From REDD to Green: A Global Incentive System to Stop Tropical Forest Clearing

David Wheeler, Dan Hammer, and Robin Kraft

Abstract

In this paper, we develop and illustrate a prototype incentive system for promoting rapid reduction of forest clearing in tropical countries. Our proposed Tropical Forest Protection Fund (TFPF) is a cash-on-delivery system that rewards independently monitored performance without formal contracts. The system responds to forest tenure problems in many countries by dividing incentive payments between national governments, which command the greatest number of instruments that affect forest clearing, and indigenous communities, which often have tenure rights in forested lands. The TFPF incorporates both monetary and reputational incentives, which are calculated quarterly. The monetary incentives are unconditional cash transfers based on measured performance, while the reputational incentives are publicly disclosed, color-coded performance ratings for each country. The incentives include rewards for: (1) exceeding long-run expectations, given a country's forest clearing history and development status; (2) meeting or exceeding global REDD+ goals; and (3) achieving an immediate reduction in forest clearing. Drawing on monthly forest clearing indicators from the new FORMA (Forest Monitoring for Action) database, we illustrate a prototype TFPF for eight East Asian countries: Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand, and Vietnam. A system with identical design principles could be implemented by single or multiple donors for individual or multiple forest proprietors within one or more countries, as well as national or local governments in individual countries, tropical regions, or the global pan-tropics. Our results demonstrate the importance of financial flexibility in the design of the proposed TFPF. Its incentives are calculated to induce a massive, rapid reduction of tropical forest clearing. If that occurs, a TFPF for East Asia will need standby authority for disbursements that may total $10–14 billion annually for the next two decades. This financial burden will not persist, however, because the TFPF is designed to self-liquidate once all recipient countries have achieved clearly specified benchmarks. We estimate that the TFPF can be closed by 2070, with its major financial responsibility discharged by 2040.

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David Wheeler
Dan Hammer
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Center for Global Development
1800 Massachusetts Ave., NW
Washington, DC 20036

202.416.4000
(f) 202.416.4050

www.cgdev.org

1. Preface

In this paper, we propose using the latest forest monitoring technology to promote tropical forest conservation in an incentive-based system called the Tropical Forest Protection Fund (TFPF). Our proposed system fulfills the central mission of REDD+ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), which is to promote conservation by rewarding governments that choose to protect their forested lands. However, the TFPF is unlike other REDD+ programs because its architecture is driven by the conviction that we're out of time: Damaging climate change and rapid sea level rise are already upon us (Wheeler, 2011). The next decade will determine whether we can roll back these threats before they become overwhelming. Urgency requires us to move rapidly in the world as it is, not as we might like it to be. To stop forest clearing, we must find a way to make REDD+ work in the Myanmars as well as the Indonesias. If we focus only on countries that are "comfortable" for conventional assistance, gains achieved there may well be lost as forest clearing shifts to other venues.

Success requires that we rapidly engage all tropical forest countries with a consistently-implemented global system that offers compelling incentives to conserve forests. This can only work if we minimize process complexity, avoid negotiation of myriad bilateral and multilateral agreements, and provide maximum flexibility for responding to the incentives that are offered. At the same time, we must respect the claims of indigenous communities whose stewardship will be critical for forest conservation. These communities are demanding direct access to REDD+ resources, because they do not believe that they will receive just shares of incentive payments that are given to national governments. Our proposed program accommodates that demand.

A global incentive program can only work if it draws on rapidly-updated information about forest clearing that is not dependent on the institutional strength, good will, or commitment to transparency of payment recipients who may have none of these traits. Fortunately, such independent information resources can now be harnessed on a global scale.

Our proposed architecture may surprise, and quite possibly unsettle, some colleagues who have worked tirelessly to protect forests by more traditional means. We are committed to reaching the same goal, albeit by an unconventional route that we believe offers more hope of success before the Earth moves to a hot state that will be catastrophic for everyone.

2. Introduction

REDD+ programs aim to conserve forests by offering incentives to reduce forest clearing. Although the basic concept seems clear, international negotiators have been slow to adopt specific measures. For example, the Cancun agreement (UNFCCC, 2011) goes no further than invocation of the need for performance benchmarks, conservation targets, national action plans and development of implementing institutions.[1] In truth, negotiators may feel little pressure to get more specific until a multilateral fund is chartered to dispense the billions of dollars that have been promised by donor countries.[2] The design of such a Green Climate Fund was discussed at the April UNFCCC meeting in Bangkok (Reuters, 2011).

While multilateral negotiations continue, Norway is providing bilateral leadership in pilot REDD+ programs with the governments of Guyana and Indonesia. The agreement with Guyana allows for as much as $250 million in total incentive payments by 2015, with $7.3 million payable in each year that Guyana clears less than 10,000 hectares of forested land (Development Today, 2011). Norway initiated the agreement in 2009 by depositing $30 million in the Guyana REDD+ Investment Fund (GRIF), which is administered by the World Bank. Recently it has deposited an additional $40 million, citing evidence that Guyana has maintained a lower deforestation rate than previously anticipated (Forbes, 2011). However, numerous critics have noted that the initial $30 million predated any performance assessment; that subsequent deforestation significantly increased; and that, in any case, no independent means of verification exist (Lang, 2011). Norway has recently relaxed the annual 10,000-hectare limit by exempting 4,500 forested hectares that Guyana will clear to build a dam, whose financing will draw on Norway's REDD+ payment.

In the Indonesia program, Norway has committed to disbursing up to $US 1 billion during the next 7-8 years, with phase 1 supporting strategy development, policy reform and institutional development; phase 2 financing a pilot program in Central Kalimantan province; and phase 3 paying for verified emissions reductions countrywide (Government of Norway, 2010; Rondonuwu and Fogarty, 2010). Phase 2 of the program has just begun, so any assessment would be premature.

In summary, implementation of REDD+ programs has just begun, and serious questions remain about the design of appropriate, verifiable performance incentive mechanisms. This paper attempts to contribute with a design that reflects the basic principles of cash on delivery (COD) aid specified by Birdsall and Savedoff (2010):

[1] See particularly Part C, starting on p. 12. The general tenor is captured by the agreement's statement that governments should "collectively aim to slow, halt and reverse forest cover and carbon loss, according to national circumstances.".

[2] The Cancun accord notes that developed countries have promised $30 billion in "fast start" funding for 2010-2012, the first step toward providing $100 billion per year from 2020, as agreed at the Copenhagen climate summit in 2009.

COD Aid is a funding mechanism that hinges on results. At its core is a contract between funders and recipients that stipulates a fixed payment for each unit of confirmed progress toward an agreed-upon goal. Once the contract is struck, the funder takes a hands-off approach, allowing the recipient the freedom and responsibility to achieve the goal on its own. Payment is made only after progress toward the goal is independently verified by a third party.

In that spirit, our proposed approach establishes measurable performance benchmarks; specifies fixed rewards per unit of achievement (judged by the benchmarks); independently audits performance; and delivers rewards automatically. It also reflects COD aid principles in setting no preconditions for planning, institutional development or policy reform. However, our approach goes further in one respect, because it does not involve a performance contract between donor and recipient. It simply performs public performance audits for all parties assessed, assigns rewards accordingly, and makes them available to deserving parties without other conditions. Countries can pursue forest conservation as they see fit, knowing in advance that their rewards will be proportionate to their publicly-measured progress against clear benchmarks.

In this paper, we develop and illustrate a prototype system for eight East Asian countries: Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam. The system relies on frequently-updated, independently-acquired information on forest clearing, as exemplified by FORMA (Forest Monitoring for Action), which processes data from NASA's MODIS system to provide monthly forest-clearing information for the pan-tropics at 1 km spatial resolution (Hammer, Kraft and Wheeler, 2009, 2011). We provide a more detailed introduction to FORMA in Appendix A4.

The remainder of the paper is organized as follows. Section 3 describes our benchmarking principles and rules for assigning payments and public performance ratings. We develop the economics of our proposed incentive payments in Section 4, while Section 5 focuses on the recipients. Section 6 introduces our proposed Tropical Forest Protection Fund, and Section 7 develops the illustrative prototype for the eight East Asian countries. Section 8 explores alternative futures for the TFPF and their implications for financing, and Section 9 summarizes and concludes the paper.

3. Setting the Ground Rules

3.1. Initial Conditions

A performance incentive system requires establishment of a benchmark against which progress can be judged. In REDD+ programs, for example, the benchmark is often forest clearing in the period preceding implementation. This implicitly assumes a "fair game", in which previous conditions were neither abnormally favorable nor unfavorable for forest clearing. Failure to satisfy this condition would make subsequently-measured progress either "too easy" (if prior conditions promoted unusually rapid clearing, which would subsequently have declined regardless) or "too hard" (in the converse case). In reality, "fair game" may be an elusive concept because forest clearing can be driven by so many factors: population size and density, travel time to markets, the quality of transport infrastructure, agricultural input prices, product prices, interest rates, exchange rates, physical factors such as topography, precipitation and soil quality, and the status of protected areas.[3] Their significance undoubtedly varies from place to place, and in each locale different factors might well be judged favorable or unfavorable for clearing in any particular period. In practice, the only realistic benchmark is probably average forest clearing during a previous period long enough to dampen the effects of short-run fluctuations in potentially-important drivers such as seasonal rainfall, product prices, exchange rates and interest rates. For this exercise, we use average clearing during the previous two years as the benchmark.

3.2. Benchmarking the Forest Transition

Once the initial benchmark is set, performance incentives can be related to the difference between the benchmark and actual clearing in each subsequent period. However, the benchmark should not be viewed as a fixed standard. It should also incorporate the normal "forest transition" that accompanies economic development, in which forest clearing gives way to regeneration as conservation values and forest management capability increase. In earlier work, Cropper and Griffiths (1994) found an inverse U-shaped forest transition curve that reached peak deforestation between per capita incomes of $US 7,000 and 16,000.[4] Our own econometric results for the period 1990-2010, reported in Appendix A1, indicate that the relationship is now monotone-declining, with the forest transition line reaching zero net deforestation at a GDP per capita of $10,150.[5]

Incorporating the forest transition changes a country's performance benchmark from a fixed value to a target path that declines toward zero clearing at an income of $10,150. It also affects the initial benchmark value, which should account for a country's relative

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[3] Nelson and Chomitz (2009), Chomitz, et al. (2006) Rudel, et al. (2009), Wunder and Verbist (2003) and Barbier (2000) have studied cross-country determinants of forest clearing over multi-year intervals. Within counties, numerous econometric studies have estimated the impact of drivers across local areas during multi-year intervals. Some studies have used aggregate data for states, provinces or sub-provinces (e.g. studies for Brazilian municipios by Pfaff (1997) and Igliori (2006), and Mexican states by Barbier and Burgess (1996)). Many studies have also used GIS-based techniques to obtain estimates at a higher level of spatial disaggregation (e.g., Chomitz and Thomas (2003) for Brazil; Cropper, et. al. (1999, 2001) for Thailand; Agwaral, et al. (2002) for Madagascar; Deininger and Minton (1999, 2002), Chowdhury (2006) and Vance and Geoghegan (2002) for Mexico; Kaimowitz, et al. (2002) for Bolivia; and De Pinto and Nelson (2009) for Panama). In rarer cases, studies have used annual national or regional aggregate time series over extended periods (e.g. Zikri (2009) for Indonesia; Cattaneo (2001) and Ewers, et al. (2008) for Brazil).

[4] We have adjusted the Cropper/Griffith estimates to $US 2010 using the US GDP deflator. Variations in peak deforestation are attributable to differences in population density.

[5] We measure GDP per capita at purchasing power parity, in constant $US 2005. Our data are drawn from IMF (2011).

performance in the years prior to the program. We determine initial benchmarks in a process designed to increase performance rewards for countries whose past performance has been better than average. First, we use the estimated global forest transition line (reported in Table A1), to calculate each country's predicted deforestation rate during the period 2000-2005. Then we divide the predicted rate by the actual rate, creating an index of the country's prior performance relative to the global norm. We retain index values greater than one and set the rest at one. We multiply this index by initial forest clearing to set the initial point for the forest transition line. The terminal point is zero for an income of $10,150, as we previously noted.

In each period, a country whose forest clearing path is below its transition path receives a performance incentive proportional to the distance between the paths. To clarify, suppose that a country achieves a 10-unit decrease below the initial benchmark in the first year. In that year, its payment is 10 times the unit payment offered by the system. Now suppose that in the second year, clearing remains constant at the reduced level but the transition benchmark falls by one unit as the economy grows toward $10,150 per capita. The country continues to receive rewards for 9 of the 10 unit reductions it achieved in the first year, because those 9 units represent carbon that has remained sequestered in the forest rather than emitted into the atmosphere. Further suppose that clearing remains at the same level as the economy continues to grow, with the transition benchmark dropping 1 unit each year. The units rewarded will fall in step, from 8 in the third year to 0 in the 11th year, and total units rewarded during the 11 years will be 55 [10 + 9 + … + 1]. By identical reasoning, the country will have a total of 100 units rewarded if it continues to reduce clearing by 1 unit each year (as the benchmark also falls by one unit).

3.3. Incorporating REDD+ Concerns

REDD+ has emerged from a sense of crisis surrounding global carbon emissions. We have little chance of avoiding a climate catastrophe unless the carbon intensity of economic activity plummets in the near future. But this will not happen fast enough under "business as usual," which includes the normal evolution captured by our estimated forest transition line. To incorporate REDD+ concerns, we introduce a second path that declines from the initial benchmark for each country to zero in a common target year for all countries. No consensus target year has emerged from international negotiations, although drafts circulated at Cancun apparently included references to a target date of 2030 (Gray, 2010). We would prefer a more ambitious target, because our proposed system is based entirely on incentives, not binding conditions. For our prototype exercise, we set a REDD path that declines from each country's initial benchmark point to zero in 2025. Countries whose forest clearing paths are below their REDD paths receive additional payments proportional to the distance between the two paths. The associated calculations are identical to those illustrated in the previous section.

3.4. Rewarding Short-Run Improvements

Once the proposed program begins, a variety of factors could propel some countries well beyond their initial clearing levels. Such factors could include price spikes for forest products, or flouting of weakly-enforced regulations by local firms. Once these countries have strayed too far above the forest transition and REDD lines, the eventual rewards from course reversal might appear too distant to warrant the fixed cost of the transition. But resetting the benchmarks for recalcitrant countries could be fatal for the entire system, since it would create perverse incentives for other countries to expand forest clearing, with the expectation of new benchmarks and greater rewards for reducing deforestation in the future. We address this problem by introducing a proportionate reward for decreased clearing from one period to the next. The reward lasts for only one period, and is given only once for a decrease in a particular range. This avoids perpetuation of periodic, identical rewards for a country whose clearing cycles around a flat line. It also avoids perverse incentives, by setting short-term rewards that are significant enough to interest recalcitrants, but substantially lower than the rewards to be gained on a path that remains below the transition and REDD lines.

To summarize, our prototype system rewards performance relative to three benchmarks: a declining forest transition line; a declining REDD target line; and last period's performance. A country that stays on a declining path below both lines will get all three rewards in each period, while a country that continually increases forest clearing will get no rewards in any period. An intermediate performance will earn an intermediate reward.

