Realistic REDD: Improving the Forest Impacts of Domestic Policies in Different Settings

Alexander Pfaff*, Gregory S. Amacher† and Erin O. Sills‡

Introduction

Policies aimed at reducing tropical forest loss have had some impact but far less than hoped (see, e.g., Amacher et al. 2011; Arriagada et al. 2012; Chomitz 2006; Joppa and Pfaff 2010a). Such policies are increasingly motivated by concern over greenhouse gas emissions from forests. The idea that reducing emissions from deforestation and degradation in developing countries can cost less than reducing industrial emissions in developed countries has focused attention on a system of international payments for verified and additional reductions in forest emissions, known as REDD.[1] Under such a system, developing countries would choose their preferred package of policies to reduce forest loss and hence emissions. Such domestic policy decisions should be informed by the theory and evidence concerning the impacts of past domestic policies on incentives for forest conservation. Two sectors are especially critical in this context: agriculture and forest extraction.

Expansion of agriculture and its associated infrastructure is the primary driver of tropical deforestation (Gibbs et al. 2010). Cleared forest is almost always converted to crops or pasture, driven by the benefits of producing staple foods or commodities such as biofuels, pulp, and fiber. Deforestation increases with government support for agriculture including new roads, provision of cheap credit, sanitary programs, and easier access to titles to land that has been cleared of forest.

*Duke University, Durham, NC; e-mail: alex.pfaff@duke.edu

†Virginia Polytechnic Institute and State University, Blacksburg, VA; e-mail: gamacher@vt.edu

‡North Carolina State University, Raleigh, NC; e-mail: sills@ncsu.edu

A longer precursor to this article—without models but with more references—is available as a Packard/Nicholas Institute white paper at http://nicholasinstitute.duke.edu/ecosystem/redd-papers-for-us-policymakers/lessonslearned. The online supplementary materials for this article also provide some additional references.

[1]This term has evolved. Reducing emissions from deforestation (RED) was a recognized strategy for mitigation of climate change at the 11th Conference of the Parties (COP11) of the UNFCCC held in Montreal in 2005. At COP13 in Bali in 2007, the concept of REDD was expanded to REDD+—reducing emissions from deforestation and forest degradation plus conservation, sustainable management, and enhancement of forest carbon stocks in developing countries. Throughout this article, we use REDD to refer to the general concept of reducing forest carbon emissions and increasing sequestration of carbon in forests in a performance- or results-based system using positive incentives.

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Forest loss due to extraction, including logging and the collection of wood fuel, is driven in part by the low net benefits of sustainable forest management. Investments in long-run forest management are discouraged by low prices for timber (due in part to supply from unsustainable and illegal operations) and a lack of credit and secure tenure for private forest lands as well as concessions on public lands. Ecosystem services provided by forests (e.g., carbon storage) do not typically generate private revenues and therefore do not affect private landowners' decisions. This lack of incentive helps to drive forest degradation, which in turn encourages deforestation by making the forest more accessible for clearing and more vulnerable to other disturbances such as fire. The low profitability of sustainable forest management also contributes to deforestation directly, by reducing the rent from keeping forest standing, relative to the rent when it is cleared.

This article, which is part of a symposium on the economics of REDD,[2] identifies three common settings for forest loss involving different types of decision-making agents that operate under different markets and institutions. That suggests using different theoretical frameworks for these three settings, which in turn generates different predictions concerning policies' impacts.

The first model, "producer profit maximization given market integration," has been applied to many private decisions about the best locations for profitable land uses, such as agriculture and forest. Its predictions have been widely studied empirically, beginning no later than von Thünen (1826). The second model, "rural household optimization given incomplete markets and household heterogeneity," has been applied to more isolated settings featuring high transactions costs that yield incomplete integration of households in input and output markets. Its policy impact predictions have been tested with surveys at household and village levels. In the third model, "public optimization given production and corruption responses by private firms," a public agency determines public forest access by balancing public goods, public revenue needs, and private rents to award concessions. There is potential for corruption, and the decisions may be affected by decentralization. This model's predictions can be tested using observed policies.

We find that past policies rarely addressed the incentives driving forest loss effectively. This helps to explain the limited impact of past policies on deforestation and forest degradation. It also suggests directions for the design of future policies. In sum, the theory and the evidence suggest that REDD success requires an understanding of all the incentives that drive forest loss, so that domestic policy can be tailored to specific settings (i.e., relevant agents and institutions).

The next three sections present the three theoretical frameworks. For each, we describe the general institutional setting that it represents; highlight hypotheses that have been proposed concerning the impacts of policies in that setting; review the relevant empirical evidence on the impacts of forest conservation policy, forest-relevant development policy, and decentralization; and discuss the implications for domestic policies that are intended to achieve REDD. We conclude with a summary of the main findings and suggestions for paths forward for REDD.

[2]The other articles are Kerr (2013), which discusses the economics of international policy to reduce emissions from deforestation and degradation; Angelsen and Rudel (2013), using the notion of a forest transition to examine REDD policies; and Lubowski and Rose (2013), presenting economic modeling insights and issues related to REDD.

Producer Profit Maximization Given Market Integration

With few exceptions, tropical deforestation is driven by demand for land for agriculture. Changes in agricultural profit from cleared land, relative to the profits from forest management, will affect rates of deforestation. Some drivers of such changes in agricultural profitability (e.g., recession, currency revaluation, violent conflict) are unlikely to be manipulated solely for the purposes of REDD because they have other consequences. Others factors affecting profits may be adjusted specifically for REDD. To help assess which are likely to reduce the loss of forest, we examine profit-maximizing land-use choices by producers well integrated in key markets.

