by the farmers (Jindal et al., 2008).

Other issues requiring consideration before a contract can be implemented include land tenure and exclusion rights and the level of risk associated with a project. If participants do not have secure property rights over the land enrolled, the likelihood of a contract being developed is low. Purchasers will devalue the carbon due to permanence concerns, while the sellers may require higher prices to help to secure the carbon. In many cases, certification standards, including the Verified Carbon Standard (VCS) require evidence that the project participants have control over the project area for the duration of the project period, which may vary from 20 to 100 years (VCS 2008). However, this may be easier said than done in practice, particularly in developing countries where property rights for poor landholders are often insecure. In many cases, the legal landowner, which is often the government, may not be the one actually managing the land. Alston and Anderson (2011) identify the need to sort out complications surrounding unclear property rights before contracts are made to ensure that the true owners of the land are included in the contract. The concern is that contracts might be made with *de jure* landowners, who will accrue the benefits from the agreement, so the *de facto* land managers may deplete the land and resources in anticipation of future exclusion.

In addition to the need for clearly defined property rights in REDD contracts, they must also specify where liability rests if carbon ultimately is released. Clear designation of liability is critical for any contract, and in the case of forest carbon, where permanence issues are widely recognized, designation of liability would appear to be required. As noted above, MacKenzie et al. (2010) argue that efficiency is increased if liability rests with the landowner, or the individual who has control over the land, as they have private information on the value of alternative uses. Assigning liability to them thus is likely to provide better incentives for the individual to maintain the carbon. In developing countries, however, liability often lies with governments and states, which are responsible for tracking national emissions levels and targets, increasing risk for reversals since project participants are not directly penalized for deforesting. Palmer (2011) identifies the need for policy innovations that promote shared liability between the state and individual landholders, such as a co-management framework with shared benefits and liability. In this case, the state would retain some liability, and thus have incentives to monitor project activities, but the individuals would also be held responsible and violations of the contract could result in withdrawals of forest-use rights (Palmer 2011).

In some cases, carbon ownership may also need to be taken into consideration. If the contract is for changing land use activities and payments are made contingent on forest conservation activities, then carbon does not directly need to be accounted for, but may influence the amount of the payments based on the estimated benefit of actions undertaken. However, contracts for offsets that sell on the carbon market will be more complicated and require more ground work before a contract can be drawn that meets verification standards and still give proper incentives to both parties. Concerns regarding carbon ownership also arise in some of the Readiness Preparation Proposals for the FCPF, where the countries identify ownership rights over sequestered carbon as an issue to be addressed. High transaction costs associated with contracting continue to be a barrier for forestry projects. Some potential solutions for dealing with these high costs include offering uniform contracts, working with groups rather than individuals, and teaming up with local intermediary groups to assist with monitoring and compliance. However, these solutions have other potential problems associated with them. For instance, poor communities may not receive any benefit from the projects if intermediaries are responsible for meeting project standards. Care also needs to be taken if contracting with groups to ensure that the benefits are distributed among all the members fairly and do not just go to those handling the contract (Jindal et al. 2008; Gong et al. 2010).

Incentive incompatibility in monitoring and reporting carbon credits is also an issue for designing REDD contracts. Donors and buyers benefit it carbon credits remain cheap, and thus may not be too concerned with stringent inspections that come at a high cost. Similarly, providers of carbon credits also have weak incentives for rigorous monitoring and inspections since they are more interested in the financial benefits from selling credits. This places the onus largely on a third party for monitoring and enforcement, which adds to transaction costs (Alston and Anderson 2011). Alston and Anderson (2011) propose a multi-level governance approach to contracting in effort to reduce transaction costs. In addition to local governments, independent research institutes or local forest associations may have lower costs with regards to negotiating, monitoring, and enforcing contracts, and thus should be utilized in the contracting process to minimize costs.

Gong et al. (2010) propose that bargaining costs could be reduced with standardized contracts that have formal arrangements for pooling resources or share-holding systems. They note, however, that standardized contracts are less flexible and due to heterogeneity of costs among participants. Standardized contracts may prevent some people with higher costs from participating. Or, if the uniform payment is too high, the efficiency of the contract decreases, where participants with low costs receive extra rents. While bundling contracts is one option for increasing the participation of smallholders in projects, the contracts become more complicated as more participants are included and incoming sharing arrangements must be incentive compatible to avoid free-riding (Gong, et al 2010). Cacho et al. (2005) identify other problems contracting with small landholders due to slow court systems and high legal costs. Negotiations can also be time consuming: for one project in Chile, project coordinators spent over a year negotiating the contracts with all the relevant parties (Cacho et al. 2005).