4. The Economics of Performance Payments

Our proposed system incorporates the basic principle of cash-on-delivery (COD) aid by rewarding each unit of performance that exceeds a benchmark. Its architecture anticipates rapid expansion to global provision of compelling rewards for forest conservation, in a non-contractual system whose rules are simple to administer, easy to understand and uniformly applied for all countries. In contrast, much discussion of REDD+ has focused on country-specific agreements whose payment schemes incorporate the economic opportunity costs of local forested lands. In our view, both theoretical considerations (Arcanda et al., 2008; Cattaneo, 2001; San et al., 2000; Wunder and Verbist, 2003.) and empirical research (Blankespoor et al., 2011) suggest that such schemes will often prove intractable, because local opportunity costs will fluctuate rapidly and widely in response to movements in key drivers such as plantation product prices, exchange rates and interest rates (Blankespoor, et al., 2011). Even if local opportunity costs were easy to compute, which is not the case, this instability would make it very difficult to establish sustainable agreements with recipient governments. In any case, a rapidly-implemented global system of the type we envision cannot achieve its goals through such a ponderous process.

4.1. Pricing CO2

In contrast, our approach adopts a globally-uniform "offer" price for forest conservation wherever it occurs. This approach imposes three conditions on the price. First, it must remain stable for a substantial period, so that potential recipients will gain confidence in the offer and the potential reward for reduced forest clearing. Second, it must be high enough to offer credible compensation for conservation, even in areas where the conversion opportunity cost is relatively high. Third, it should not be higher than the marginal cost of CO2 reduction in the energy sector, which is the effective unit price at which energy producers can be induced to reduce CO2 emissions. This provides a natural competitive standard for the forest sector, because failure to halt forest clearing at this price would be a clear signal to reallocate scarce mitigation resources to the energy sector, whose contribution to global CO2 emissions is at least twice that of the forest sector (WRI, 2011).

Table 1 provides evidence from recent research on conversion opportunity costs in tropical forests, translated from the economic opportunity value of specific land parcels to the offer price for sequestered CO2 that would make conservation an equally-profitable activity (RFF, 2011). These results include interior areas far removed from the current deforestation frontier, as well as areas at the clearing margin. Many interior areas have very low opportunity costs because they are distant from population clusters, markets and viable transport links. The converse is generally true for active deforestation areas, so higher-opportunity-cost tracts provide the relevant targets for a program that pays to prevent clearing at the current deforestation margin.

Taking this interior/frontier cost differential into account, the global results presented in Table 1 suggest that significant reduction in clearing at the current deforestation margin will require pricing that warrants conservation in a relatively high percentage of forested areas. At 80%, for example, the associated offer price for sequestered CO2 is near $27/ton.

Table 1: CO2 Price Equivalent of Conversion Opportunity Cost: Tropical Forest Land

Cumulative % of Tropical Forest Conserved	Marginal Opportunity Cost, $/tCO2
50	0.62
60	4.77
70	12.00
80	27.31
90	71.95
95	126.06
99	289.84

Source: Resources for the Future (2011)

As we previously noted, the other relevant comparator is the marginal cost of CO_2 reduction in the energy sector. A conservative estimate of this cost is provided by the price at which CO_2 emissions permits actually trade in the European Union Emissions Trading System (EU ETS). Drawing on data from BlueNext,[6] the leading exchange, we calculate the average daily spot price of European Union Allowances for 2008-2012, which are issued by EU member states according to their national allocation plans. We match these daily spot prices (quoted in Euros) with daily US dollar exchange rates provided by the US Federal Reserve Board (FRB 2011). Figure 1 displays the daily BlueNext series in dollars, from the first reported trades on Feb. 29, 2008 to trades on April 21, 2011. After trading near $US 40/ton CO_2 in May-July 2008, the allowance price dropped to $10.31 in February 2009 before rebounding to a range near $20.

Figure 1: Daily EU Emissions Allowance Price, February 2008–April 2011

The EU ETS price is the most reliable benchmark in this context, although it reflects the economics of the European energy sector, where emissions intensities are already low by world standards. It is certainly conservative from a global perspective, since there may well be plentiful opportunities for energy-sector CO_2 emissions reduction at lower cost in developing countries. However, as we have shown in Table 1, an offer price substantially below $27/ton may be insufficient to induce conservation in many active deforestation areas. And, in any case, the need for long-run stability in pricing requires us to specify an offer price that will be maintained for a long period of time. We therefore settle on a price of $25/ton CO_2, which is at the 82nd percentile for EU Allowance prices observed from February 2008 to April 2011, and higher than any price observed since January 1, 2009. We recognize that a significantly lower offer price might prove sufficient for the task, but we

[6] BlueNext is a joint venture of the New York Stock Exchange and Caisse des Dépôts; a French public financial institution.

prefer to err on the high side to encourage a rapid, massive decrease in forest clearing. And it would be difficult to justify going substantially above $25/ton, since energy-sector opportunities would be plentiful in that range.

4.2. Establishing the Rental Rate for Sequestered Carbon

As Chomitz, et al. (2006) note[7], a performance payment system rewards carbon sequestration by paying the equivalent of a "rental" value on each ton of CO2 that has not been emitted into the atmosphere. A natural standard for setting the rental value is multiplication of the CO2 price by the interest rate for long-run notes that are considered risk-free by the market. We take a conservative approach by using 5.45%, the average 10-year rate on US treasury notes since 1990 (USFRB, 2011). This allows for the possibility of a substantial increase above the 2010 rate (3.22%) if inflation moves back toward historical levels. It is perfectly possible, of course, to use the current 10-year rate as the basis for setting payments in each year, but that might prove destabilizing in practice. A more realistic approach, which we adopt here, is to avoid resetting the rate in the short/intermediate term in order to maintain a stable offer price.

4.3. Setting the Area Standard for CO2 Pricing

The final calculation step is translation of CO2 rental per ton into rental per hectare of tropical forest that is conserved rather than cleared. We follow Chomitz, et al. (2006)[8] in adopting 500 tons of CO2 sequestered per hectare as the reference standard. When combined with the unit rental payment for CO2 (5.45% of $25/ton annually), it yields annual payments per tropical forest hectare conserved of $681. We adopt this as the unit payment for performance in the forest transition component of our incentive system. Given the need to reduce emissions quickly, we set the unit payment for performance in the REDD component at twice the transition level, or $1,362/hectare. Both transition and REDD payments are long-run obligations which may continue for many periods, as the previous examples have shown. In contrast, the third component – single-period payments for improvements – is only incurred once for improvement in a particular range. Because the implicit obligation is much shorter-term and the importance of promoting course reversal for rapid-clearing countries is very high, we set the single-period payment at four times the REDD payment, or $5,448/hectare.

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[7] For a more detailed discussion, see pp. 206-208.

[8] See p. 195.

5. Who Receives Payments?

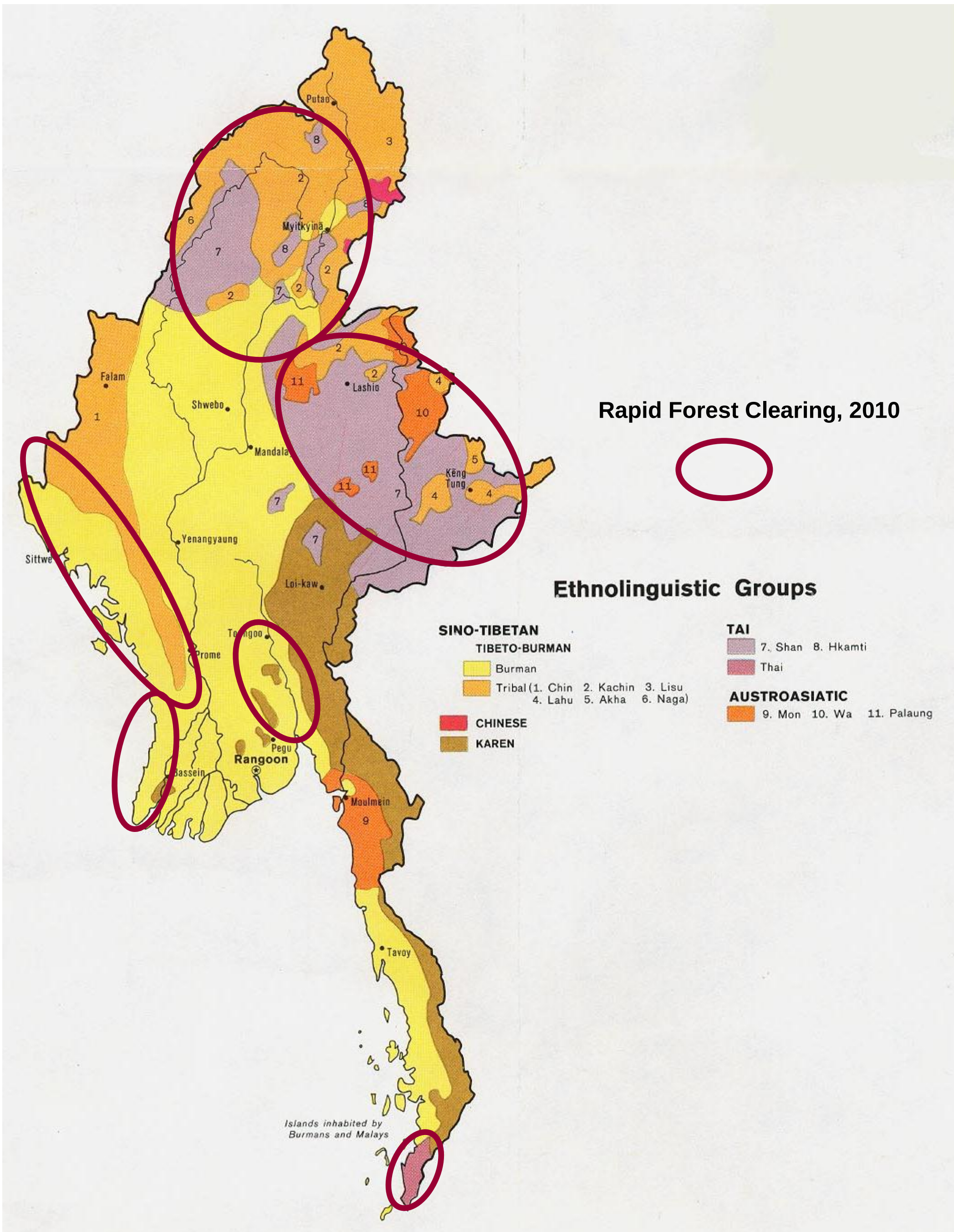
To be credible and sustainable, our proposed program must achieve the broadest possible geographic coverage to avoid displacing deforestation to non-covered areas. The coverage imperative provides a prime motivation for our proposal because, as we noted in Section 2, pilot REDD programs are already so mired in local negotiations, contracting and institutional development that extending the same approach to pan-tropical coverage would be prohibitively cumbersome, time-consuming and expensive.

In principle, our system could offer performance incentives to the myriad local proprietors of forested land. However, global tractability dictates channeling performance rewards through national governments, for two main reasons. First, more decentralized programs could only reward clearly-identifiable proprietors. The associated information requirements would be prohibitive for a global program and, in many developing countries, land tenure problems would limit coverage and invite displacement of forest clearing to areas with ill-defined property rights. Second, a national focus recognizes that many factors drive forest clearing, from export taxes to local road-building. Only national governments have the reach and authority to influence the full set of factors, and the information needed to determine which policy instruments should be adjusted to reduce forest clearing at least social cost. Our proposed system provides a powerful incentive for governments to make cost-minimizing policy adjustments, since the unit reward for performance will not vary with local implementation costs.

Although a focus on national governments appears inescapable, one critical exception has to be incorporated into a viable program. In many tropical forest countries, national governments coexist with indigenous communities that have traditional claims to the forested lands they inhabit. In some countries, forest clearing is concentrated in areas dominated by indigenous communities. As Figure 2 shows, Myanmar provides a striking example: The circled regions, identified by FORMA as areas of rapid forest clearing, overlap heavily with ethnic minority regions identified by the map.

National governments may recognize indigenous claims rhetorically, and in some cases substantively, but disputes remain rife and they have escalated in some countries as preparations for REDD programs have begun. In Indonesia, for example, indigenous communities in forested areas of Sumatra, Kalimantan, Sulawesi and Irian Jaya are demanding direct access to REDD funds on two grounds: (1) They are the legitimate stewards of many forested areas, and (2) The prospect of large payments for conservation in their areas may induce governments to abrogate their traditional claims and divert payments to claimants that have more political influence. The unfortunate history of relations between national governments and indigenous peoples in many countries lends credence to these claims, which are proving to be major sticking points for REDD preparations.[9]

Figure 2: Myanmar: Forest Clearing and Indigenous Communities



[9] For numerous related reports, see http://www.redd-monitor.org/.

In our proposed system, we acknowledge these claims by allocating a significant percentage of performance payments to indigenous communities that inhabit forested areas. We recognize the difficulties associated with establishing an appropriate percentage, as well as the identities of legitimate claimants in each country. In our view, the claims questions is and will remain opaque to outsiders, and is better settled by consensus among the indigenous communities themselves. While we could attempt to develop methods for determining appropriate percentage allocations country-by-country, we would inevitably be hobbled by ignorance about local conditions. And, in any case, we believe that the exercise would not warrant the controversy that it would inevitably provoke. We therefore opt for simplicity and adopt the recommendation of Indonesia's State Environment Minister (Simamora, 2010) by allocating 20% of performance payments to indigenous communities in each country.

6. Implementation: The Tropical Forest Protection Fund

We vest our system in a proposed Tropical Forest Protection Fund (TFPF) that will operate under simple, consistent, transparent global rules with a small professional staff. The TFPF will be overseen by a board of trustees who are highly-respected figures in international finance, conservation and indigenous rights. Under strictly-defined guidelines, they will be empowered to alter the TFPF's operating parameters as future circumstances warrant. The TFPF will administer an automatic reward-for-performance system with the small set of parameters specified in Box 1. For this prototype exercise, we use the parameter values developed in the previous sections.

Box 1: TFPF Parameter Values

General parameters:

1. CO2 emissions charge per ton ($US 25)
2. Interest rate (5.45%)
3. Tons of CO2 emitted per hectare cleared (500)
4. REDD target date for zero forest clearing (2025)
5. REDD performance payment multiplier (2)
6. Short-run performance payment multiplier (4 x REDD)
7. Percentage of payments assigned to indigenous communities (20)

Parameters for each country:

8. Initial clearing level
9. Initial multiplier (from income-predicted vs. actual deforestation)
10. Predicted year for zero net deforestation (from past income growth

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The TFPF will operate as an autonomous institution that rewards measured results without formal contracts with recipients. Its staff will have four basic functions: (1) Monitoring information about forest clearing and financial flows to ensure that the TFPF's operations conform to its charter; (2) Ensuring that payments go to the intended recipients; (3) Supplying the trustees with assessments of TFPF results and recommendations for altering parameters as conditions evolve; (4) Public reporting of results, including a color-coded rating system that summarizes the status of each recipient country in our three performance dimensions (transition line, REDD line, period-to-period improvement).

6.1. Financing Mechanisms

The TFPF will make regular performance payments to national governments and indigenous communities. Payments to national governments will be sent to officially-designated accounts used by those governments for global transactions. A government could, in principle, refuse to accept payments from the TFPF, but this seems extremely unlikely because the payments will have no strings attached. In case of refusal, the payments will be deposited in an escrow account, at interest, and the total accrued sum retransmitted to the government's account in each period until the funds are accepted.

Payment to indigenous communities will require delegated recipient entities. These may emerge rapidly in some countries but not in others. Recognizing this reality, the TFPF charter will specify that payments allocated to indigenous peoples in each country be deposited in an escrow account, at interest, and held until a recipient entity emerges. Before payment, each entity will be certified (and periodically re-certified) by an appropriately-designated global council that will consult with representatives of indigenous communities and local experts in each country.