Institutional Setting and Incentives

In a classic land-use model (see Appendix A), producers at forest sites decide whether to deforest or instead to manage the forest, and they make that choice to maximize their expected profit. Expected revenue is affected by output price, transport and other costs, and risk of expropriation if tenure is not secure. The cost of production on any deforested land is affected by the prices of labor, capital, and land as well as by the land's agricultural productivity. This model emphasizes the heterogeneity across forested sites including differences in distances to market and in factors observed only locally (not by a federal agency or policy analyst). An implied important feature of the model is spatial variation in the profits from agriculture, relative to forest management.

If, across a landscape, net agricultural profit is positive at a short distance from market but falls as that distance increases (holding other factors fixed), then the model predicts forests will be cleared up to a threshold market distance, beyond which the forest will be left standing. The prediction is probabilistic, and thus more realistic, if for any market distance we assume a distribution (across sites) of the net influence of other factors that affect the profit from clearing. In this case, the probability of deforestation is predicted to fall as the market distance increases, which implies that the avoided deforestation from any protected area falls with market distance.

This model can help to examine policy impacts on many decisions that affect the forest, such as clearing for crops, forest management using fire, enrollment in eco-payment programs, and responses to tenure insecurity, including site protection or lower investment in forest stocks. Land-tenure regimes under which titles are easier to obtain and defend after the forest is cleared raise clearing, as do policies that raise agricultural output prices or lower the costs of production. REDD payments for increasing carbon storage in forests directly encourage forest conservation. Lower transport costs affect land use at the distance threshold for deforestation (all else equal), implying highest forest impacts at intermediate distances but little impact closest to the market. Finally, if local governments observe factors not observed by policy analysts or federal agencies, then federal policies based only upon observables (which could imply one-size-fits-all policies) may be less efficient than locally determined policies that can be tailored to the local conditions.

Empirical Evidence

With these hypotheses in mind concerning the impacts of key policies in the setting of the model, we next review empirical evidence on forest impacts of development and conservation policies.

Development policies

Here we consider policies that are not specifically aimed at forests but are relevant due to their impacts on agriculture, a competing land use. As these "nonforest" or "development" policies influence the incentives for using forested land, they could be adjusted to help generate REDD.[3]

Transport and infrastructure policies

Investments in new roads increase access while lowering commodity transport costs. This can increase forest loss, although increased profit within forest management could counter that. While forest regions have been opened for development and deforestation most often by public investments in transport infrastructure, private logging roads also can increase access to forests. This implication of the land model—that lower transport costs raise forest losses—is supported by empirical analyses that include broad variation in socioeconomic and biogeophysical factors.

The model also suggests that the impacts of new roads vary over space, as a function of prior roads. Nelson and Hellerstein (1997) find that in Mexico prior roads affect the impacts of roads. Pfaff et al. (2011) find in the Brazilian Amazon that new roads have lower short-run impacts in regions with high prior road development and in regions with the lowest prior road development. Thus REDD could be achieved by shifting new roads to locations that result in less deforestation (and the same for pipelines). Angelsen and Rudel (2013) emphasize the same logic in suggesting that a shift in road investments from isolated forest frontiers to mosaic settings could increase both rural welfare and REDD.

The classic land-use model also suggests that policies affect the impacts of other policies. For example, other policies influence the forest impacts of new roads. Sills et al. (2006) describe policies implemented by the Acre State government (within Brazil's Amazon), including titling, establishing protected areas, and monitoring. These sought in part to lower the impacts of roads on deforestation while still harnessing the roads' benefits for sustainable forest management.

Agriculture policies

In this model, governments can support agriculture by supporting output prices (import tariffs, subsidies for processing) or input prices (subsidized credit, fertilizer), by lowering taxes, and by conducting research and development for pest and disease risks. Without any offsetting supports for forest production, these policies cause increased forest loss. Although government support for agriculture is a long-standing policy within both developed and developing countries, some components could be reconsidered under REDD, especially when there may be a domestic constituency for subsidy reductions, which could lower state expenditures and raise eco-services.

Biofuels cultivation is increasing and, on cropland or timberland, may raise deforestation because the supply of the displaced crop or forest output will fall, which in turn will increase its price and production elsewhere. Subsidies to biofuel production on nonagricultural land may, in principle, lower carbon emissions from fuels without causing forest loss, although

[3]Even without explicit REDD contracts, global funds could be used to cover the costs of changes in development that generate REDD. This is the spirit of the UN Global Environment Facility's funding for the "incremental costs" to forested countries of actions, like the relocation of a planned road, that generate global benefits (see Kerr 2013).

inefficiently if the land is not productive (if the land is productive, it is less likely it would not be in agriculture).

Security of land tenure

The model suggests that forest clearing is encouraged where it results in squatters' rights and eventually title to the land. Even if land clearing is not followed by a profitable use, it still may be worthwhile if it yields a title that facilitates credit and resale. Another land tenure issue in many tropical forest regions is the lack of recognition of traditional land tenure. In combination with incomplete and overlapping land records, it facilitates land acquisition by powerful actors, reducing incentives for longer-term management by the traditional owners. Alston, Libecap, and Mueller (2000) argue that in the Brazilian Amazon, only land cleared for at least five years is protected against expropriation. Tenure or expropriation risk has likely encouraged net tropical deforestation, but it is worth noting that tenure security could also increase the deforestation from some investments (e.g., in oil palm) since tenure security can encourage any land use that has longer-term payoffs.

Landowners also may respond to tenure insecurity by physically defending land, which is costly. As it may be easier to demarcate and monitor cleared agricultural lands, such private enforcement costs could help to increase clearing. These kinds of costs are likely to be higher if public enforcement is low due to budget constraints, remote location, or corruption. Furthermore, even if the forest is not cleared, difficulty in defending forested land could reduce investments in silviculture or the incentives to minimize damage to the residual stand during logging operations.