Bluffstone et al. (2013) identify problematic issues with implementing REDD+ projects in community-controlled forests in developing countries. One concern is that REDD+ projects may disrupt well-functioning community forest systems by placing restrictions on the use of forest resources or by creating conflicts within the community due to the influx of carbon credit payments. The importance of community involvement in the contracting and negotiating process is well recognized by policy makers, but the specific details of how this will be achieved and what community participation actually looks like have yet to be worked out. Another concern is that bundled, fund-based payments (as opposed to direct carbon credit payments to sellers) managed by local or national governments will turn into another type of contingency-based aid, which undermines the original intention of REDD as a market-based mechanism. However, since community-controlled forest areas tend to be small, buyers may not be willing to negotiate contracts with such small entities (Bluffstone et al. 2013). Finding a balance between the role of government and the involvement of local, indigenous communities when designing contracts, thus, remains an area for future research and development.

Contracts with Asymmetric or Imperfect Information

While model contracts may be designed under assumptions of perfect information, the reality is much different. Asymmetric information refers to the idea that the "agent" has some information about the service they are providing that the "principal" does not know. They may be able to use this information to their advantage for economic gain, and in the process reduce the effectiveness of the contract. For example, an individual landowner knows the opportunity costs of increased forest carbon storage while a principle does not, so the landowner may over-state their true costs of producing some environmental benefit. Contracts for REDD will need to be carefully written to account for this uncertainty about the benefits landowners may receive.

Given that imperfect or asymmetrical information is typically detrimental for the buyer, uniform compensation payments will likely result in different levels of benefits accrued based on variations in costs faced by the sellers. At a minimum, payments need to exceed the combined implementation costs and opportunity cost of the next best use of the land if rational actors are to participate. With perfect information, one could separate the high cost and low cost participants and offer them separate contracts accordingly, but this option is rarely feasible. If two different contracts are offered distinguishing between high and low cost participants, the low cost people have the incentive to sign up for the high cost contracts to receive the additional rent unless the contractor can successfully screen the participants, which requires substantial information at a potentially high cost. Uniform, high payouts may ensure that the majority of eligible participants are properly incentivized to participate in the program, where the low cost participants in this case receive extra information rents, but such payments are inefficient and reduce the number of people the program is able to reach, and thus the environmental benefits.

Ferraro (2008) examines the problem of asymmetrical information in contracts for PES programs, where the buyers have less information about the associated costs of the contract than the landowners providing the services, allowing for additional information rents to be extracted from the buyers. He offers three potential solutions: observe landowners to acquire more accurate information on the true costs, screen the high-cost landowners from the low-cost by offering a menu of incentive compatible contracts, and third, use procurement auctions to allocate contracts. He concludes that different approaches work better in different environments, but overall, more research and experimentation should be done in this area before real conclusions about contract design can be made. Mason and Plantinga (2010) model contracts with asymmetric information between governments and landowners about the opportunity cost of the land. The objective of the government is to limit budget expenditures while ensuring additionality of the offsets. In their model, the opportunity costs of the offsets are private information to the landowners and the carbon price is exogenously determined. They derive the optimal contracts for two types of landholders, one for people who have high opportunity costs and one for people with low opportunity cost, where the low cost owners have the advantage of extracting additional rents. The contract structure includes a per unit payment and a lump-sum transfer from the service provider back to the government. Under this structure, the high types do not earn any rents, but the low types would extract enough information rent to make them indifferent, and thus truthfully reveal their type. The contract has the added benefit of identifying ex-post how much additional forestation took place due to the contract, allowing governments to estimate additionality. They then examine the different costs imposed on the government based on offering voluntary contracts or a uniform subsidy to all landowners. Their results indicated that offering a menu of contracts yields significantly lower costs.