The TFPF will pay for performance measured at frequent intervals, across many countries and regions, so trends in its overall payment flows should be relatively stable and predictable within the budgetary time frames that are relevant for donors. Birdsall and Leo (2011) have proposed several potential funding sources.

If the economic analyses of Stern, et al. (2006), Nauclér and Enkvist (2009) and RFF (2011) are correct, then TFPF payments based on a CO2 charge of $25/ton will quickly reduce forest clearing in many countries. If even $25/ton induces a minimal response, then mitigation resources should be re-deployed to more cost-effective projects in the energy sector. Overall responsiveness to the TFPF should become apparent after a two- or three-year adjustment period. We will explore the potential magnitudes of payments in Section 8.

Inevitably, the TFPF will confront short-run surpluses and deficits as fixed donor funding cycles interact with fluctuating payment requirements. Short-run surpluses might well be transient, so they can be held in escrow, at interest, to cover subsequent short-run deficits. Additional shortfalls can be covered by vesting the TFPF with short-term borrowing authority, guaranteed by donor governments to maintain a premium rating.

It is important to note that the TFPF will ultimately be self-liquidating. Its payments may increase sharply for some years, but they will inevitably fall as countries either reduce forest clearing to zero or fail to keep clearing below the steadily-declining forest transition and REDD lines. As our illustrative exercise will show, the TFPF might reasonably be expected to self-liquidate after about 50 years of operation.

6.2. Public Performance Ratings

The information that drives incentive payments can also provide strong reputational incentives for improvement. Publication of payment flows alone is insufficient in this context, since payments will vary with forest size across countries achieving the same proportional reduction in clearing. To be effective, public performance ratings should be scale-free and extremely easy to interpret. At the firm level, such ratings have significantly improved the environmental performance of polluters in Indonesia, the Philippines, China and Vietnam.[10] The ratings color-code good and bad environmental performance, judged against relevant local benchmarks (compliance with local regulations, community complaints, etc.). In a similar vein, the TFPF will color-code countries' performance using the rules specified in Box 2, against benchmarks defined by transition lines, REDD lines and clearing in the previous period.

Box 2: Public Performance Ratings for Reduced Forest Clearing

Definitions:

C = Current forest clearing

dT = C – [clearing on the forest transition line]

dR = C - [clearing on the REDD line]

dC = C - [clearing in the previous quarter].

	Measure / benchmark			
Rating	dT / transition line	dR / REDD line	dC / previous quarter	Supplementary note
Green	Negative	Negative	Negative	or C is zero
Aqua	Negative	Negative	Positive/Zero	C Positive
Blue	Negative/Zero	Positive/Zero	Negative	C Positive
Blue	Positive/Zero	Negative/Zero	Negative	C Positive
Yellow	Negative/Zero	Positive/Zero	Positive/Zero	C Positive
Yellow	Positive/Zero	Negative/Zero	Positive/Zero	C Positive
Orange	Positive	Positive	Negative	C Positive
Red	Positive	Positive	Positive/Zero	C Positive

[10] One of the authors (Wheeler) participated in the design and implementation of all four systems: PROPER in Indonesia; EcoWatch in the Philippines; GreenWatch in China; and the Environmental Information and Disclosure System (EIDS) in Vietnam. For further discussion and assessments of results, see Wheeler, et al. (2000); Afsah, Blackman and Ratunanda (2004), and Blackman (2010).

To summarize, a country whose forest clearing in a period is lower than all three benchmarks (or zero) gets the best rating (Green); a country whose clearing is higher than all three benchmarks gets the worst rating (Red); and ratings deteriorate as clearing successively exceeds clearing in the past quarter, the REDD line benchmark and the transition line benchmark. Since ratings are determined by local benchmarks, any country can receive any rating in each period.

7. An Illustration for Eight East Asian Countries

We illustrate the TFPF with an exercise for eight East Asian countries that have tropical forest regions: Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam. Figure 3 displays FORMA indices of forest clearing in the eight countries from December 2005 to December 2010.[11] Each graph indexes monthly changes on the left axis and annualized changes on the right axis. The monthly series display marked seasonality, with strikingly-regular patterns in Cambodia, Malaysia and Myanmar. In the case of Myanmar, for example, the index reaches an annual minimum during the period October-December, and then increases rapidly to an annual maximum during April-May. During the five-year period, the annual peak index value rises over tenfold, from 43.1 in May 2006 to 460.5 in May 2010.

Annualizing the data removes the seasonal component, permitting a clearer view of longer-run trends. Figure 3 shows striking differences among countries during the past five years: declining trends for Indonesia, Lao PDR and China, with pronounced fluctuations around trend; steady increases (again with fluctuations) for Cambodia, Malaysia and Myanmar; and sudden increases in 2010 for Thailand and Vietnam. Pronounced scale differences across countries reflect differences in the geographic extent of large-scale clearing. In Indonesia, for example, the annualized index falls from 6,267 in July 2007 to 3,726 in December 2010. Lao PDR exhibits a similar proportional decline, but at much smaller scale, from a maximum of 268 in February 2008 to 123 in December 2010. Changes in China's southern tropical forests are similar in scale to the Laotian changes.

Among countries with increasing trends, Malaysia and Myanmar have dominant scales. From December 2006 to December 2010, Malaysia's annualized index rises from 2,107 to 3,099, and Myanmar's from 148 to 1,847. In contrast, maximum index values for Cambodia, Thailand and Vietnam are 213, 39 and 116, respectively.

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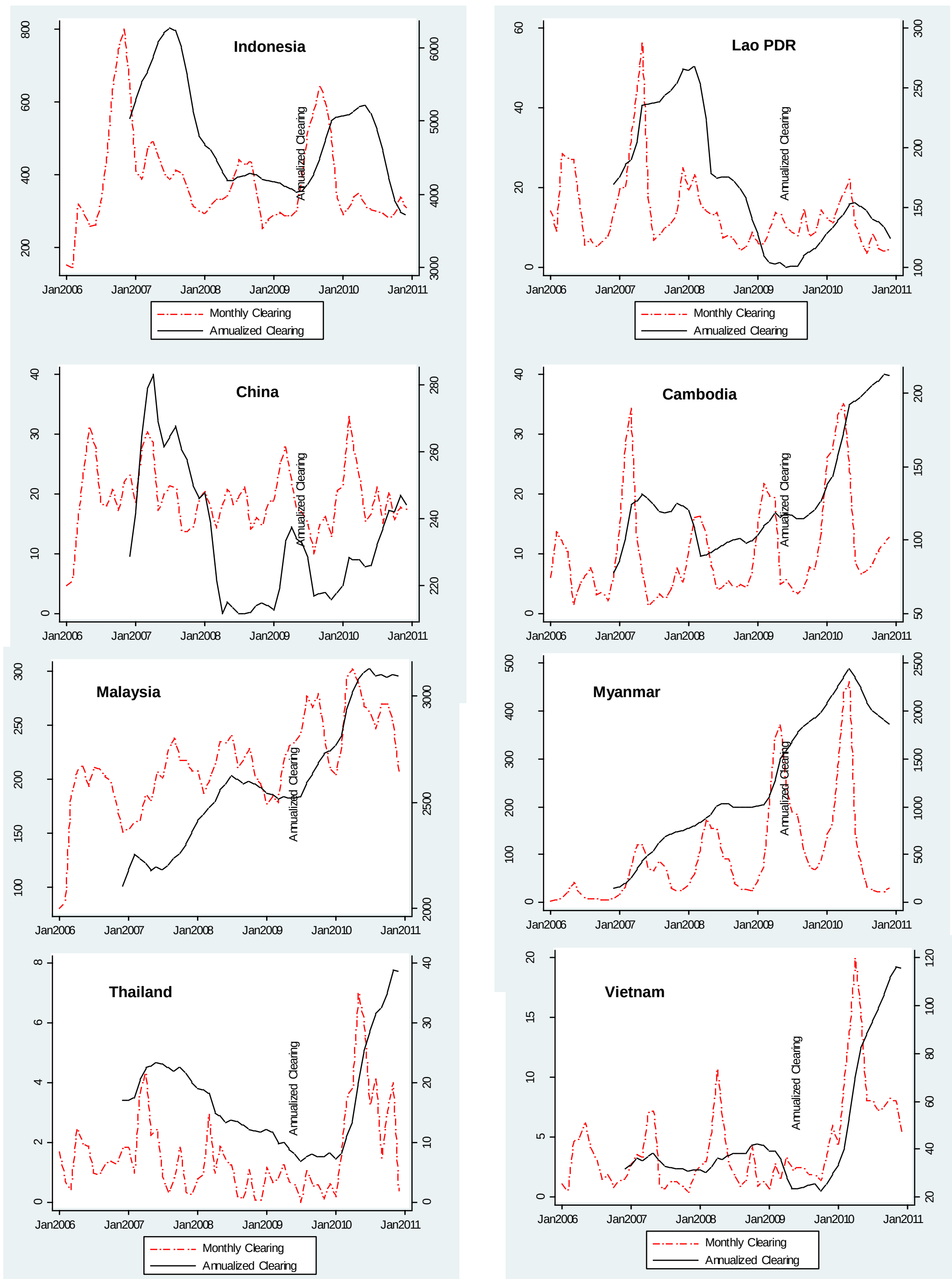
[11] Each unit of forest clearing reported by FORMA is formally defined as "one square kilometer within which large-scale forest clearing has occurred with high probability since 2000". The monthly FORMA clearing index for a particular area is therefore the increase in square kilometers with a high probability of forest clearing since the previous month. To eliminate normal seasonal fluctuations and other short-run transients, all monthly measures used for performance indicator calculations are 24-month moving averages.

For our illustration, we assume that TFPF operations began in January 2008 and establish payments and performance ratings through December 2010, the latest reporting month for FORMA. Then we assess the implications of alternative country responses for forest clearing and TFPF financing during the next several decades. We use the TFPF parameters that have been discussed in previous sections and summarized in Box 1.

Figure 3: Forest Clearing Indices for Southeast Asian Countries: December 2005–December 2010



7.1. Assessment Benchmarks

We believe that rapid feedback will increase the impact of payments and performance ratings, as well as cementing the credibility of the TFPF in its early years. Accordingly, our prototype system operates on a quarterly basis. We avoid short-term cyclical fluctuations by using 24-month moving averages of forest-clearing indices. FORMA estimates begin in December 2005, so the first observation available for assessment is the final quarter of 2007.

Table 2 provides information for setting the eight countries' forest transition lines. It presents alternative forecasts of the years when countries will reach normal zero-clearing income ($10,150), based on income growth rates during the past 10, 20 and 30 years. The first three columns report regression-estimated growth rates for real GDP per capita at purchasing power parity. Average growth rates and standard deviations are progressively lower as the estimation period expands from 10 to 30 years. These differences are reflected in estimated zero-clearing years, in the next three columns, whose average dates vary from 2026 for the projection from growth in the past decade to 2035 for the projection from growth since 1980. When countries are ranked by year of arrival at normal zero-clearing income, Malaysia is first because it has already arrived (in 1997). Lao PDR is among the last to arrive in all cases. China and Thailand are the first arrivals after 2010, followed by Vietnam, then Indonesia and Myanmar. Rank correlations for the three projection sets are high, particularly for the 10-year and 30-year variants (ϱ = .94).

Since we are taking the long view in this illustration, we adopt 30-year growth rates for our benchmark projections. These yield the zero-clearing dates reported in column 4, in ascending order: Thailand (2013), China (2016), Vietnam (2036), Indonesia (2042), Cambodia (2051), Lao PDR (2059), Myanmar (2066).

While we use historical evidence to set the forest transition line, the choice of end point for the REDD line is arbitrary. As we previously explained, we have chosen 2025 because it provides a strong incentive for countries to move aggressively on forest clearing.

Table 2: Historical Income Growth and Projected Zero-Clearing Years

	Regression-Estimated Annual Growth Rate, GDP Per Capita			Year for Zero Clearing, Projected from Growth Rate			Rank of Zero-Clearing Year (From Earliest Year)			GDP Per Capita at Purchasing Power Parity Const. $US 2005[a]			
Country	30-Yr 1980–2010	20-Yr. 1990–2010	10-Yr. 2000–2010	30-Yr 1980–2010	20-Yr. 1990–2010	10-Yr. 2000–2010	30-Yr 1980–2010	20-Yr. 1990–2010	10-Yr. 2000–2010	1980	1990	2000	2010
Cambodia[b]	4.43	5.44	7.20	2051	2042	2034	6	6	5		779	1,024	1,909
China	8.88	9.15	10.29	2016	2015	2015	3	2	3	526	1,103	2,682	6,794
Indonesia	3.13	2.50	3.94	2042	2051	2035	5	8	6	1,521	2,131	2,754	3,971
Lao PDR	3.43	4.29	5.49	2059	2048	2039	7	7	8	716	949	1,331	2,201
Malaysia	3.54	2.80	3.20	1997	1997	1997	1	1	1	4,923	6,705	10,344	13,257
Myanmar	4.41	7.74	8.34	2066	2039	2037	8	5	7	342	320	517	1,129
Thailand	4.55	3.09	4.11	2013	2018	2015	2	3	3	2,282	4,028	5,645	8,302
Vietnam	5.30	5.86	6.04	2036	2033	2032	4	4	4	627	910	1,606	2,832
St. Dev.	1.83	2.41	2.43	24.30	18.73	14.89							
Mean	4.71	5.11	6.08	2035	2030	2026							

Correlations	Rank(30)	Rank(20)
Rank(20)	0.76	
Rank(10)	0.94	0.87

a Source: IMF (2011)

b Cambodia data available after 1985.

7.2. Country Performance, 2008–2010

Figure 4 highlights the magnitude of inter-country performance differences from Q1 2008 to Q4 2010. In each graph, the horizontal dashed line is initial benchmark clearing (actual clearing adjusted by the initial relative performance multiplier); the bold, downward-sloping dashed line is the country's forest transition line, and the lighter downward-sloping line is its REDD line. For assessment, we separate the countries into three broad groups:

(1) Poor performers: Cambodia, Malaysia and Myanmar. All three countries increase their annualized forest clearing from Q1 2008 to Q4 2010. Cambodia fluctuates near the initial benchmark line through 2009, and then increases clearing sharply through Q4 2010. Malaysia, having reached normal zero-clearing income in 1997, has a forest transition line set at zero clearing throughout the period. Its forest clearing continues to grow rapidly after Q1 2008, so it moves steadily away from its initial benchmark and REDD lines. For Myanmar, the downward movements of benchmarks along the

transition and REDD lines after Q1 2008 are dwarfed by the rapid growth of forest clearing, which nearly quadruples by Q4 2010.