Tenure security can also affect profit-maximizing migration decisions, and thus the rate of deforestation when agricultural frontiers spill over into forests. For example, a lack of tenure security attracts migrants to regions if land can be obtained by deforestation (Merry et al. 2008). Thus such flows of labor can increase forest clearing. Carr, Pan, and Bilsborrow (2006) argue that both high birthrates and in-migration to tropical forests in Latin America are driven in part by tenure insecurity.

Conservation policies

Here we discuss empirical evidence concerning impacts of policies aiming specifically to achieve forest conservation: protected areas (PAs) and payments for ecosystem services (PES).

Protected areas

PAs are the most common conservation policy. Joppa and Pfaff (2009) find the tendency globally has been to create PAs in locations with low clearing. While isolation could be optimal (e.g., due to land costs and species distributions), it might also imply that deforestation impacts of those PAs are low since in such isolated locations (far from roads and cities, on higher slopes) most forest would still be standing without PAs. In light of these locational tendencies for PAs, Joppa and Pfaff (2010b) find that most PA impact evaluations overestimate the impacts of PAs by using baselines that do not reflect locations. The early test of this by Andam et al. (2008) for Costa Rica for 1963–1997 found that controlling for locations reduces impact estimates by over half.

Pfaff et al. (2009) confirm this finding for Costa Rica for the 1986–1997 period, but they focus on testing another model prediction: PA impacts can vary greatly across space. Results for more than 140 countries in Joppa and Pfaff (2010a) provide global support for both the Andam et al. (2008) and Pfaff et al. (2009) results. Pfaff et al. (forthcoming) and Pfaff and Robalino (2011) test another implication of this logic, that differences in location-choice rules for different types of PAs generate differences in impact. For the Brazilian Amazon, federal PA sites face higher clearing threats than state PA sites, and thus have avoided more deforestation. Also, despite permitting some deforestation, multiple-use PAs avoided more deforestation than stricter protection due to site differences. Stricter protection often appears to be feasible only farther from threat (see Nelson and Chomitz 2011 for global evidence).

Finally, we consider the implications of the classic land-use model's profit-maximizing choices for areas *outside* of the PAs. Spillovers due to private and other public responses to the establishment of a PA affect a PA's total forest impact and include socioeconomic impacts (e.g., from lowering the labor demand in agriculture or raising it in tourism). For deforestation impact, even the sign of net local spillovers from profit-maximizing response to PAs is unclear, given the differences across development settings. While Robalino et al. (2012) find greater clearing of the land surrounding PAs, given responses in Costa Rica's relatively mature land and labor markets, Pfaff et al. (2012) find less clearing of such land in the Brazilian Amazon, an ongoing frontier.

Payments for ecosystem services

Payment for ecosystem services such as water quality, species habitat, and carbon storage can reward landowners for conserving forest and thereby aid at least those who are paying.[4] PES may not aid anyone if this new price does not affect service supply, e.g., is refused on high-profit lands but is accepted by landowners who would not have cleared their forest anyway. The latter situation is analogous to isolated PAs. It is suggested by the land-use model because PES programs are voluntary, and enrollment raises profit more for those who have low-profit lands.[5]

Miranda, Porras, and Moreno (2003) examine this prediction for the well-known early Costa Rican PES program and find participants and nonparticipants differ in characteristics that affect land use. Those who participated might not have cleared even without payments. A low national clearing rate supports this argument, and payments tended to be for lands with lower threats (Robalino and Pfaff forthcoming). However, as in the case for the PAs, impacts varied over space (Pfaff et al. 2007). When a local nongovernmental organization helped PES to target clearing threats, the forest impact was higher (Arriagada et al. 2012).

Mexico's early program payments (for hydroservices) also went to sites facing relatively low threat, as predicted by voluntary enrollment. Alix-Garcia, Shapiro, and Sims (2012) compare recipients to those who applied but were not selected and find higher (though still limited) forest impacts than in Costa Rica. This higher impact is consistent with Mexico's higher national deforestation rate. Because the model suggests that responses to PES also could generate

[4]Having higher stocks of forest may benefit others too (e.g., collectors of nontimber forest products like fuelwood).

[5]See Pattanayak, Wunder, and Ferraro (2010) for discussion of this feature of voluntary programs, as well as evidence about PES.

impact *outside* the parcels that are paid, Alix-Garcia et al. (2012) examined nearby land and find increased deforestation in high-PES regions relatively isolated from product markets (i.e., where local demand is generally met by local supply rather than by outside goods). This significant local effect when markets are incomplete motivates the rural household optimization model presented within the next section.

Rural Household Optimization Given Incomplete Markets and Household Heterogeneity

In contrast to the setting underlying the classic profit maximization land-use model, households on the margins of tropical forests may not be fully integrated in markets. Often these households are farmers whose income is their farming profit and who consume part of their own production. Incomplete markets and production integrated with consumption affect REDD both by changing policy impacts and by creating new policy levers. They imply that endowments and preferences, by shifting the marginal values of labor and land, affect decisions to clear versus manage forest. Household heterogeneity is central in studies using this framework, while spatial heterogeneity, central in the classic land-use model, has tended to be limited by the scope of household surveys.

Institutional Setting and Incentives

High transaction costs result in incomplete or effectively missing markets for labor and land in rural economies in developing countries. Limited access to formal credit and insurance, as well as shallow markets for forest products, are also the norm for many tropical forest regions. Household production models are widely used to examine agricultural and forest production by rural households in such settings (see Appendix A). Insights for REDD can be drawn from applications of these models to the allocation of labor between clearing of forest, production on cleared land, harvest of forest products, domestic chores, and wage employment.

As in classic profit-maximizing land-use models that feature market integration, here too we would expect both market access and biophysical characteristics to affect labor allocation decisions as well as their land-use consequences. However, because in this case the markets are incomplete, households' assets and preferences will also influence their decisions.