Cordero-Salas (2012) proposes self-enforcing contracts (relational contracts) as a potential solution for asymmetric information. Cordero-Salas (2012) characterizes the optimal REDD self-enforcing contract and provides parameters under which private enforcement is sustainable when the opportunity cost of the land (i.e., the seller's type) is private information. The optimal payment scheme suggests that all payments should be made contingent on forest conservation at the end of the contracting period, regardless of the seller's type and the information available for the buyer about the types. Thus, the optimal contract does not prescribe any ex ante payment. If the value of the relationship is sufficiently productive, a first-best self-enforcing contract can be implemented when the buyer does not know the seller's type, but even if the gains from the relationship are small, relational contracts may still induce some level of carbon offset conservation, though below the first-best level, depending on how restrictive the value of the relationship is.

Alternatively, MacKenzie et al. (2010) model an optimal contract between buyers and sellers of carbon offsets for reforestation and afforestation programs, where the main goal is ensuring permanence of the offsets and minimizing the risk that the seller will breach the contract due to a better outside option. The main framework for their contract is an upfront payment from the buyer to cover initial costs of the carbon sequestration project, and then the rest is realized upon completion of the contract. The buyer is liable for the amount of carbon sequestered in the contract even if the seller reneges, which is also the case under the UNFCCC stipulations for carbon contracts and the sale of offsets (UNFCCC 2005), and the seller is uncertain of the future opportunity costs for the contracted offsets. They include constraints for permanence and moral hazard in their contract model and allow for an upfront payment that varies depending on the probability of other profitable opportunities for breaching the contract and the cost of inducing precautionary effort by the seller. In their contract, the upfront payment decreases as the incentives for the seller to breach the contract increases due to high opportunity costs or low levels on contract enforcement. They conclude that an optimal contract determines the per unit prices of the offset based on outside factors that influence the seller's future opportunity costs, such as agricultural prices. Further, they conclude that switching the liability of impermanent offsets from buyer to seller, or sharing the liability increases efficiency of the contract.

In line with the conclusions from McKenzie et al. (2010), Engel et al. (2011) develop different payment mechanisms for contracts that vary with external factors, where the objective is to reduce the risk of landholders converting land to alternative uses given changes in opportunity costs. They believe that due to increased pressures on land for agricultural production and population pressures, the payment plans in a REDD project need to be able to adapt to these changing demands, and properly incentivize landholders to abide by the conservation standards stipulated in the contract. Thus, they propose a different type of payment scheme that includes a per hectare fixed payment, which is commonly used, and a variable per hectare payment based on an agricultural commodity index or current carbon prices. They simulate their model for a period of 30 years using data on commodity prices and carbon prices to index the variable payments with a probability of forest permanence greater than 90 percent.

In their simulations, Engel et al. (2011) find that as the volatility in the opportunity cost of alternative land uses, which is based on soy prices, increases, the probability of converting forests to agriculture decreases, along with the per hectare cost of the project. In this case, the most efficient payment schedule would include lower fixed payments and higher variable payments, where the average cost for the project is US$2200 per hectare. When carbon prices are used to index the variable payments, they find that fixed payments are more cost efficient, but the cost increases significantly to approximately US$3800 per ha. This implies that program costs can be significantly reduced by including variable payments indexed by agricultural commodity prices, rather than one fixed payment.

Along similar lines, Arguedas and van Soest (2011) examined optimal conservation contracts given that farmers have fixed and variable costs and find that in this case, the contract regulator may be able to achieve a first-best outcome given asymmetric information. Under this contract, there are two payments, one for fixed costs (creating management plans, buying equipment, etc.) and the other for variable costs (fertilizer, labor, crop variations, etc.). They find that if these costs are negatively correlated, then farmers should be incentivized to truthfully reveal their type. The authors made three key assumptions in obtaining this result, 1) all costs are external, and outside the farmers' control, 2) observing the true costs would be prohibitively expensive for the principle offering the contracts, and 3) the fixed and variable costs have systematic relationships, either negatively or positively correlated. They model two types of farmers, low marginal conservation cost and high marginal conservation cost, each with some level of fixed costs that may or may not vary across farmers. They find that under complete information, the first best contract is not incentive compatible, where type one, low cost farmers have the incentive to pretend to be high cost farmers to receive additional rents. However, given asymmetric information, where the farmers know their type, but the principal cannot distinguish between the two types, a first best solution can be reached under certain conditions. If type one, low marginal cost farmers face higher fixed costs than type two farmers, then incentive compatible contracts can be offered inducing each farmer to truthfully reveal his or her type, and select the appropriate contract.