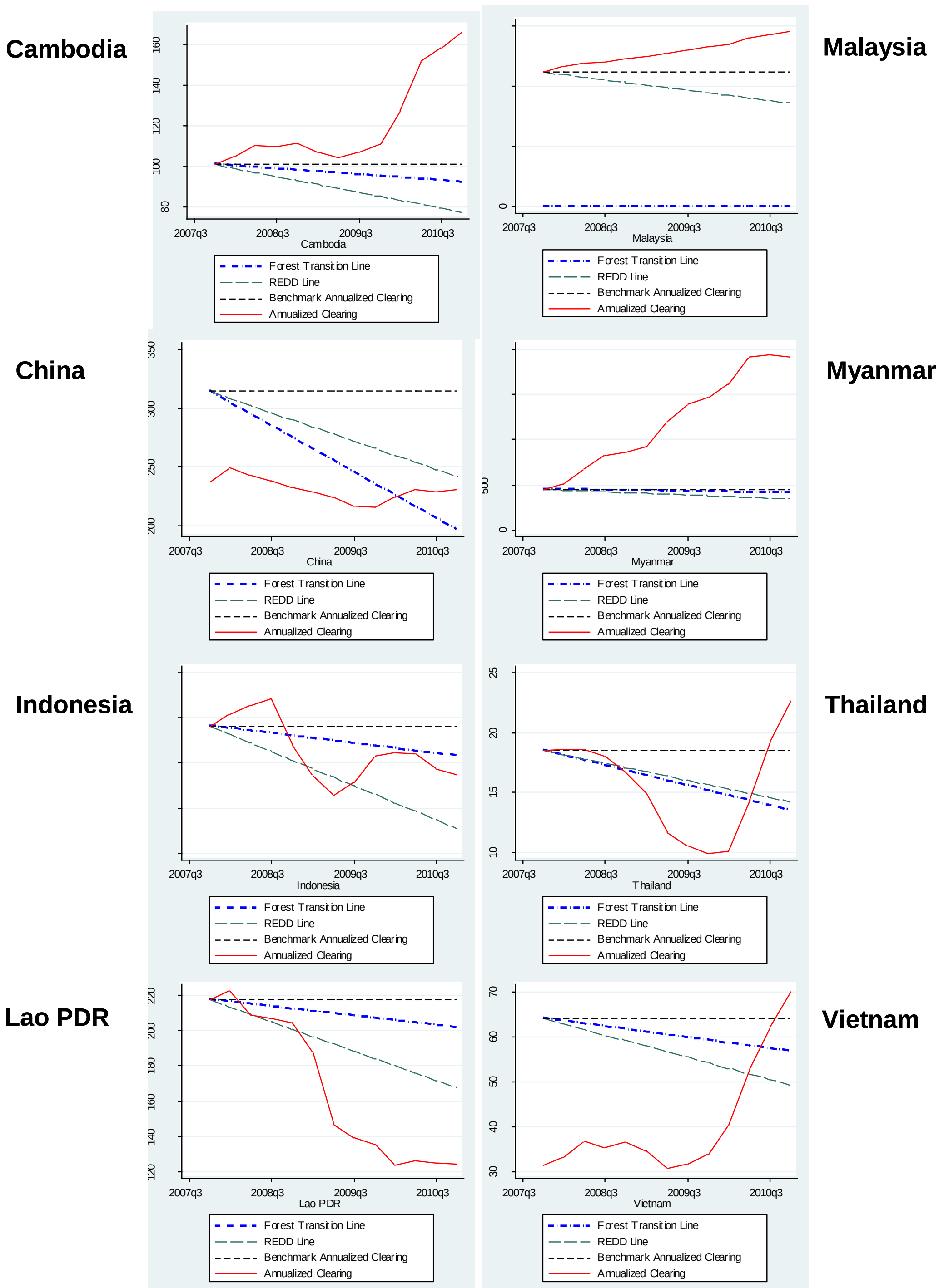
(2). Good performers: China, Indonesia and Lao PDR. All three countries exhibit declining trends in forest clearing during the three-year period. China begins well below its initial benchmark, which has been adjusted upward to reflect its superior performance on deforestation during the period 2000-2005. Its decline from 2008 to 2010 is relatively modest, but it starts from such a low point that it remains below the REDD line throughout the period, and below the transition line for most of it. Here it is worth recalling why we have given China the "head-start advantage" of an initial benchmark point higher than its actual clearing level. China's deforestation rate during 2000-2005 was significantly below its expected rate, given its income during that period. As we have previously explained, we make the adjustment because it is important to reward previously-superior performance with an initial premium.

Indonesia's case is quite different: Its clearing actually exceeds initial clearing during the first few quarters, but then falls and remains below the forest transition line for the rest of the three-year period. However, its level-off after the initial plunge keeps it below the REDD line for only a short period. After that, it stays above the REDD line through Q4 2010.

Lao PDR is the best performer in the group. At first its clearing tracks the declining REDD line (staying below the forest transition line). Then it plunges to a point far below the transition and REDD lines for the remainder of the period.

(3). Mixed performers: Thailand and Vietnam. Thailand resembles Lao PDR through 2009, but then it reverses course and resembles Cambodia and Myanmar in 2010. Vietnam has a different profile because, like China, it begins with a premium earned by slower-than-expected deforestation during the period 2000-2005. Its clearing remains roughly constant and far below the transition and REDD lines through 2009 and then, like Thailand, it jumps past both lines, to a point where clearing in Q4 2010 exceeds initial clearing in Q1 2008.

Figure 4: Forest Clearing Performance, 2008 - 2010



7.3. Performance Payments

Figure 5 plots the performance payment streams that accompany the forest clearing records in Figure 4. In each graph, transition payments are represented by thick dash/dot lines; REDD payments by dashed lines; and payments for quarterly improvements by solid lines. For the three poor performers, Cambodia, Malaysia and Myanmar, transition and REDD payments are zero throughout because clearing remains above the transition and REDD lines. Cambodia has a few quarters in which forest clearing drops, and these are reflected in the short pulse in quarterly payments. Similarly, forest-clearing drops in Myanmar during Q4 2010, and this is reflected in a brief payment episode

The payment profiles of the three good performers, China, Indonesia and Lao PDR, are strongly differentiated by their forest clearing patterns. China stays below the REDD line longer than it stays below the transition line, and the result is a REDD payment profile that rises higher and lasts longer than the transition payment profile. China also has a significant early set of quarterly performance payments, reflecting the decline in forest clearing during the corresponding period in Figure 4.

Indonesia looks quite different: Its payment profiles are dominated by quarterly payments, which reflect the sharp drop in forest clearing that starts in late 2008. Indonesia's transition payments increase during the period when it is well below the transition line, and level off as clearing levels off while the transition line continues to decline. REDD payments exhibit a small, brief increase during the short period when clearing is below the REDD line, but return to zero soon afterward.

For Lao PDR, three downward movements in clearing during different intervals are rewarded by quarterly payments that peak in mid-2009. After the sharp decline Lao PDR remains well below the transition and REDD lines, and the result is steady growth in transition and REDD payments.

Vietnam stays far below its transition and REDD lines for much of the three-year period, exceeding them both only toward the end. The result is rapid growth in transition and REDD payments, with a decline beginning only toward the end of the three-year period. Vietnam has relatively few periods in which forest clearing actually declines, and this is reflected in the sparse and relatively small payments for quarterly performance. In this context, it is worth noting why the decline in payments is not sharper after the jump in Vietnam's forest clearing. Recall that credits for units of sequestered carbon are cumulative below the transition and REDD lines. At the same time, progressive subtraction of credits accompanies benchmark decreases along the lines themselves. Transition and REDD payments in any period reflect the difference between these two cumulative factors, which can create relatively long lags in the response of payments to sudden changes with respect to the lines. This explains why the sudden surge in Laotian clearing generates only a modest initial decline in payments: The country is still receiving rental payments for the many cumulative carbon units that have previously been sequestered. These prior credits will be used up if clearing remains above the line for an extended period, and payment will return to zero

Figure 5: Country Performance Payments, 2008–2010

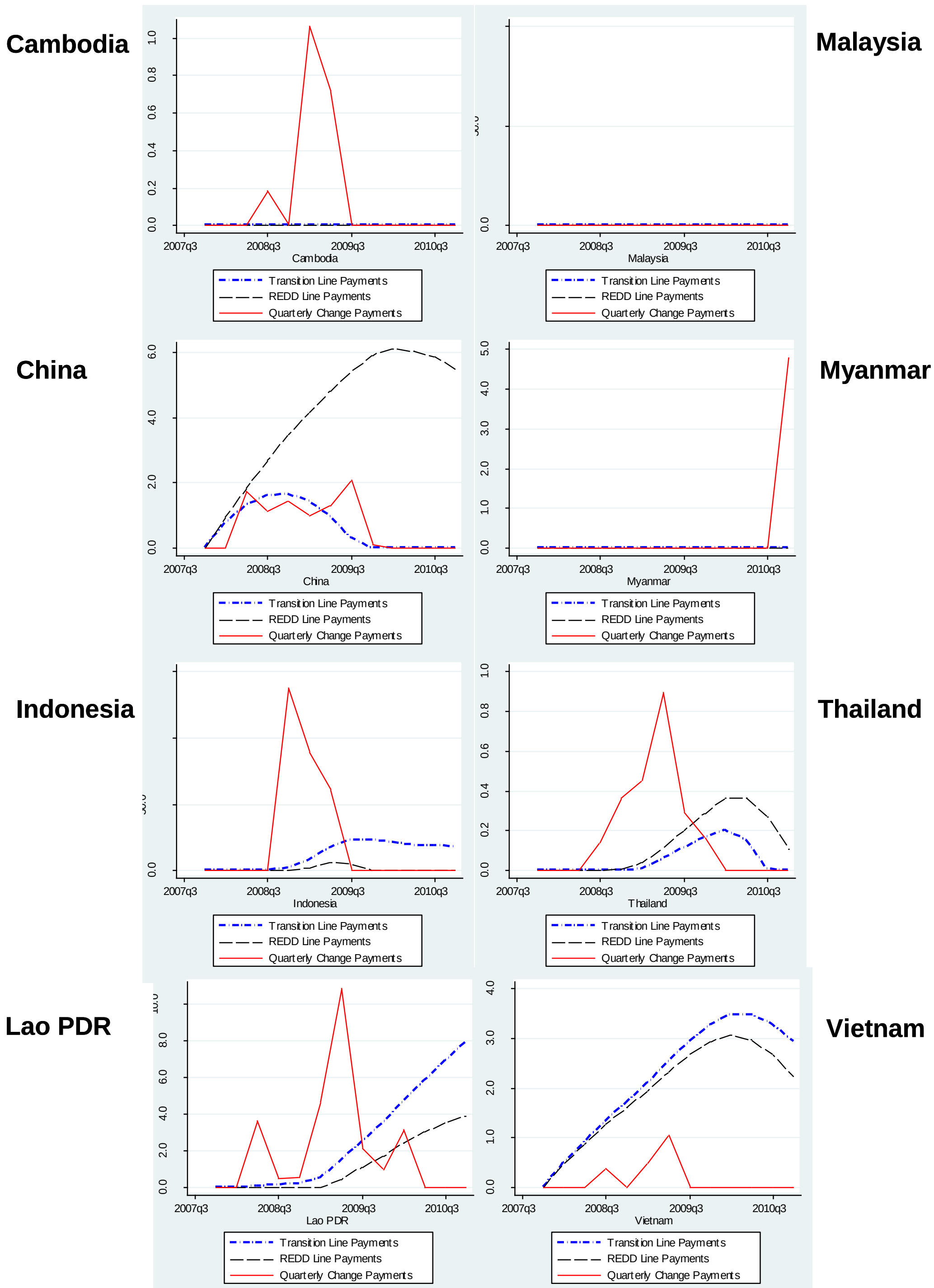


Table 3: Annual TFPF Payments to Government and Indigenous Recipients by Country, 2008–2010

	Payment						Totals		
	2008		2009		2010				
Country	Government	Indigenous	Government	Indigenous	Government	Indigenous	Government	Indigenous	Grand total
Cambodia	0.15	0.04	1.42	0.35	0	0	1.57	0.39	1.96
China	14.89	3.72	21.99	5.50	18.77	4.69	55.65	13.91	69.56
Indonesia	111.14	27.78	187.25	46.81	61.22	15.30	359.61	89.89	449.50
Lao PDR	4.14	1.03	23.88	5.97	33.16	8.29	61.18	15.29	76.47
Malaysia	0	0	0	0	0	0	0	0	0
Myanmar	0	0	0	0	3.86	0.96	3.86	0.96	4.82
Thailand	0.41	0.10	2.23	0.56	1.17	0.29	3.81	0.95	4.76
Vietnam	7.27	1.82	17.8	4.45	19.23	4.81	44.30	11.08	55.38
Total	172.49		318.21		171.75				662.45

Thailand initially exhibits a plummet in forest clearing, followed by an equally rapid increase. The result is the dominant profile of quarterly performance payments during the period of decrease. Both transition and REDD payments only begin increasing after Thailand's clearing falls past the respective lines, and the relative transience of this improvement dictates a relatively quick reversal of the transition and REDD payment streams.

Table 3 provides totals for payments to the eight countries during the three-year period, divided into amounts paid to national governments and indigenous communities. Indonesia is the largest recipient by far, receiving about $449.5 million: $359.6 million for the national government and $89.9 million for indigenous communities. Significant payments also go to Lao PDR ($61.2 million to the government, $15.3 million to indigenous communities); China ($55.7 million; $13.9 million) and Vietnam ($44.3 million; $11.1 million). Overall, the TFPF makes payments of $662.5 million to the eight countries from 2008 to 2010.

7.4. Public Performance Ratings

Figure 6 presents quarterly performance ratings that reflect the rules specified in Box 2. The figure provides a striking picture of variation, both across countries and over time. Five countries are in the Green range for at least part of the time, with particularly long runs for China, Thailand and Lao PDR. On the other hand, seven countries have at least some Red ratings and one, Malaysia, is rated Red throughout. Myanmar and Cambodia also come close, with only a few observations better than Red. Lao PDR exhibits the most unambiguous improvement, moving from Orange/Red at the outset to consistent Green/Blue after a few quarters. Vietnam shows the most striking deterioration, with a long run in Green/Blue suddenly giving way to Orange/Red. Indonesia and Thailand exhibit the most variation, with ascents from Red to Green and then significant descents (to Yellow for Indonesia, Red again for Thailand).

Figure 7 summarizes the pattern for the eight countries as a group. We calculate the regional performance rating using weighted country ratings, where color ratings are valued from 1 (Red) to 6 (Green), and the weights are country shares in total eight-country forest clearing, period-by-period. As Table 4 shows, Indonesia, Malaysia and Myanmar dominate the other countries because their forest clearing operates on a far larger scale. The clearing shares of Malaysia and Myanmar increase through the 12-quarter assessment period. Since these countries are almost entirely Red-rated, they have a strong effect on the regional rating. Figure 7 shows that the regional average is never higher than Yellow and stays mostly in the Orange/Red range.