Market incompleteness is characterized by Sadoulet and de Janvry (1995) as "bands" that exist between purchase and sale prices for outputs and inputs, including labor. Thus a household pays more to buy than it receives when selling due to, for example, transport costs or information costs. Dependent on not only general conditions, such as roads or cellular networks, but also household characteristics such as auto ownership and numeracy, these "price bands" can vary by household. Price bands imply that households' preferences and endowments may influence the net effects of shifts in relevant prices and technologies, with implications for the net impacts of a REDD policy like PES or REDD-supported projects that change conditions for rural households (by, e.g., disseminating new production technologies, clarifying tenure rules, improving credit access, adjusting prices, or creating employment such as in tourism or the processing of forest products).

For example, as in profit maximization models, high profit leads households to clear land for production. But also, as in the standard "backward-bending labor supply," increases in income and the value of labor's marginal product can raise leisure demands. That sort of effect, working through the household's preferences, suggests potential for reduced time allocation to clearing of the forest and thus could offset some of the direct effects on rates of land clearing from high output prices or better technologies (even more so if households satisfice rather than maximize).

The existence of localized markets contributes to market incompleteness or imperfections that can generate such additional effects. Households could be well integrated into local markets, but nonetheless their *regions* may be isolated from larger markets because of high transport cost, which, again, can affect the overall impact of a REDD policy on deforestation and degradation. For example, as in the profit maximization model, PES raise the opportunity cost of clearing and thus can reduce forest loss. However, the income from PES could cause shifts in households' consumption. For example, households may choose to consume more beef and milk. If cattle are raised locally on deforested land and there are barriers to trade with other regions, this change in consumption may significantly offset the price-based reduction in forest losses.

Empirical Evidence

We next review empirical evidence on forest impacts in settings of rural household optimization.

Development policies

We consider policies that are relevant to forests and REDD due to their impacts on agriculture.

Transport policies

The travel cost of getting from a forested parcel to the household's residence or to the nearest road or market is a robust predictor of deforestation (Sills and Caviglia-Harris 2008). This core prediction of the classic profit maximization land-use model with market integration holds even when households' assets and preferences affect deforestation too. This confirms that REDD could be generated by, for example, the strategic relocation of planned transportation investments.

Roads are also a critical determinant of market integration: new roads may shift a region from being isolated and having incomplete markets (the rural household optimization setting) to being connected with fully integrated and complete markets (the classic land-use setting). Within the rural optimization model, market integration can improve off-farm labor opportunities and thereby raise household income. Thus clearing pressure could increase in response to improved market access but also be reduced if labor shifts off the farm, and either rise or fall due to shifts in demands with increased household income. Shively (2001) finds reduction in labor allocation to farming when wages are higher, suggesting that education—which is also made more accessible by roads and raises home labor's opportunity cost—could reduce deforestation in the long term.

Agriculture policy

A profit maximization model predicts that higher output prices and improved agricultural technology cause an increase in clearing. In the rural household optimization model, such shifts in output prices and technology can also have income effects that raise the value of leisure for net sellers of goods. These income effects can dampen the increase in clearing, although for net buyers (common in Africa) higher output prices encourage clearing through both income and substitution. Separately, we note that price variation can lead risk-averse households to produce their own food, implying more local deforestation. Technology shifts that are labor intensive can draw labor out of clearing land, which can lower deforestation if labor markets are incomplete (as in a rural household optimization model), although this might be a purely short-term phenomenon. Both Maertens, Zeller, and Birner (2006) and Klasen et al. (2010) find that, at least for some time, more labor intensity (terracing) in lowland paddy rice production can draw labor out of highland clearing.

Adoption of more labor-intensive production technologies may require access to credit, and improving access to formal credit could have the additional benefit of reducing demand for pasture to keep cattle as "walking savings accounts" (Siegmund-Schultze et al. 2007). However, Zwane (2007) argues that given the differences across households in their consumption leisure substitutions, increased availability of credit can have variable impacts on clearing depending on initial household income. At low incomes, for example, increased credit is likely to cause more clearing for production, while at high incomes a rise in demand for leisure could dampen such an effect.

Security of land tenure

In much of the literature involving household optimization, the tenure regime is implicit, with households assumed to acquire agricultural land solely by investing labor in clearing forest. This assumes forest clearing confers tenure, that is, zero tenure security for forests but secure rights for cleared lands. To combat such clearing incentives, REDD could support the establishment of new titling systems that include forest and clarify tenure for forest under existing titling systems.

Variation in tenure security can influence labor allocation not only for forest clearing but also for tree planting. Deininger and Jin (2006) and Ayalew, Dercon, and Gautam (2011) found tenure insecurity to decrease tree planting in Ethiopia. Shively (1998) found tree investments to be sensitive to prices and risk preferences in the Philippines. Thus raising tenure security in concert with other policy, such as raising wood fuel prices through reduced access to public forests for charcoal production, could expand the private area under forest and increase the supply of wood from private sources.

Family planning

Household optimization models suggest that family planning is another relevant policy. Household size and the number of men have been found to be linked to clearing (Zwane 2007), although in a case study of the Amazon, Van Wey, D'Antona, and Brondízío (2007) find the number of women has a larger impact on deforestation and land use. In the spirit of rural household optimization models, they attribute this finding to off-farm employment and social program payments to women and girls, which can reduce cash constraints and allow the purchase of inputs, including hired labor.

Conservation policies

Heterogeneity of rural households also affects the impacts of conservation interventions, such as those being implemented under REDD projects (see Sunderlin and Sills 2012). Coomes, Barham, and Takasaki (2004) claim a weakness of past conservation development efforts "lies in their founding on a limited understanding of the microeconomic logic that gives rise to livelihood heterogeneity among forest peoples." Other past weaknesses are the lack of sustained funding, limited local participation, and little monitoring and evaluation for learning and adaptive management.