Arguedas and van Soest (2011) provide some examples of how these findings could be applied empirically, primarily in situations where costs move in the same direction for increased conservation and agricultural (or private) activities. For example, if the water table is high, then it may be easier or less costly to promote increased biodiversity by creating ponds or natural habitats, but it is also less costly to increase agricultural yields on the same land because water is more accessible. So in this case, as the cost of increasing biodiversity decreases, the costs of increasing agricultural productivity increase, or the costs are negatively correlated, and thus their contract would properly incentivize landowners to truthfully reveal their types, maximizing the efficiency of the contract.

The recent increase in contract research related to forest activities and emissions reductions is likely a direct result of the increasing prominence of REDD and the need for finding ways to minimize transaction costs to make projects more viable. While some strides have been made towards identifying what an incentive compatible contract might look like under different circumstances and information levels, the next step is to create actual contracts that can be implemented and tested in the field.

VI. Conclusion

As REDD becomes an increasingly important way to mitigate climate change worldwide, so does the need to address the prominent issues that have thus far prevented full integration of REDD activities into compliance mechanisms to reduce global emissions, such as the CDM and European emissions trading scheme. The World Bank, through the Forest Carbon Partnership Facility has garnered substantial financial support and has made great strides in developing REDD initiatives in numerous countries, though the long-term funding of REDD remains uncertain. This is largely due to the limited nature of voluntary payments and the lack of international resolve in setting caps on greenhouse gas emissions beyond 2012.

Of course, even if funding were available for REDD activities, a number of issues still remain with implementing it on a global scale. Measurement, monitoring, and verification remain difficult to address, and the systems that have been proposed to handle these issues typically involve high transactions costs. Beyond measurement of the carbon itself, concerns with additionality, permanence and leakage remain as barriers. There is evidence already that these issues have reduced the value of forest carbon credits in the markets that do exist, and these lower prices have undoubtedly reduced investment expectations.

Although there is a robust literature on REDD, until recently, very little of it has focused on contracting. In order for individuals to be paid to maintain or enhance carbon storage in forests, they will need to sign some sort of contract that stipulates the services they will provide and the payment they receive. There is little information available to guide policy makers or investors on what these contracts should look like. Developing incentive compatible contracts will become increasingly important as REDD projects moved beyond the pilot phase to widespread implementation.

Many of the remedies that have been suggested to handle REDD may in fact create additional inefficiencies. For instance, the indiscriminant use of discount factors to reduce the value of services provided can also reduce incentives for service providers to engage in the activity. Some authors have suggested that forestry projects have permanence discounts, for example, which account for local rates of forest fires. Using these discounts, however, may eliminate the incentive landowners have to protect their land against fires. It is thus vitally important to develop contracts that provide incentives to increase efficiency rather than reduce it.

Previous research on environmental contracts illustrates the many tradeoffs that must be addressed when designing contracts and implementing payments for REDD. Bundling contracts with small landholders has reduced transaction costs in some cases, but the complexity of the contract increases as more people become involved. Also, project objectives may focus on either behavioral changes in land use management, or maximizing sequestered carbon, which may influence contract design and have been found to have varying impacts on the efficiency of the contract. High levels of social capital and trust between the buyers and sellers may make up for information constraints, however permanence discounts or buffer stocks may send the opposite signal. Self-enforcing contracts, where it is in the best interest of the environmental service providers to comply with the contracts, and induce positive changes in land-use or forest management may be one way to reduce transaction costs. If sellers are incentivized to uphold their end of the contract, less monitoring and enforcement is required, reducing transaction costs, though verification and reporting of offsets will still be required.

Given the large magnitude of potential reductions in carbon emissions from REDD activities on a global scale, research that helps to reduce the burden of high transaction costs and risks associated with leakage and permanence will go a long way towards achieving the goals set forth by the UNFCC and Conference of Parties, all of whom are committed to reducing forest related emissions and slowing deforestation rates. Further research on contract design and incentives will be one step towards this goal.

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