Figure 6: Country Performance Ratings, Q1 2008 to Q4 2010

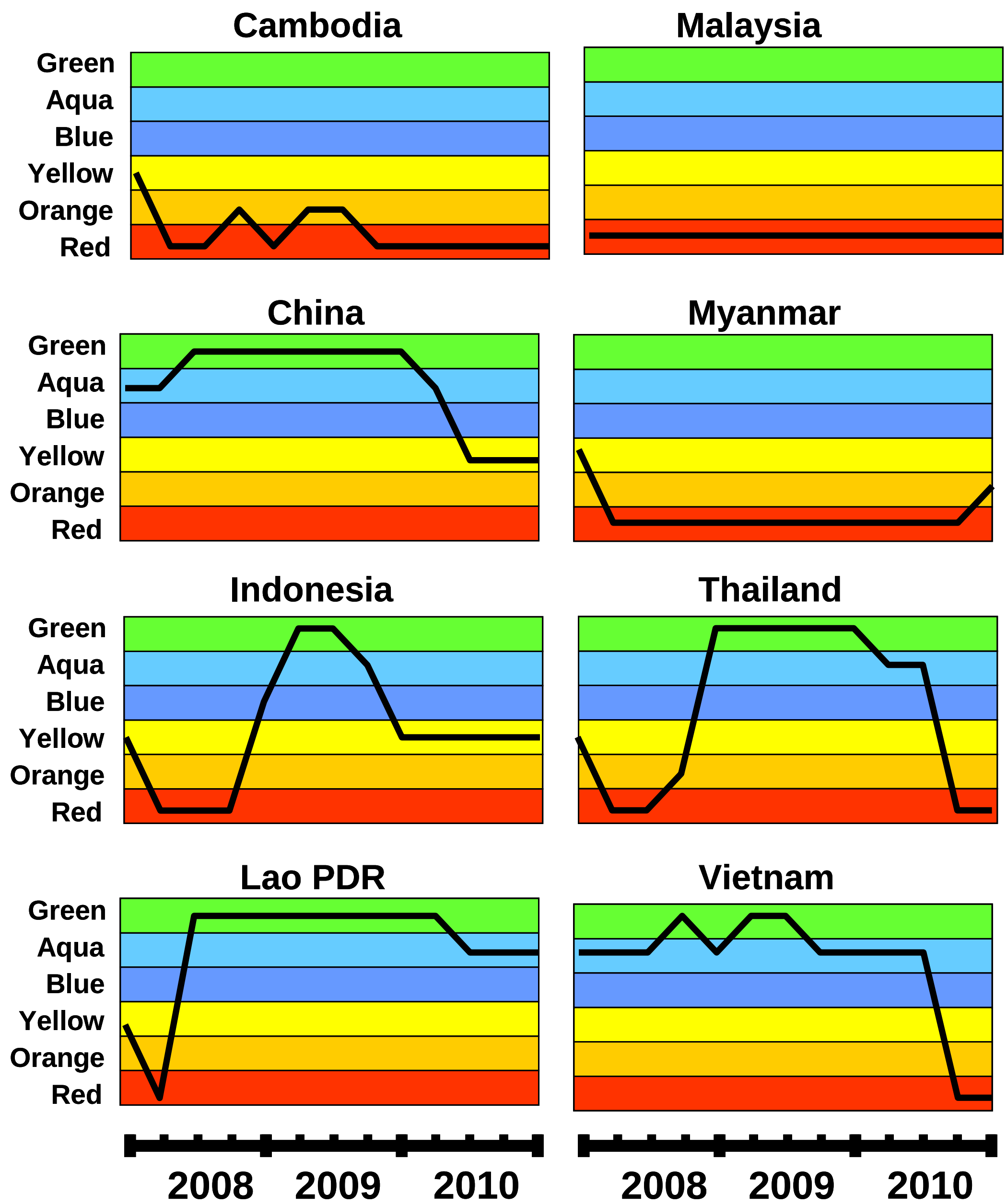
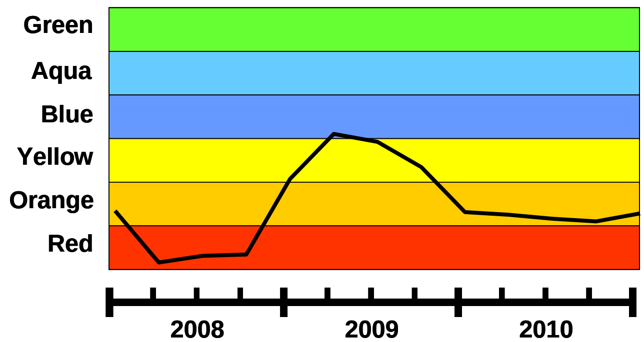


Figure 7: Weighted Average Performance Rating: Eight Countries



We believe that such color-coded ratings are useful performance indicators, since they are both easy for the public to interpret and grounded in a detailed, three-dimensional performance assessment. In summary, Figure 6 indicates that China, Lao PDR and Vietnam are generally good performers; Cambodia, Malaysia and Myanmar are poor performers, and Indonesia and Thailand fall in between. Overall, the region's performance for 2008-2010 is poor.

Table 4a: Annualized Forest Clearing Index[a]

	2007	2008				2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Cambodia	101	105	110	110	111	107	104	107	111	127	152	158	166
China	237	249	242	238	233	229	224	216	216	224	231	229	231
Indonesia	4,910	5,040	5,139	5,212	4,698	4,365	4,138	4,282	4,577	4,620	4,607	4,433	4,367
Lao PDR	218	223	209	207	205	187	147	139	135	123	126	125	124
Malaysia	2,234	2,334	2,373	2,408	2,447	2,489	2,537	2,596	2,653	2,687	2,796	2,848	2,909
Myanmar	448	502	681	818	864	924	1,197	1,393	1,467	1,610	1,918	1,936	1,918
Thailand	18	19	19	18	17	15	12	11	10	10	14	19	23
Vietnam	31	33	37	35	37	35	31	32	34	40	53	62	70

Table 4b: Percent of Total Annualized Forest Clearing

	2007	2008				2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Cambodia	1.2	1.2	1.3	1.2	1.3	1.3	1.2	1.2	1.2	1.3	1.5	1.6	1.7
China	2.9	2.9	2.8	2.6	2.7	2.7	2.7	2.5	2.3	2.4	2.3	2.3	2.4
Indonesia	59.9	59.3	58.3	57.6	54.6	52.3	49.3	48.8	49.7	48.9	46.6	45.2	44.5
Lao PDR	2.7	2.6	2.4	2.3	2.4	2.2	1.8	1.6	1.5	1.3	1.3	1.3	1.3
Malaysia	27.3	27.4	26.9	26.6	28.4	29.8	30.2	29.6	28.8	28.5	28.3	29	29.7
Myanmar	5.5	5.9	7.7	9	10	11.1	14.3	15.9	15.9	17.1	19.4	19.7	19.6
Thailand	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Vietnam	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.7

[a] Formally dimensioned in km^2, but not directly comparable with conventional forest clearing estimates. See Footnote 11 for a detailed discussion

8. Alternative Futures and Their Implications for Finance

Although we believe that our illustration for 2008-2010 provides useful insights, we readily acknowledge that one of its implicit premises is artificial. The TFPF did not exist during that period, nor did any other REDD-type incentive system, so our prototype payments and ratings are assigned to countries that were operating with no expectation of external rewards for good performance in forest clearing. To motivate our forecasting exercise, we assume that the TFPF incentives were consistently applied during 2008-2010, and that all eight countries have been persuaded that the TFPF is a credible institution. They respond with reduced forest clearing, in anticipation of substantial financial and reputational rewards.

To provide a benchmark assessment of the financial implications, we assume that all eight countries are fully organized to respond by 2012, and reduce forest clearing to zero in another five years. Then we investigate alternative scenarios in which countries respond faster or slower, with different REDD target years and transition lines anchored by different zero-clearing years. We compare results using present values of payment streams.

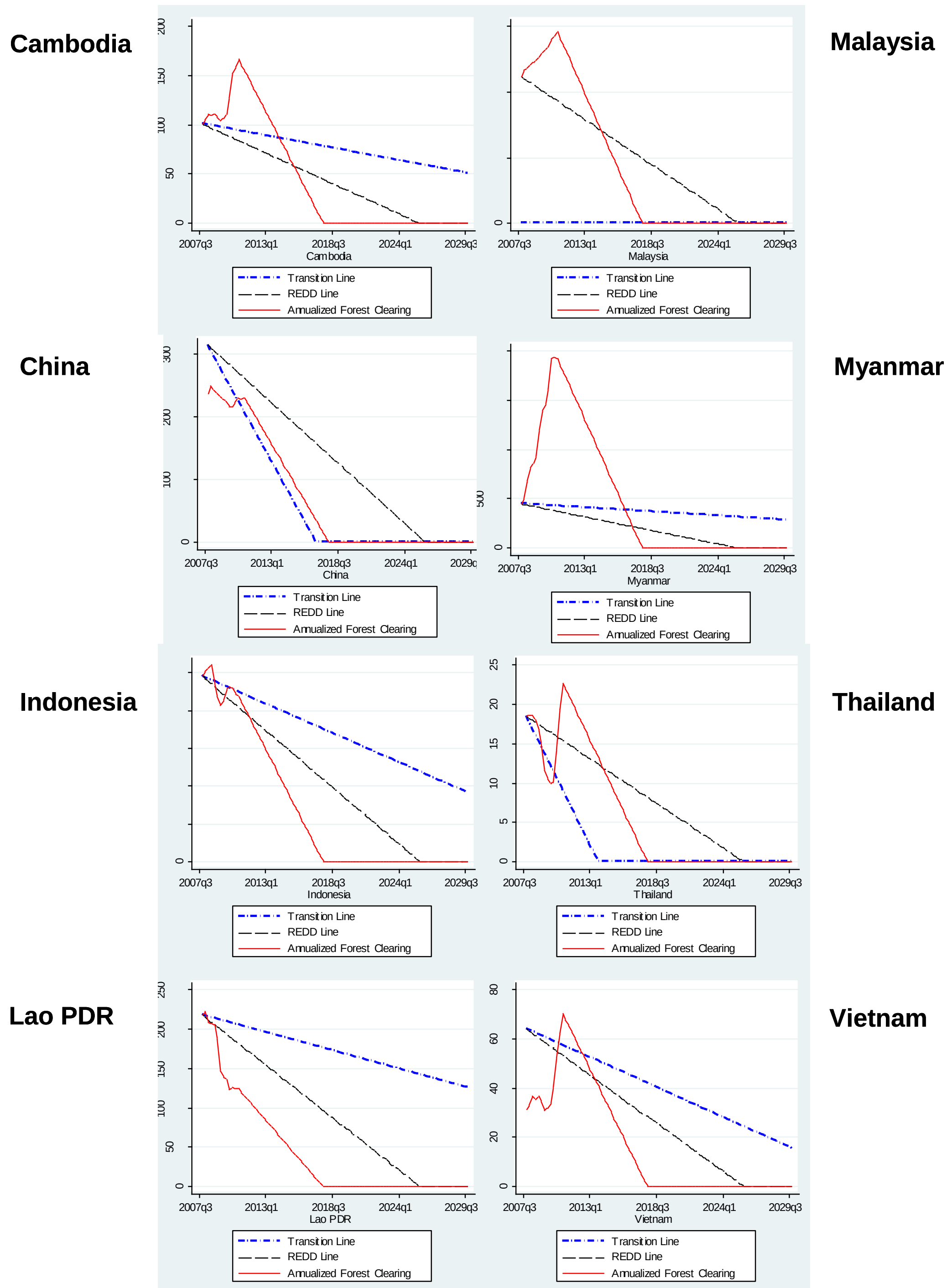
8.1. A Halt to Forest Clearing by 2017

Using our benchmark assumptions, Figure 8 plots transition lines, REDD lines and annualized forest clearing through 2030. Country cases are very different, because reduced clearing after 2010 starts from different positions relative to the transition and REDD lines. In general, the poorer countries benefit most from incentive payments because their transition lines have shallow slopes that reflect distant zero-clearing years. Examples are provided by Indonesia, Lao PDR and Vietnam, with a particularly powerful effect for Lao PDR because it is already well below its transition and REDD lines in Q4 2010. As the figure shows, the three countries earn substantial performance payment flows in all three dimensions (quarterly reduction, transition line and REDD line).

The cases of Cambodia, Malaysia and Myanmar are quite different. Cambodia reverses course in short order, moving from clearing well above the transition line in Q4 2010 to clearing below both transition and REDD lines after 2014. Cambodia therefore benefits from three payment streams: Rewards for quarterly improvements; REDD payments as long as clearing stays below the REDD line, and prolonged transition line payments because Cambodia does not achieve zero-clearing income ($10,150) until 2051 at its projected growth rate (4.43%).

Myanmar's path is similar to Cambodia's, although Myanmar's forest clearing in Q4 2010 is higher relative to its initial benchmark, so it has less time beneath the REDD line to collect payments. On the other hand, its rapid descent from high initial clearing ensures a flow of large quarterly performance payments, and its low initial income ($US 859 in 2005) and moderate projected growth rate (4.41%) determine a late zero-clearing year (2066) and a long period in which it receives transition line payments.

Figure 8: Country Scenarios with Zero Clearing in Q4 2017



Malaysia's path also looks similar to Cambodia's, with one major difference: Having reached normal zero-clearing income in 1997, Malaysia has a transition path that is constant at zero throughout the period. Therefore, its rapid reduction of clearing after 2010 earns only two sets of reward payments (REDD line and quarterly improvement). And both series are relatively short-lived, since Malaysia's zero clearing line intersects with its REDD line in 2025.

China and Thailand are differentiated from the other countries by their relationships to their transition lines. For each country, the transition line arrives at zero clearing before the actual clearing path. This is traceable to a high initial income for Thailand ($7,132) and a high projected income growth rate for China (8.88%). Like Malaysia, both countries receive performance payments in only two dimensions, REDD and quarterly.

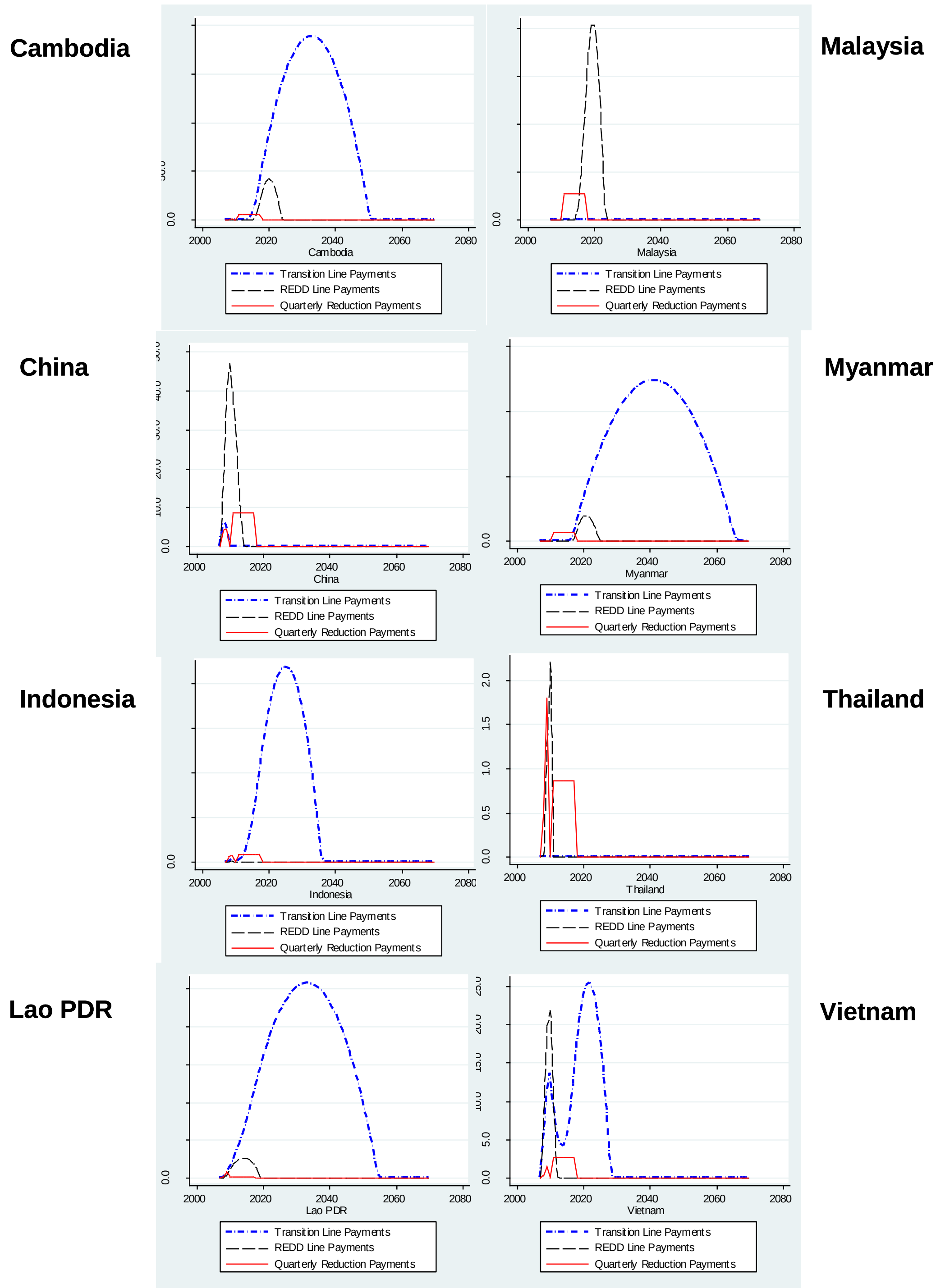
8.2. Payment Flows, 2011–2067

Figure 9 and Appendix Table A2 extend the country scenarios to the termination of payments in 2067. The most striking patterns are evident for Cambodia, Myanmar, Indonesia and Lao PDR, whose late zero-clearing years ensure that transition line payments dominate the overall payment flows. Nevertheless, quarterly and REDD line payments are frequently at parity with or greater than transition line payments in the early years, when it is most important to lock countries into the system by offering significant rewards.