Integrated conservation and development projects

Integrated conservation and development projects (ICDPs) have been the main approach for balancing conservation and local livelihoods, which is also a central challenge for REDD. ICDPs seek to raise local income through economic activities such as ecotourism, beekeeping, or the sustainable harvesting and processing of forest products. The strategy behind such projects is that they (1) require intact ecosystems as inputs, (2) draw labor out of activities that are more damaging to the environment, and/or (3) compensate for, and thus encourage the acceptance of, legal restrictions on previously accessible natural resources (Weber et al. 2011). In terms of our models, (1) rests on typical incentives logic from classic land-use models, (2) rests on incomplete labor markets, and (3) may be most important for isolated rural sites that are harder to monitor.

Reviews have found little evidence of ICDP effectiveness (Garnett, Sayer, and Du Toit 2007; Naughton-Treves, Holland, and Brandon 2005). Leisher et al. (2010) argue that community forest management for timber, tourism, and mangrove restoration can promote both poverty alleviation and forest conservation. Yet they note that both the rates and the benefits of participation tend to be concentrated among better off households. Bauch (2010) and Weber et al. (2011) study forest-based microenterprises in the Tapajós National Forest in the Brazilian Amazon and also find that households with more durable assets are more likely to participate. While participation has increased cash income, there is no evidence that it has reduced agricultural activities considered a threat to forest conservation. These limited impacts are not surprising in isolated areas with barriers to accessing markets for non-timber forest products (NTFPs) and limited tourism appeal (e.g., no charismatic species).

Non-timber forest products

Sills et al. (2003) categorize NTFPs as either low-value, high-volume products (wood fuel, fodder) or high-value, low-volume products (Brazil nuts, chicle). Intervention concerning the former (e.g., providing alternative fuels) seeks to reduce collection and thus degradation, but intervention concerning the latter (e.g., facilitating market access) seeks to increase the value of products to raise the opportunity cost of labor and land in agricultural production. Some recent literature suggests neither is effective for REDD, arguing that wood-fuel use is not a major driver of forest degradation (except charcoal in a market setting (Arnold et al. 2006)) and that the potential for poverty alleviation through NTFP commercialization is limited (Wunder 2001). Nevertheless, the rural household optimization model, and the related evidence, suggest that REDD policies should consider the multiple roles of forests such as the "safety net" or "natural insurance" function of NTFPs in buffering income shocks (Pattanayak and Sills 2001).

Such functions can give forests a role in adaptation to climate change, which should not be undermined by REDD, although we recognize that such roles are unlikely to be sufficient as the primary incentive to conserve forest.

Restrictions on wood collection for fuel historically were implemented to protect public forests and ensure ongoing timber production. More recently, collection also has been restricted through community or joint forest management. Some evidence, especially from Africa, suggests that households respond to wood fuel scarcity by planting trees and relying more on private fuelwood supplies (Van 't Veld et al. 2006). However, if many households are at their minimum use levels, then restricting access can impose costs while not reducing collection. Based on a review of the empirical evidence, Köhlin et al. (2011) conclude that households reduce fuelwood consumption as its market or shadow price increases, although not by a lot, while Sills et al. 2003 find for India that ownership of fuel substitutes does not reduce wood collection from public access forests—only private.

Public Optimization Given Production and Corruption Responses by Private Firms

When REDD funds go through governments, their effectiveness depends on public choices. Making such global payments conditional on decisions about roads, PAs, tenure, and public lands can influence those choices. This is a critical issue since most tropical forests are owned by the state, although much forest is managed through concessions and other agreements with private actors such as logging firms, commercial ranchers, and plantation firms. Those actors too may try to influence public decisions about parameters of forest management (e.g., via corruption). Thus we examine a model of public optimization given both production and corruption responses by private actors.

Institutional Setting and Incentives

In tropical forests, logging often occurs through concessions from the state to private harvesters. Carbon concessions under REDD (e.g., eco-restoration concessions in Indonesia) could function like harvesting concessions and should be informed by all the challenges in defining their terms.

Terms of concessions

Concessions designate a specific volume or area for harvest and can cover small or large areas and be short or long term. Firms that win harvest rights pay royalties (lump sum or based on area, volumes, or species). Recent concessions sometimes also specify environmental goals (preserving species, preventing high grading, minimizing damage [reduced-impact logging]). Public rent capture from concessions has often been inadequate (Merry and Amacher 2005). The harvesters who bid on concessions are usually relatively large, in order to handle the concession obligations, and they also may have enough political capital to influence government choices.

Different levels (or political layers) of government make different choices. Higher levels determine the number and location of concessions, what firms are eligible (e.g., domestic versus international), and which allocation mechanisms should be used (e.g., bidding). The lower levels determine the size and the duration of concessions, tax levels, and the type and rate of royalties.

Theoretical approach

In REDD-relevant concessions research, the typical theoretical approach is to assume the government acts first and in anticipation of firms' responses, including harvest level and method (Amacher et al. 2007). The government maximizes a social welfare function that balances goals for public goods from forest with rents earned by harvesters, but it faces several constraints (see Appendix A). The most common is a budget target, which generates binding demands on royalty collection and can involve external income (e.g., REDD or other income conditional on forests).

In such a public optimization model, the private harvesting firm chooses the harvest level and harvest method, which affects the public goods provided by the forest. The harvester reports its harvest level to the government to determine what royalties the firm should pay to the state. Misreporting harvest level or method is illegal, and if the harvester is caught, it must pay a fine.

Detecting illegal behavior requires costly monitoring that might be hampered by bribes to government officials open to corruption. The vulnerability to corruption could be lowered by paying officials more while also monitoring them, but the costs further constrain state choices. Monitoring, bribery, and corruption proofing are all included in our public optimization model.

Budgets and royalties, monitoring, and corruption

Boscolo and Vincent (2007) and Amacher et al. (2007) find that a revenue-neutral (given a binding budget target) but steeper royalty function decreases the chosen harvest volume. They also find that the budget constraint can lead to less than perfect enforcement, as governments far from forests may choose not to incur the high cost of efforts to detect illegal logging. This affects other choices: for example, low enforcement may lead harvesters to underreport harvest levels.

REDD payments, while conditional upon not clearing the forest, could help governments meet the budget constraint. Loosening this budget constraint could lessen the pressures to permit additional harvests in order to raise revenues through royalties. It could also permit the option to make use of more costly monitoring efforts in order to reduce the influence of bribes. Although the underreporting of harvest levels will rise with royalties, it will fall with greater enforcement.

The issue of budget constraints also leads back to the issue of corruption, since revenue-constrained governments may be unable or unwilling to enforce key elements of the concession contract. Worse yet for REDD policy design, Karsenty (2008) suggests the nature of corruption differs by country, which means that the REDD design best for one place may not be best for others.

Decentralization

Decentralization is not explicit but is implicit within a public optimization model because different governments face different constraints and weigh differently the public goods provided by standing forests relative to the rents earned by harvesters. Any decentralization model states how government actors differ. For instance, typically global or federal actors are assumed to put higher weights on public goods or broad externalities than would a state or local actor. In addition, and critically for REDD, the sensitivity of the policy process to bribery surely varies by level of government. This affects the likely impacts of REDD concession fees because such payment may filter down from federal to local government following particular rules, and across-government transfers from REDD funds could be used to help cover key local enforcement costs.

Empirical Evidence

Having presented the general theoretical framework concerning public decisions to award private concessions, given corruption, we next review analyses of public policy in such settings.

Concessions

Illegal logging erodes revenue capture and thus also the government's ability to enforce concessions. Common policy suggestions are to raise royalty rates, in order to increase revenue and reduce excess harvest, and to raise enforcement and use of area-based, lump-sum royalties. However, Amacher et al. (2011) emphasize that the exact actions required are neither clear nor, to date, particularly well studied across the full range of conditions within the forested tropics.

Given the importance of budget targets, as highlighted in the model, REDD or general forest-conditional payments might lower the pressure to increase harvests for royalty revenues, and they might allow more enforcement. In this context, REDD payments would function like debt relief. Furthermore, if through baselines and monitoring REDD payments were conditional on forest, they would not only provide income but also shift incentives for any actions that affect the forest. However, all of the challenges of timber-harvesting concessions, including corruption, surely could arise in concessions created for REDD (i.e., for carbon storage rather than timber).

Corruption

There is clear evidence of corruption in the forest sectors of various developing countries that contain tropical forests (e.g., Contreras-Hermosilla 2002). Bribes, in particular, have been singled out as key barriers to the improvement of forest policies. The economics literature has suggested that such corruption should be expected if rents to government-owned resources are relatively high while probabilities of detection and punishment are relatively low (Jain 2001).

Jain (2001) suggests corruption can be limited by a well-financed enforcement system. Such a system could involve higher wages for relevant government officials and a higher probability of detecting corruption. Contreras-Hermosilla (2002) finds corruption is higher when there are underpaid inspectors, complex regulations concerning property rights, bureaucracy for obtaining forest permits, low penalties for illegal logging, and open-access native forests.

It may be widely accepted that the rule of law affects rates deforestation, yet studies are needed to examine the specific mechanisms by which corruption may often raise deforestation. Because analogous issues apply to REDD, it is important to know how corruption undermines policy; for example, shifting the royalty function might be circumvented through adjustments in bribes.

Decentralization

Most tropical forests are state owned. While the millions who live there have some rights to use the forest, historically they have had no legal right to manage it or to block its exploitation. Recently, however, governments have devolved forest ownership and forest management to local institutions, increasingly granting some property rights to the forest to local communities. As of 2001, more than sixty countries had reported decentralization in natural resources (Agrawal 2001).

Although individual and state ownership of forests were long considered the only options, there is increasing interest in rights regimes with management responsibility held by forest users. McKean (2002) suggests common property regimes with local controls can be the most efficient management given the low costs of monitoring and enforcement and high productivity in large units. Decentralization can aid participation and accountability, although ensuring that local institutions are accountable to the entire local population remains a challenge. In addition, as highlighted in the classic land model, local actors may have better information on conditions and preferences.

Decentralized management has been successful in some locations. For example, Nepstad et al. (2006) claim that indigenous Amazon communities are excluding trespassers interested in clearing forest land, despite relatively high payoffs from production (which means the land faces a high deforestation threat). Forests in India have been sustainably managed by communities for decades (Agrawal 2001), and there is evidence that community councils conserved forests more effectively than state agencies (Baland and Platteau 1996, Bray et al. 2003; Somanathan, Prabhakar, and Mehta 2009). Yet decentralization is not a panacea. Certainly it can increase deforestation if attention is not paid to local incentives, as there is no reason to assume that traditional communities are inherently focused on conservation. For instance, if people suspect rights will be revoked, they may take forest profits while they can.

For REDD, decentralization is likely to require cooperation across levels of government. However, relevant past outcomes are mixed. For example, although revenue-sharing agreements between government entities are common for publicly owned forests, they have not always been successful. For example, Smith et al. (2003) argues that in Indonesia, the allocation of forest-harvest permits by district government rarely is consistent with the intention of the national government. Siebert and Elwert (2004) note that central government officials in Benin have been resistant to local control of resources and concerned about local power over the rent capture from harvest of government forests (legal and illegal) that would follow from reallocation via decentralization.

In the context of REDD, decentralization and tenure security are "two-edged swords." Security of tenure, which raises willingness to invest in the future, could lead to more forest or instead to more plantations. Decentralization, which raises the effects of local preferences and information, could lead to more management of standing forest or instead to more clearing. Consider, for example, that the state of Pará, located in the Brazilian Amazon, could have been split into three states following a recent plebiscite. It is not at all clear that having more states would lower the rate of forest loss.