Among Cambodia's three payment streams, quarterly payments are $6.3 million annually through 2017, REDD line payments reach a maximum of $21.4 million in 2020, and transition line payments peak at $188.3 million in 2033. Quarterly payments yield the most income in the early years (2011-2015). Quarterly performance payments dominate for Myanmar (at $73.2 million/year) through 2017. REDD line payments, which peak at $98.8 million in 2021, remain significant in the payment stream through 2024. Ultimately, however, Myanmar's payment stream is dominated by the long, shallow trajectory of its transition line. Transition payments rise to a maximum of $1.24 billion in 2041, and then decline steadily to zero in 2067.

Indonesia's scale is the largest, and this is reflected in its payment flows. It receives negligible REDD payments, because its decline in clearing after 2010 never compensates for its earlier re-crossing of the REDD line and loss of rental credits (see Figure 4). Quarterly performance and transition line payments are both very large, however, particularly the latter. Indonesia receives annual payments of $166.6 million for quarterly improvements from 2011 to 2017. At the same time, transition payments speedily increase to very large values, reaching a maximum of $4.37 billion in 2025. Lao PDR displays similar transition line dominance, with payments reaching a maximum of $513.9 million in 2033.

Figure 9: Country Financial Flows with Zero Clearing in 2017 ($US Million)



Countries that are initially richer or fast-growing display a different balance across payment streams, because their transition payments terminate much sooner. Malaysia's case is dominated by REDD line payments (although quarterly payments are also significant initially) because it receives no transition line payments. The same thing is basically true for China, and Thailand's brief transition payment series is matched by its REDD and quarterly performance payments. Vietnam's rapid projected income growth produces a similar effect: The dominance of REDD payments in the early years is followed by a relatively brief surge of transition payments which ends in 2029.

Appendix Table A3 summarizes total payment flows for the eight countries from 2008 to 2067. The early years, 2011-2013, are dominated by quarterly performance payments as countries begin rapid reduction of forest clearing but some remain above their transition and REDD lines. Total payments are $374.3 million/year. Then REDD payments increase quickly as clearing in most countries drops below their REDD lines. REDD payments reach $523.4 million/year in 2020, and then decline to zero in 2025 as REDD lines terminate at zero. Meanwhile, transition payment flows rapidly increase to dominant status. They reach $1 billion by 2015, $2 billion by 2017, $4 billion by 2020, and a maximum of $5.74 billion in 2026, before tapering to $5.2 billion in 2030, $1.9 billion in 2040, $1.3 billion in 2050 and $524 million in 2060. Payments cease in 2067, after Myanmar reaches the terminal point on its transition line.

Total payments from the TFPF peak in 2026 at $5.74 billion, of which $1.15 billion goes directly to indigenous communities. During the 60-year period from 2008 to 2067, total payments amount to $2.95 billion for quarterly performance improvements, $3.30 billion for REDD line performance, and $124.96 billion for transition line performance. Total payments overall are $130.94 billion, of which $104.75 billion goes to national governments and $26.19 billion to indigenous communities.

8.3. Alternative Futures

Our first scenario has assumed that all countries reach zero clearing in 2017, the REDD line target year is 2025, and normal zero-clearing years are projected using growth rates for 1980-2010. In this section, we consider a much broader set of alternatives based on all combinations of the following settings: historical growth experiences (1980-2010, 1990-2010, 2000-2010). REDD target years (2020, 2025, 2030); and years in which countries achieve zero clearing (2012, 2015, 2017, 2020, 2030).

Table 5 summarizes the results using present values of total payments and average payments by decade. In each case, 80% of the payments are allocated to national governments and 20% to indigenous communities. We order the table in a three-way sort, by increasing zero-clearing year, decreasing REDD terminal year, and decreasing growth rate calculation years. Figures 10.1 – 10.3 summarize the table information in box plots. Figure 10.1 shows that our benchmark scenario, which projects income growth from 30-year samples, is the intermediate case. Present values of total payment flows are generally higher for the 20-year benchmark, and much lower for the 10-year benchmark. As Table 5 shows, the 10-year result reflects recent growth rates that are significantly higher than longer-run rates. Higher growth rates generate more rapid increases in projected incomes. These lead to arrival at normal zero-clearing income ($10,150) closer to the present, which means fewer years of annual rental payments for clearing that is below the transition path.

Figure 10.2 presents box plots for REDD line termination in 2020, 2025 and 2030. Overall, these variations have fewer consequences than the others. Median values for the distributions are nearly identical, although extending the target year does increase higher-range values.

Figure 10.3 shows that the most significant parameter by far is the year in which all eight countries arrive at zero clearing. The five box plots summarize results over a wide range of responses, from near-instantaneous (clearing falls to zero by next year) to 20-year adjustment (zero clearing in 2030). The relationship is non-linear, with rapidly-falling present values as the adjustment period increases. From a median of $105.3 billion for the shortest adjustment period (2012), the present value of total payments falls successively to $69.6 billion (2015), $54.2 billion (2017), $36.5 billion (2020) and $12.6 billion (2030).

The other columns of Table 5 provide information on payment distributions across decades. To illustrate using an extreme case, the second row assumes a REDD terminal year of 2030 and income growth projected from the 20-year sample. This variant produces the shallowest transition and REDD lines, on average, and consequently the longest rental payment periods for clearing below the two lines. These periods are maximized by the second-row assumption that forest clearing ends next year. The result is the greatest financial requirement in the whole set: a present value of $144.8 billion, with average annual payment flows across the decades of $9.7 billion, $14.1 billion, $12.7 billion and $3.7 billion. All payments terminate by 2049 in this scenario because all countries have reached the normal zero-clearing income ($10,150).

Our benchmark exercise for this paper is more conservative, assuming a terminal clearing year of 2017, REDD line target of 2025, and income growth projected from the 30-year sample. This variant yields a much lower present value ($54.2 billion) and decadal average payment values ($3.4 billion, $5.4 billion, $3.2 billion, $1.7 billion, $970 million, $317 million), although the latter persist for two additional decades because some countries are slower to arrive at zero-clearing income.

Table 5: Payment Flows in Alternative Scenarios, 2010–2069

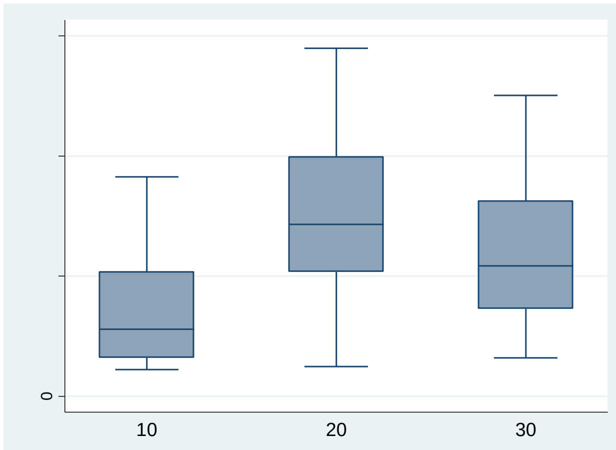
Parameter Values				Average Annual Payments ($US Million)					
Zero-Clearing Year	REDD Terminal Year	Growth Rate Calc. Years	Present Value of Total Payments ($US Mill.)	2010–2019	2020–2029	2030–2039	2040–2049	2050–2059	2060–2069
2012	2030	30	125,189	9,316	12,389	6,008	1,963	1,086	302
2012	2030	20	144,840	9,685	14,064	12,682	3,673	0	0
2012	2030	10	91,364	8,634	8,907	780	0	0	0
2012	2025	30	105,291	7,970	9,427	6,010	1,968	1,087	302
2012	2025	20	124,941	8,339	11,102	12,686	3,674	0	0
2012	2025	10	71,463	7,289	5,945	782	0	0	0
2012	2020	30	92,079	6,141	8,754	6,010	1,968	1,087	302
2012	2020	20	111,729	6,510	10,429	12,686	3,674	0	0
2012	2020	10	58,251	5,460	5,272	782	0	0	0
2015	2030	30	81,294	5,452	8,403	4,196	1,765	973	266
2015	2030	20	99,659	5,851	10,158	10,324	2,248	0	0
2015	2030	10	51,827	4,812	5,021	323	0	0	0
2015	2025	30	69,627	4,449	6,925	4,210	1,785	993	289
2015	2025	20	87,981	4,848	8,685	10,351	2,249	0	0
2015	2025	10	40,141	3,810	3,550	342	0	0	0
2015	2020	30	66,541	4,084	6,668	4,227	1,810	1,015	312
2015	2020	20	84,883	4,484	8,433	10,384	2,251	0	0
2015	2020	10	37,032	3,446	3,300	364	0	0	0
2017	2030	30	59,334	3,680	6,199	3,194	1,658	927	272
2017	2030	20	76,635	4,094	8,018	8,787	1,471	0	0
2017	2030	10	33,029	3,071	2,935	266	0	0	0
2017	2025	30	54,230	3,350	5,407	3,200	1,667	927	272
2017	2025	20	71,528	3,764	7,226	8,797	1,473	0	0
2017	2025	10	27,913	2,741	2,145	270	0	0	0
2017	2020	30	52,959	3,197	5,280	3,232	1,715	970	317
2017	2020	20	70,222	3,612	7,107	8,857	1,478	0	0
2017	2020	10	26,585	2,589	2,029	312	0	0	0
2020	2030	30	37,958	2,312	3,679	2,002	1,478	839	255
2020	2030	20	53,337	2,743	5,590	6,453	587	0	0
2020	2030	10	17,751	1,834	1,020	191	0	0	0
2020	2025	30	36,440	2,236	3,387	2,030	1,523	877	298
2020	2025	20	51,770	2,667	5,304	6,506	590	0	0

Table 5, continued

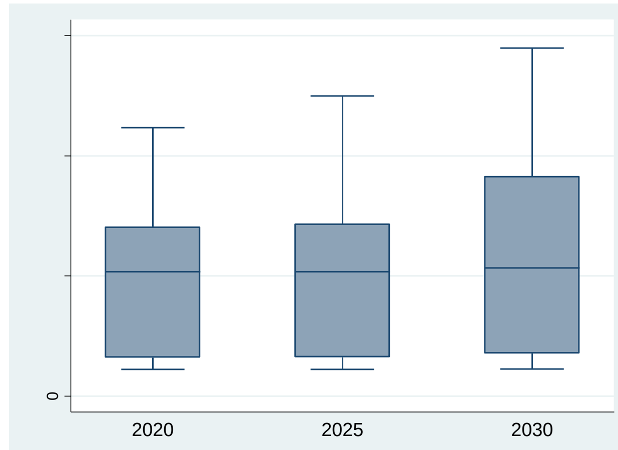
Parameter Values				Average Annual Payments ($US Million)					
Zero-Clearing Year	REDD Terminal Year	Growth Rate Calc. Years	Present Value of Total Payments ($US Mill.)	2010–2019	2020–2029	2030–2039	2040–2049	2050–2059	2060–2069
2020	2025	10	16,157	1,758	737	224	0	0	0
2020	2020	30	36,471	2,220	3,373	2,075	1,594	929	345
2020	2020	20	51,746	2,651	5,297	6,587	608	0	0
2020	2020	10	16,083	1,742	734	281	0	0	0
2030	2030	30	16,293	965	1,080	855	999	701	319
2030	2030	20	12,733	981	974	354	24	0	0
2030	2030	10	11,395	919	853	157	0	0	0
2030	2025	30	16,111	941	1,080	855	999	701	319
2030	2025	20	12,551	957	974	354	24	0	0
2030	2025	10	11,214	895	853	157	0	0	0
2030	2020	30	16,007	933	1,080	855	999	701	319
2030	2020	20	12,447	949	974	354	24	0	0
2030	2020	10	11,110	887	853	157	0	0	0

Figure 10: Scenario Variations in Present Value of Total Payments

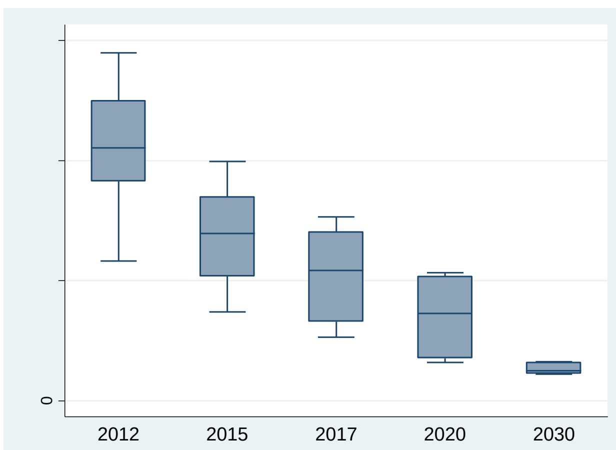
10.1: Historical Growth Period



10.2: REDD Target Years



10.3: Zero Clearing Years



Such variation across scenarios has major implications for financing. Is it plausible to suppose that all tropical forest countries would halt clearing almost overnight? Our results show that the financial incentive to do so would be huge. In our benchmark scenario for example (REDD target year 2025, 30-year growth sample), shortening the zero-clearing year from 2017 to 2012 would nearly double the present value of payments (from $54.2 billion to $105.3 billion). And, as we previously noted, the available evidence indicates that a large percentage of tropical forest land has a conversion opportunity cost below our proposed CO_2 price ($25/ton). By implication, the global response to the TFPF might well be a rapid, massive reduction of tropical forest clearing. This would, of course, be a very good thing. But, as the results in Table 5 show, it would also require that the East Asia TFPF have standby credit authority for disbursements as high as $10-14 billion per year for its first two decades of operation. A global TFPF might require disbursements several times greater. In the larger scheme of things these are not enormous sums. And it would seem well worth the cost, if the TFPF succeeded in halting tropical forest clearing so quickly

9. Summary and Conclusions

In this paper we have developed and illustrated a global incentive system, the Tropical Forest Protection Fund (TFPF), for promoting rapid reduction of forest clearing in tropical countries. The TFPF is a cash-on-delivery system that rewards independently-monitored performance without formal contracts. The system responds to forest tenure problems in many countries by dividing incentive payments between national governments, which command the greatest number of instruments that affect forest clearing, and indigenous communities, which often have tenure rights in forested lands.