Discussion and Conclusions

The prospect of rewards under international climate policy for avoided forest carbon emissions has increased the focus on tropical forest conservation. Yet the record of past efforts to reduce deforestation and forest degradation is not particularly encouraging. The reasons for this mixed track record vary across institutional settings that feature different degrees of market integration and interaction between the government and the agents engaged in land and forest management.

There are opportunities to reduce the loss of tropical forests at a cost that is low relative to other options for reducing carbon emissions, including options in the developed countries that would pay for REDD. Yet claims about the opportunities for forest conservation have likely been overstated, as the sometimes low opportunity cost of land in production is just a lower bound on REDD's costs. There are also costs to clarify land tenure, distribute payments, establish, manage, and monitor protected areas, and reform agriculture and infrastructure policies that affect forests.

Summary of Domestic Policy Recommendations

To examine such issues, this article has described three theoretical frameworks that apply to three common settings that feature different agents, institutions, and incentives. These models, and the empirical evidence related to these settings, identify potential drivers of deforestation and forest degradation that are the keys to the design of domestic policies that will achieve REDD.

Strategically locate transportation and conservation interventions

The empirical evidence concerning the main settings that underlie both a classic land-use model of profit maximization, given good market integration, and a model of rural household optimization, given incomplete market integration and heterogeneous households, suggests that REDD could be generated through the strategic relocation of public transportation investments. Where private logging roads are important, a public optimization model suggests that effectively regulating such roads may require close attention to the incentives for local government officials.

In addition, strategic location of conservation policies, such as PAs and PES, is suggested by the evidence concerning REDD policy impacts relative to what would occur without a policy. If little baseline clearing would occur, even perfectly enforced policies will have limited impacts. Moreover, a public optimization model, and empirical evidence, suggest enforcement should not be assumed and that private pressure will affect siting decisions for conservation interventions.

Raise opportunity costs of labor in deforestation

The classic profit-maximizing land-use model and rural household optimization model both offer support for policies that raise opportunity costs of labor in deforestation by increasing access to off-farm employment, education, or labor-intensive agricultural technologies when the labor markets are imperfect on forest margins. In isolated labor markets, interventions that offer higher returns to household labor in alternative activities such as NTFP collection or ecotourism may effectively draw labor out of deforestation (because in these settings household labor is not easily replaced with hired labor). That said, within these isolated settings it is difficult to sustain higher returns for such alternative activities because of a lack of market access for alternative products.

Consider the income effects of policies

The rural household optimization model also suggests that policies that increase returns to labor, or increase output prices, can generate income effects. In more isolated regions, higher income may encourage deforestation by increasing the demand for agricultural products that are produced in the forested region itself, due to barriers to trade. Yet income could instead dampen deforestation to the extent that it increases demands for leisure—in settings of household labor—thereby increasing the effective costs of forest clearing. For the households that are net buyers of agricultural outputs, increased output prices will have the opposite effects: depressing demands for the outputs and for leisure because of reduced income. Thus, especially when considering a forest margin that is isolated from markets, the same policy could have very different effects across settings with different household production systems and degrees of market integration.

Improve access to credit and land tenure

Improving access to credit and land tenure are also common policy recommendations. Their impacts can vary too, depending on whether they are made available for operations on cleared land, forestland, or both. Also relevant is whether the agriculture that typically replaces forest production has a long investment horizon and thus benefits from credit and tenure security.

Maintain local access to NTFPs

Finally, while collection of NTFPs is usually not considered a major deforestation driver (except in specific cases with strong demand, e.g., for charcoal in growing African cities), access to NTFPs can be a central element of households' livelihood strategies nonetheless. This should be recognized in the design of REDD policy. More generally, REDD policy success will depend on local acceptance, which is based in part on perception of what is fair in light of local needs.

Charting a Path Forward

Perceptions of the prospects for REDD vary depending on which school of thought one adheres to concerning the role(s) of policies in reducing forest loss. One school asserts, at least implicitly, that to stop deforestation one need simply pay the opportunity cost of foregone uses (profits in agriculture that are not generated). This approach supports a focus on regions where profit from forest loss is perceived to be low and suggests that REDD will be relatively cheap. There is even concern that REDD will be too easy, in the sense of reducing pressure on other countries to shift incentives and behaviors in ways that address climate issues in the long term.

An opposing school of thought recognizes that REDD will require much more than just offsetting the opportunity costs of any foregone land uses, concluding that REDD's total costs will be considerably higher (although some elements of additional costs are difficult to quantify). Underlying this view is pessimism about the possibilities for reducing forest loss, a perspective that often is based in part on significant failures of previous policy efforts, plus a perceived lack of governance capacity within forested countries to implement appropriate policies effectively.

A review of past policy interventions to reduce forest loss is indeed sobering. Many such policies did not target, address, or even clearly identify all of the critical incentives for land uses. Interventions lacked local engagement and stakeholder participation. Weak governance and lack of land-titling systems limited the effectiveness of these programs. Furthermore, few programs were subject to impact evaluations, making it difficult to know which policies had succeeded. What is clear, however, is that many features of past policies could be drastically improved.

We suggest that the future of REDD policy and outcomes likely lies somewhere between these two opposing schools of thought. Domestic policies can lower deforestation—if they have local support and are based on informed designs. The nature of past failures suggests a potential for gains from locally appropriate interventions. For example, if better monitoring can accurately track reductions in greenhouse gas emissions, then requirements and incentives can be based on that outcome while many of the specific policy details could be left in the hands of local actors who are better positioned to intervene significantly and sustainably in relevant local processes. In general, consulting with all actors affected could help identify effective and sustainable policies.

Appendix A Theoretical Models

Model 1: Profit Maximization Given Producers Well Integrated in Input and Output Markets

For forest site *i*, a producer chooses deforestation ($D_i = 1$) or forest management ($D_i = 0$) to maximize expected profit. Expected revenue is affected by output price (p, one for each good), transport cost (τ that may vary by output), other costs (c_i), and a risk of expropriation in forest (r_i) if forest tenure is insecure. There is heterogeneity in market distance (d_i) as well as in the factors that are observed only locally (ε_i, with cdf F); that is, they are not observed later by the empirical analyst and also may not be observed by a public actor located in a capital city far from a rural frontier:

$$\max_{\{Di\}} \text{ profit at site } i = D_i \cdot \pi_{clear}(p, \tau, d_i, c_i, \varepsilon_i) + (1 - D_i) \cdot (1 - r_i) \cdot \pi_{forest}(p, \tau, d_i, c_i, \varepsilon_i) \quad (1)$$

Model 2: Rural Household Optimization Given Incomplete Markets Plus Heterogeneity

As in Sills et al. (2003) and Fisher, Shively, and Buccalo (2005), consider a rural household on the forest margin, maximizing utility from consumption of goods that are purchased (q_o) and produced (q_a, q_f) plus home time (t_H), given preferences (Φ) and technology or fixed inputs

($\Psi_{a,f}$). Households produce agriculture (Q_a) and forest products (Q_f) using purchased inputs (i_c at cost c), household time (T), and hired time (t_w) employed only in forest clearing. They allocate total time among home time, agriculture (t_a), clearing for agriculture (t_D), gathering forest products (t_f) and off-farm wage labor (t_o). Adding time to walk to work, based on distance from home to the agricultural fields or the forest, yields local landscape predictions that are similar to patterns around markets as described in **(1)**.

Production from open-access forest (Q_f) rises with collection and with deforestation (L_D), given that slash-and-burn yields both cleared agricultural lands and forest products. Forest output is affected by human capital and biophysical conditions (Ψ_f, which can reflect prior collection). Agricultural output rises with time in agriculture (t_a) and own and hired clearing (t_D, t_w), given household production endowments and technologies including human capital (Ψ_a). Production occurs on land that was cleared earlier (L) and during the period modeled (L_D). A budget limits expenditures on consumption (q_o), inputs (i_c), and labor (t_w) to be no more than the total value of production plus labor earnings (t_o), unless there is net external income (I) such as remittances or transfers. With REDD, the external income I can be a function of L_D, that is, transfers conditional on not having cleared the forest. Price bands for goods and labor are per unit transaction costs (ξ_a, ξ_f, ξ_t) that can be conceived as transport cost or losses from imperfect market information.

$$\max_{\{q,t\}} U\left(q_o, q_a, q_f, t_H; \Phi\right) \quad (2)$$

subject to these constraints:

$T \geq t_H + t_a + t_D + t_f + t_o - t_w$	Household's Total Time Constraint
$Q_f = f\ (t_f,\ L_D;\ \Psi_f)$	Forest-Product-Collection Function
$Q_a = a(i_c,\ t_a,\ L,\ L_D(t_D,\ t_w);\ \Psi_a)$	Agricultural Production Function
$I(L_D) + \Sigma_{i=a,f}\ (p_i - \xi_i) \bullet Q_i + (w-\xi_t) \bullet t_o \geq p_o q_o + p_a q_a + p_f q_f + c i_c + w t_w$	Household Budget

Model 3: Public Optimization Given Production and Corruption Responses by Private Firms

In a typical model of such decisions, like **(3)**, the government actor maximizes a social welfare function that is a weighted combination of the public goods provided by the forests (g) and the rents earned by the harvesters and all others affected (π), yielding a function such as V. In this problem, government is assumed to face any or many of several constraints on its choices. Most common is a budget target, B, that can generate binding demands on royalty collection and may depend in part on external income (I) that could include REDD (forest-conditional) income.

The private harvesting firm chooses the harvest level (l) and harvest method (h), affecting the level of public goods provided by the forest $g(l,h)$, which falls with the harvest l (sold at price p) but rises with the method's sensitivity h, which has cost c. The harvester also gives a report (x) on harvest level. That determines royalties paid to the state, $R(x)$, and it could be underreporting; that is, x may be below the actual harvest level (l), implying illegal logging. If a harvester is caught underreporting harvest or using less sensitive methods than agreed, then that firm pays fines F.

Catching such illegal behavior requires public monitoring, with required expenditures (e) rising with monitoring effort (m). For given effort, detection of anything illegal that is occurring can be reduced by bribes (b_2) to lower-level government officials if they are open to corruption. That vulnerability can be lowered by "corruption proofing" officials (at cost k_2), for instance with higher salaries and perhaps also monitoring of them (as opposed to of harvest level and method). We add similar bribery (b_1) and corruption proofing (k_1) concerning higher levels of government which determine the level of deviation from the default balance (β_0) between public goods and rents within the "social" welfare function.

This describes a strategic situation. The best public choice varies with expected responses by firms, which in turn will be functions of observed and of expected future government choices. For example, taking bribes of inspectors (b_2) as given, lower government levels may not monitor effectively, thus perhaps $m^*=0$. However, the determination of the optimal bribes is strategically complex. For instance, were government to spend heavily (high k_2) to corruption-proof officials, then optimal bribes (b_2) and the optimal deviation of reported from actual harvests could be zero.

$$\max_{\{m, k1, k2; R(.); F(.)\}} E[V] = g(l, h) + \pi \bullet (\beta_0 + b_1 \bullet (1 - k_1)) \tag{3}$$

where $\pi \equiv$ firm rents $= p \bullet l - c \bullet h - R(x) - m \bullet (1-(b_2 \bullet (1-k_2)) \bullet F(x-l,h) - b_1 - b_2$

subject to: $B \leq I(g) + R(x) + m \bullet (1-(b_2 \bullet (1-k_2)) \bullet F(x-l,h) - e(m,k_1,k_2)$

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