The TFPF incorporates both monetary and reputational incentives, which are calculated quarterly. The monetary incentives are cash transfers based on measured performance, while the reputational incentives are publicly-disclosed, color-coded performance ratings for each country. All incentives are calculated using three benchmark dimensions: (1) a forest transition line that declines from initial benchmark forest clearing to zero in a country's projected year of arrival at normal zero-clearing income per capita ($10,150); a REDD line that declines from initial benchmark clearing to zero in a specified target year; and (3) forest clearing in the previous quarter. Dimension (1) rewards countries whose progress exceeds long-run expectations, given their forest clearing history and development status. Dimension (2) provide additional incentives for meeting or exceeding ambitious REDD goals. Rewards in dimension (3) encourage course reversal for countries whose forest clearing has taken them beyond the transition and REDD lines.

Drawing on monthly forest clearing indices from the new FORMA (Forest Monitoring for Action) database, we have developed a prototype system for eight East Asian countries: Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand and Vietnam. A system with identical design principles could be implemented by single or multiple donors for individual or multiple forest proprietors within one or more countries, as well as national or local governments in individual countries, tropical regions, or the global pan-tropics.

Our illustrative results demonstrate the importance of financial flexibility in the design of the proposed TFPF. The available evidence on forest conversion economics suggests that our proposed pricing and payment scheme could induce a rapid, massive reduction of tropical forest clearing. If this occurs, the East Asia TFPF will need standby authority to disburse payments as high as $10-14 billion annually for two decades. This financial burden will not persist, however, because the TFPF is designed to self-liquidate after all countries have reached the terminal points on their REDD and transition lines. We estimate that the East Asian TFPF can be closed by 2070, with its major financial responsibility discharged by 2040.

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Appendix A1

Estimating the Relationship Between the Deforestation Rate and Income

Cropper and Griffiths (1994) find an environmental Kuznets (inverse U-shaped) curve for the deforestation rate whose peak lies between per capita incomes of $US 7,000 and 16,000.[12] In this paper, we re-estimate the relationship using data from the period 1990-2010. We use a panel dataset based on forest cover reported by the World Bank's World Development Indicators for the years 1990, 2000, 2005 and 2010. We calculate average annual deforestation rates for each interval (1990-2000, etc.), and do the same for income. Our income measure is per capita GDP at purchasing power parity reported by the IMF (IMF, 2011), converted to constant $US 2005 using the US implicit price deflator for GDP. Using these measures for 195 countries, we pool the data to form a panel. Then we estimate the relationship between the deforestation rate and log GDP per capita by fixed effects, random effects and robust regression.

Our results are reported in Table A1. Following Cropper and Griffiths, we also estimated the same equations with the log of population density and a quadratic term to test for the environmental Kuznets relationship. Neither population density nor the inverse U-shaped relationship was significant in any of these experiments. We conclude that recent evidence is consistent with a monotone declining relationship between deforestation and income.

The first six columns in Table A1 report results and Hausman tests for fixed- and random-effects estimates for the full country sample and cases where 1% and 5% of sample observations are clipped from the tails of the distribution of deforestation rates. We experiment with clipping to test for robustness, given the presence of numerous outlier values in the tails of the distribution. Random effects estimation is preferable because it is more efficient, but its use depends on failure of the appropriate Hausman test to reject the null hypothesis of equal parameters in random and fixed effects estimation. As the table shows, outliers cause the random- and fixed-effects estimates to diverge significantly in the full and 1% clipped samples. However, failure of the Hausman test does occur in the 5% clipped sample (χ^2 1.56; p=.2118), and the results for that sample are very similar to the robust regression results for the full, 1% clipped and 5% clipped samples.

As we explain in the paper, econometric estimation of the deforestation/income relationship has two uses in this context: (1) Calculation of the ratio between predicted and actual deforestation for each country, which determines the initial point for its forest transition and REDD lines; and (2) Calculation of the income at which the representative sample country arrives at zero net deforestation. Zero-deforestation income is calculated for each regression

[12] We have adjusted the Cropper/Griffith estimates to $US 2010 using the US GDP deflator. Variations in the EKC peak are attributable to differences in population density.

by setting the deforestation rate at zero in the linear estimating equation, solving for the associated value of log GDP per capita, and calculating the exponential of the log. Estimated incomes for relevant regressions are presented in the table.

The slope of the transition path is a critical determinant of performance incentives in our system: The steeper the slope, ceteris paribus, the shorter the period in which countries earn positive incentives for forest clearing at levels below the forest transition line. In the table, the 5%-clipped random effects estimate and the three robust regression estimates are statistically indistinguishable. To provide the maximum benefit of the doubt, we opt for the 5%-clipped random effects estimates because they yield the largest zero-deforestation income ($10,147, which we round to $10,150).

Table A1: The Deforestation Rate and Income Per Capita

Dependent Variable: Annual Deforestation Rate (1990-2000, 2000-2005, 2005-2010)

	Full Sample		1% Clipped		5% Clipped		Full Sample	1% Clipped	5% Clipped
	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Robust	Robust	Robust
Log GDP Per Capita Const $US 2005)	-2.619 (5.37)**	1.594 (1.02)	-1.834 (5.63)**	0.063 (0.07)	-1.272 (5.98)**	-0.704 (1.40)	-1.303 (9.95)**	-1.289 (9.87)**	-1.221 (PPP (9.77)**
Constant	22.946 (5.43)**	-13.161 (0.99)	16.452 (5.82)**	0.220 (0.03)	11.736 (6.33)**	6.861 (1.58)	11.976 (10.56)**	11.850 (10.46)**	11.226 (10.32)**
Hausman Tests	χ^2 8.14 (p=.0043)		χ^2 5.34 (p=.0209)		χ^2 1.56 (p=.2118)				
Observations	512	512	500	500	460	460	512	500	460
Countries	174	174	173	173	170	170			
R-squared	0.13	0.13	0.13	0.13	0.16	0.16			
Est. Income For Zero Net Deforestation					$10147		$9832	$9824	$9840

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Appendix A2

Annual Payment Flows with Transition to Zero Clearing in 2017 by Country ($US Million)

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Cambodia	2008	0.0	0.0	0.2	0.2	0.1	0.0
Cambodia	2009	0.0	0.0	1.8	1.8	1.4	0.4
Cambodia	2010	0.0	0.0	0.0	0.0	0.0	0.0
Cambodia	2011	0.0	0.0	6.3	6.3	5.1	1.3
Cambodia	2012	0.0	0.0	6.3	6.3	5.1	1.3
Cambodia	2013	0.0	0.0	6.3	6.3	5.1	1.3
Cambodia	2014	0.8	0.0	6.3	7.2	5.7	1.4
Cambodia	2015	6.1	0.2	6.3	12.6	10.1	2.5
Cambodia	2016	16.4	2.6	6.3	25.3	20.2	5.1
Cambodia	2017	31.9	8.3	6.3	46.5	37.2	9.3
Cambodia	2018	50.5	15.4	0.0	65.8	52.7	13.2
Cambodia	2019	68.2	19.9	0.0	88.1	70.5	17.6
Cambodia	2020	84.8	21.4	0.0	106.1	84.9	21.2
Cambodia	2021	100.1	19.9	0.0	120.0	96.0	24.0
Cambodia	2022	114.2	15.4	0.0	129.6	103.6	25.9
Cambodia	2023	127.0	7.9	0.0	134.9	107.9	27.0
Cambodia	2024	138.7	0.5	0.0	139.1	111.3	27.8
Cambodia	2025	149.1	0.0	0.0	149.1	119.3	29.8
Cambodia	2026	158.3	0.0	0.0	158.3	126.6	31.7
Cambodia	2027	166.2	0.0	0.0	166.2	133.0	33.2
Cambodia	2028	173.0	0.0	0.0	173.0	138.4	34.6
Cambodia	2029	178.5	0.0	0.0	178.5	142.8	35.7
Cambodia	2030	182.8	0.0	0.0	182.8	146.2	36.6
Cambodia	2031	185.8	0.0	0.0	185.8	148.7	37.2
Cambodia	2032	187.7	0.0	0.0	187.7	150.1	37.5
Cambodia	2033	188.3	0.0	0.0	188.3	150.6	37.7
Cambodia	2034	187.7	0.0	0.0	187.7	150.1	37.5
Cambodia	2035	185.8	0.0	0.0	185.8	148.7	37.2
Cambodia	2036	182.8	0.0	0.0	182.8	146.2	36.6
Cambodia	2037	178.5	0.0	0.0	178.5	142.8	35.7
Cambodia	2038	173.0	0.0	0.0	173.0	138.4	34.6
Cambodia	2039	166.2	0.0	0.0	166.2	133.0	33.2
Cambodia	2040	158.3	0.0	0.0	158.3	126.6	31.7
Cambodia	2041	149.1	0.0	0.0	149.1	119.3	29.8
Cambodia	2042	138.7	0.0	0.0	138.7	110.9	27.7
Cambodia	2043	127.0	0.0	0.0	127.0	101.6	25.4
Cambodia	2044	114.2	0.0	0.0	114.2	91.3	22.8

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Cambodia	2045	100.1	0.0	0.0	100.1	80.1	20.0
Cambodia	2046	84.8	0.0	0.0	84.8	67.8	17.0
Cambodia	2047	68.2	0.0	0.0	68.2	54.6	13.6
Cambodia	2048	50.5	0.0	0.0	50.5	40.4	10.1
Cambodia	2049	31.5	0.0	0.0	31.5	25.2	6.3
Cambodia	2050	11.2	0.0	0.0	11.2	9.0	2.2
Cambodia	2051	0.0	0.0	0.0	0.0	0.0	0.0
China	2008	6.1	9.0	4.3	19.3	15.5	3.9
China	2009	5.7	20.3	4.5	30.5	24.4	6.1
China	2010	0.0	23.5	0.0	23.5	18.8	4.7
China	2011	0.0	18.3	8.8	27.1	21.7	5.4
China	2012	0.0	11.9	8.8	20.7	16.6	4.1
China	2013	0.0	5.1	8.8	13.9	11.1	2.8
China	2014	0.0	0.1	8.8	8.9	7.2	1.8
China	2015	0.0	0.0	8.8	8.8	7.0	1.8
China	2016	0.0	0.0	8.8	8.8	7.0	1.8
China	2017	0.0	0.0	8.8	8.8	7.0	1.8
China	2018	0.0	0.0	0.0	0.0	0.0	0.0
Indonesia	2008	1.2	0.0	137.3	138.4	110.8	27.7
Indonesia	2009	59.4	13.4	149.7	222.6	178.1	44.5
Indonesia	2010	38.2	0.0	0.0	38.2	30.6	7.6
Indonesia	2011	22.8	0.0	166.6	189.5	151.6	37.9
Indonesia	2012	94.9	0.0	166.6	261.6	209.3	52.3
Indonesia	2013	258.8	0.0	166.6	425.4	340.3	85.1
Indonesia	2014	514.3	0.0	166.6	681.0	544.8	136.2
Indonesia	2015	861.6	0.0	166.6	1,028.2	822.6	205.6
Indonesia	2016	1,300.5	0.0	166.6	1,467.2	1,173.7	293.4
Indonesia	2017	1,831.2	0.0	166.6	1,997.9	1,598.3	399.6
Indonesia	2018	2,401.5	0.0	0.0	2,401.5	1,921.2	480.3
Indonesia	2019	2,907.3	0.0	0.0	2,907.3	2,325.9	581.5
Indonesia	2020	3,338.2	0.0	0.0	3,338.2	2,670.6	667.6
Indonesia	2021	3,694.1	0.0	0.0	3,694.1	2,955.3	738.8
Indonesia	2022	3,975.1	0.0	0.0	3,975.1	3,180.1	795.0
Indonesia	2023	4,181.2	0.0	0.0	4,181.2	3,345.0	836.2
Indonesia	2024	4,312.3	0.0	0.0	4,312.3	3,449.9	862.5
Indonesia	2025	4,368.5	0.0	0.0	4,368.5	3,494.8	873.7
Indonesia	2026	4,349.8	0.0	0.0	4,349.8	3,479.9	870.0
Indonesia	2027	4,256.1	0.0	0.0	4,256.1	3,404.9	851.2
Indonesia	2028	4,087.5	0.0	0.0	4,087.5	3,270.0	817.5
Indonesia	2029	3,844.0	0.0	0.0	3,844.0	3,075.2	768.8
Indonesia	2030	3,525.5	0.0	0.0	3,525.5	2,820.4	705.1
Indonesia	2031	3,132.1	0.0	0.0	3,132.1	2,505.7	626.4
Indonesia	2032	2,663.8	0.0	0.0	2,663.8	2,131.0	532.8
Indonesia	2033	2,120.5	0.0	0.0	2,120.5	1,696.4	424.1

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Indonesia	2034	1,502.3	0.0	0.0	1,502.3	1,201.9	300.5
Indonesia	2035	809.2	0.0	0.0	809.2	647.4	161.8
Indonesia	2036	121.3	0.0	0.0	121.3	97.0	24.3
Indonesia	2037	0.0	0.0	0.0	0.0	0.0	0.0
Lao PDR	2008	0.6	0.0	4.7	5.3	4.2	1.1
Lao PDR	2009	8.7	3.3	18.6	30.6	24.5	6.1
Lao PDR	2010	27.5	12.9	3.2	43.5	34.8	8.7
Lao PDR	2011	46.9	19.1	4.7	70.8	56.6	14.2
Lao PDR	2012	68.6	23.4	4.7	96.8	77.4	19.4
Lao PDR	2013	92.8	26.0	4.7	123.5	98.8	24.7
Lao PDR	2014	119.5	26.8	4.7	151.1	120.9	30.2
Lao PDR	2015	148.7	25.9	4.7	179.4	143.5	35.9
Lao PDR	2016	180.4	23.3	4.7	208.4	166.7	41.7
Lao PDR	2017	214.6	18.9	4.7	238.2	190.6	47.6
Lao PDR	2018	249.8	11.4	0.0	261.1	208.9	52.2
Lao PDR	2019	283.0	1.0	0.0	284.0	227.2	56.8
Lao PDR	2020	314.1	0.0	0.0	314.1	251.2	62.8
Lao PDR	2021	342.8	0.0	0.0	342.8	274.3	68.6
Lao PDR	2022	369.4	0.0	0.0	369.4	295.5	73.9
Lao PDR	2023	393.7	0.0	0.0	393.7	315.0	78.7
Lao PDR	2024	415.8	0.0	0.0	415.8	332.6	83.2
Lao PDR	2025	435.6	0.0	0.0	435.6	348.5	87.1
Lao PDR	2026	453.2	0.0	0.0	453.2	362.6	90.6
Lao PDR	2027	468.6	0.0	0.0	468.6	374.9	93.7
Lao PDR	2028	481.7	0.0	0.0	481.7	385.4	96.3
Lao PDR	2029	492.6	0.0	0.0	492.6	394.1	98.5
Lao PDR	2030	501.3	0.0	0.0	501.3	401.0	100.3
Lao PDR	2031	507.7	0.0	0.0	507.7	406.2	101.5
Lao PDR	2032	511.9	0.0	0.0	511.9	409.5	102.4
Lao PDR	2033	513.9	0.0	0.0	513.9	411.1	102.8
Lao PDR	2034	513.6	0.0	0.0	513.6	410.9	102.7
Lao PDR	2035	511.1	0.0	0.0	511.1	408.9	102.2
Lao PDR	2036	506.3	0.0	0.0	506.3	405.1	101.3
Lao PDR	2037	499.3	0.0	0.0	499.3	399.5	99.9
Lao PDR	2038	490.1	0.0	0.0	490.1	392.1	98.0
Lao PDR	2039	478.7	0.0	0.0	478.7	382.9	95.7
Lao PDR	2040	465.0	0.0	0.0	465.0	372.0	93.0
Lao PDR	2041	449.0	0.0	0.0	449.0	359.2	89.8
Lao PDR	2042	430.9	0.0	0.0	430.9	344.7	86.2
Lao PDR	2043	410.5	0.0	0.0	410.5	328.4	82.1
Lao PDR	2044	387.8	0.0	0.0	387.8	310.3	77.6
Lao PDR	2045	363.0	0.0	0.0	363.0	290.4	72.6
Lao PDR	2046	335.9	0.0	0.0	335.9	268.7	67.2
Lao PDR	2047	306.5	0.0	0.0	306.5	245.2	61.3
Lao PDR	2048	274.9	0.0	0.0	274.9	219.9	55.0

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Lao PDR	2049	241.1	0.0	0.0	241.1	192.9	48.2
Lao PDR	2050	205.1	0.0	0.0	205.1	164.0	41.0
Lao PDR	2051	166.8	0.0	0.0	166.8	133.4	33.4
Lao PDR	2052	126.3	0.0	0.0	126.3	101.0	25.3
Lao PDR	2053	83.5	0.0	0.0	83.5	66.8	16.7
Lao PDR	2054	38.5	0.0	0.0	38.5	30.8	7.7
Lao PDR	2055	2.3	0.0	0.0	2.3	1.9	0.5
Lao PDR	2056	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	2007	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	2008	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	2009	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	2010	0.0	0.0	0.0	0.0	0.0	0.0
Malaysia	2011	0.0	0.0	111.0	111.0	88.8	22.2
Malaysia	2012	0.0	0.0	111.0	111.0	88.8	22.2
Malaysia	2013	0.0	0.0	111.0	111.0	88.8	22.2
Malaysia	2014	0.0	1.4	111.0	112.4	89.9	22.5
Malaysia	2015	0.0	28.1	111.0	139.1	111.3	27.8
Malaysia	2016	0.0	99.0	111.0	210.0	168.0	42.0
Malaysia	2017	0.0	214.6	111.0	325.6	260.5	65.1
Malaysia	2018	0.0	340.2	0.0	340.2	272.2	68.0
Malaysia	2019	0.0	406.5	0.0	406.5	325.2	81.3
Malaysia	2020	0.0	406.5	0.0	406.5	325.2	81.3
Malaysia	2021	0.0	340.2	0.0	340.2	272.2	68.0
Malaysia	2022	0.0	207.7	0.0	207.7	166.1	41.5
Malaysia	2023	0.0	33.4	0.0	33.4	26.7	6.7
Malaysia	2024	0.0	0.0	0.0	0.0	0.0	0.0
Myanmar	2008	0.0	0.0	0.0	0.0	0.0	0.0
Myanmar	2009	0.0	0.0	0.0	0.0	0.0	0.0
Myanmar	2010	0.0	0.0	4.8	4.8	3.9	1.0
Myanmar	2011	0.0	0.0	73.2	73.2	58.6	14.6
Myanmar	2012	0.0	0.0	73.2	73.2	58.6	14.6
Myanmar	2013	0.0	0.0	73.2	73.2	58.6	14.6
Myanmar	2014	0.0	0.0	73.2	73.2	58.6	14.6
Myanmar	2015	0.0	0.0	73.2	73.2	58.6	14.6
Myanmar	2016	3.1	0.0	73.2	76.3	61.1	15.3
Myanmar	2017	49.0	10.4	73.2	132.6	106.0	26.5
Myanmar	2018	140.7	49.0	0.0	189.7	151.8	37.9
Myanmar	2019	233.0	78.9	0.0	311.9	249.5	62.4
Myanmar	2020	321.2	95.5	0.0	416.7	333.4	83.3
Myanmar	2021	405.4	98.8	0.0	504.2	403.4	100.8
Myanmar	2022	485.5	88.9	0.0	574.3	459.5	114.9
Myanmar	2023	561.5	65.6	0.0	627.1	501.7	125.4
Myanmar	2024	633.5	29.0	0.0	662.5	530.0	132.5
Myanmar	2025	701.4	0.0	0.0	701.4	561.1	140.3

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Myanmar	2026	765.3	0.0	0.0	765.3	612.2	153.1
Myanmar	2027	825.1	0.0	0.0	825.1	660.1	165.0
Myanmar	2028	880.9	0.0	0.0	880.9	704.7	176.2
Myanmar	2029	932.6	0.0	0.0	932.6	746.0	186.5
Myanmar	2030	980.2	0.0	0.0	980.2	784.2	196.0
Myanmar	2031	1,023.8	0.0	0.0	1,023.8	819.0	204.8
Myanmar	2032	1,063.3	0.0	0.0	1,063.3	850.7	212.7
Myanmar	2033	1,098.8	0.0	0.0	1,098.8	879.1	219.8
Myanmar	2034	1,130.3	0.0	0.0	1,130.3	904.2	226.1
Myanmar	2035	1,157.6	0.0	0.0	1,157.6	926.1	231.5
Myanmar	2036	1,181.0	0.0	0.0	1,181.0	944.8	236.2
Myanmar	2037	1,200.2	0.0	0.0	1,200.2	960.2	240.0
Myanmar	2038	1,215.4	0.0	0.0	1,215.4	972.3	243.1
Myanmar	2039	1,226.6	0.0	0.0	1,226.6	981.3	245.3
Myanmar	2040	1,233.7	0.0	0.0	1,233.7	986.9	246.7
Myanmar	2041	1,236.7	0.0	0.0	1,236.7	989.4	247.3
Myanmar	2042	1,235.7	0.0	0.0	1,235.7	988.6	247.1
Myanmar	2043	1,230.6	0.0	0.0	1,230.6	984.5	246.1
Myanmar	2044	1,221.5	0.0	0.0	1,221.5	977.2	244.3
Myanmar	2045	1,208.3	0.0	0.0	1,208.3	966.7	241.7
Myanmar	2046	1,191.1	0.0	0.0	1,191.1	952.9	238.2
Myanmar	2047	1,169.8	0.0	0.0	1,169.8	935.8	234.0
Myanmar	2048	1,144.5	0.0	0.0	1,144.5	915.6	228.9
Myanmar	2049	1,115.1	0.0	0.0	1,115.1	892.0	223.0
Myanmar	2050	1,081.6	0.0	0.0	1,081.6	865.3	216.3
Myanmar	2051	1,044.1	0.0	0.0	1,044.1	835.3	208.8
Myanmar	2052	1,002.5	0.0	0.0	1,002.5	802.0	200.5
Myanmar	2053	956.9	0.0	0.0	956.9	765.5	191.4
Myanmar	2054	907.2	0.0	0.0	907.2	725.8	181.4
Myanmar	2055	853.5	0.0	0.0	853.5	682.8	170.7
Myanmar	2056	795.7	0.0	0.0	795.7	636.6	159.1
Myanmar	2057	733.8	0.0	0.0	733.8	587.1	146.8
Myanmar	2058	667.9	0.0	0.0	667.9	534.4	133.6
Myanmar	2059	598.0	0.0	0.0	598.0	478.4	119.6
Myanmar	2060	524.0	0.0	0.0	524.0	419.2	104.8
Myanmar	2061	445.9	0.0	0.0	445.9	356.7	89.2
Myanmar	2062	363.8	0.0	0.0	363.8	291.0	72.8
Myanmar	2063	277.6	0.0	0.0	277.6	222.1	55.5
Myanmar	2064	187.4	0.0	0.0	187.4	149.9	37.5
Myanmar	2065	93.1	0.0	0.0	93.1	74.5	18.6
Myanmar	2066	9.9	0.0	0.0	9.9	7.9	2.0
Myanmar	2067	0.0	0.0	0.0	0.0	0.0	0.0
Thailand	2008	0.0	0.0	0.5	0.5	0.4	0.1
Thailand	2009	0.0	0.6	1.8	2.4	2.0	0.5
Thailand	2010	0.0	1.1	0.0	1.1	0.9	0.2

		Payments ($US Million)					
Country	Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
Thailand	2011	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2012	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2013	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2014	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2015	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2016	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2017	0.0	0.0	0.9	0.9	0.7	0.2
Thailand	2018	0.0	0.0	0.0	0.0	0.0	0.0
Vietnam	2008	4.5	4.3	0.4	9.1	7.3	1.8
Vietnam	2009	11.0	9.9	1.5	22.5	18.0	4.5
Vietnam	2010	13.7	10.9	0.0	24.6	19.6	4.9
Vietnam	2011	9.6	4.5	2.7	16.8	13.4	3.4
Vietnam	2012	6.3	0.1	2.7	9.1	7.3	1.8
Vietnam	2013	4.5	0.0	2.7	7.2	5.7	1.4
Vietnam	2014	4.2	0.0	2.7	6.9	5.5	1.4
Vietnam	2015	5.4	0.0	2.7	8.1	6.4	1.6
Vietnam	2016	8.1	0.0	2.7	10.7	8.6	2.1
Vietnam	2017	12.3	0.0	2.7	14.9	11.9	3.0
Vietnam	2018	17.1	0.0	0.0	17.1	13.7	3.4
Vietnam	2019	20.9	0.0	0.0	20.9	16.8	4.2
Vietnam	2020	23.6	0.0	0.0	23.6	18.9	4.7
Vietnam	2021	25.1	0.0	0.0	25.1	20.1	5.0
Vietnam	2022	25.4	0.0	0.0	25.4	20.3	5.1
Vietnam	2023	24.5	0.0	0.0	24.5	19.6	4.9
Vietnam	2024	22.4	0.0	0.0	22.4	17.9	4.5
Vietnam	2025	19.2	0.0	0.0	19.2	15.3	3.8
Vietnam	2026	14.7	0.0	0.0	14.7	11.8	2.9
Vietnam	2027	9.1	0.0	0.0	9.1	7.3	1.8
Vietnam	2028	2.5	0.0	0.0	2.5	2.0	0.5
Vietnam	2029	0.0	0.0	0.0	0.0	0.0	0.0

Appendix A3

Total Annual Payment Flows with Transition to Zero Clearing in 2017 ($US Million)

	Payments ($US Million)					
Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
2008	12.3	13.2	147.4	172.9	138.3	34.6
2009	84.9	47.5	178.0	310.4	248.3	62.1
2010	79.3	48.4	8.0	135.7	108.5	27.1
2011	79.3	41.9	374.3	495.5	396.4	99.1
2012	169.9	35.4	374.3	579.6	463.7	115.9
2013	356.1	31.0	374.3	761.4	609.1	152.3
2014	638.8	28.4	374.3	1,041.5	833.2	208.3
2015	1,021.7	54.2	374.3	1,450.2	1,160.1	290.0
2016	1,508.5	124.8	374.3	2,007.6	1,606.1	401.5
2017	2,138.9	252.2	374.3	2,765.4	2,212.3	553.1
2018	2,859.6	416.0	0.0	3,275.6	2,620.5	655.1
2019	3,512.5	506.3	0.0	4,018.8	3,215.0	803.8
2020	4,081.8	523.4	0.0	4,605.2	3,684.2	921.0
2021	4,567.5	459.0	0.0	5,026.4	4,021.2	1,005.3
2022	4,969.5	311.9	0.0	5,281.4	4,225.1	1,056.3
2023	5,287.9	106.9	0.0	5,394.8	4,315.8	1,079.0
2024	5,522.7	29.5	0.0	5,552.2	4,441.7	1,110.4
2025	5,673.8	0.0	0.0	5,673.8	4,539.1	1,134.8
2026	5,741.3	0.0	0.0	5,741.3	4,593.1	1,148.3
2027	5,725.2	0.0	0.0	5,725.2	4,580.2	1,145.0
2028	5,625.6	0.0	0.0	5,625.6	4,500.5	1,125.1
2029	5,447.7	0.0	0.0	5,447.7	4,358.2	1,089.5
2030	5,189.8	0.0	0.0	5,189.8	4,151.9	1,038.0
2031	4,849.5	0.0	0.0	4,849.5	3,879.6	969.9
2032	4,426.7	0.0	0.0	4,426.7	3,541.4	885.3
2033	3,921.5	0.0	0.0	3,921.5	3,137.2	784.3
2034	3,333.9	0.0	0.0	3,333.9	2,667.1	666.8
2035	2,663.7	0.0	0.0	2,663.7	2,131.0	532.7
2036	1,991.3	0.0	0.0	1,991.3	1,593.0	398.3
2037	1,878.0	0.0	0.0	1,878.0	1,502.4	375.6
2038	1,878.5	0.0	0.0	1,878.5	1,502.8	375.7
2039	1,871.5	0.0	0.0	1,871.5	1,497.2	374.3
2040	1,856.9	0.0	0.0	1,856.9	1,485.5	371.4
2041	1,834.8	0.0	0.0	1,834.8	1,467.9	367.0
2042	1,805.2	0.0	0.0	1,805.2	1,444.2	361.0
2043	1,768.1	0.0	0.0	1,768.1	1,414.5	353.6
2044	1,723.5	0.0	0.0	1,723.5	1,378.8	344.7
2045	1,671.4	0.0	0.0	1,671.4	1,337.1	334.3
2046	1,611.7	0.0	0.0	1,611.7	1,289.4	322.3

	Payments ($US Million)					
Year	Transition Line	REDD Line	Quarterly Performance	Total	National Gov't	Indigenous Communities
2047	1,544.5	0.0	0.0	1,544.5	1,235.6	308.9
2048	1,469.8	0.0	0.0	1,469.8	1,175.9	294.0
2049	1,387.6	0.0	0.0	1,387.6	1,110.1	277.5
2050	1,297.9	0.0	0.0	1,297.9	1,038.3	259.6
2051	1,210.9	0.0	0.0	1,210.9	968.7	242.2
2052	1,128.8	0.0	0.0	1,128.8	903.0	225.8
2053	1,040.4	0.0	0.0	1,040.4	832.3	208.1
2054	945.7	0.0	0.0	945.7	756.6	189.1
2055	855.8	0.0	0.0	855.8	684.6	171.2
2056	795.7	0.0	0.0	795.7	636.6	159.1
2057	733.8	0.0	0.0	733.8	587.1	146.8
2058	667.9	0.0	0.0	667.9	534.4	133.6
2059	598.0	0.0	0.0	598.0	478.4	119.6
2060	524.0	0.0	0.0	524.0	419.2	104.8
2061	445.9	0.0	0.0	445.9	356.7	89.2
2062	363.8	0.0	0.0	363.8	291.0	72.8
2063	277.6	0.0	0.0	277.6	222.1	55.5
2064	187.4	0.0	0.0	187.4	149.9	37.5
2065	93.1	0.0	0.0	93.1	74.5	18.6
2066	9.9	0.0	0.0	9.9	7.9	2.0
2067	0.0	0.0	0.0	0.0	0.0	0.0

Appendix A4

FORMA Methodology

FORMA utilizes data recorded daily by the Moderate Resolution Imaging Spectrometer (MODIS), which operates on NASA's Terra and Aqua (EOS PM) satellite platforms. Although its signal-processing algorithms are relatively complex, FORMA is based on a common-sense observation: Tropical forest-clearing involves the burning of biomass and a pronounced temporary or long-term change in vegetation color, as the original forest is cleared and replaced by pastures, croplands or plantations. Accordingly, FORMA constructs forest-clearing indicators from MODIS-derived data on the incidence of fires and changes in vegetation color as identified by the Normalized Difference Vegetation Index (NDVI). It then calibrates to local forest-clearing by fitting a statistical model that relates the MODIS-based indicator values to the best available information on actual forest-clearing in each area. FORMA incorporates local diversity by dividing each country into WWF ecoregions and separately fitting the model to data for each ecoregion. The dependent variable for each pixel is coded 1 if it has experienced forest-clearing within the relevant time period, and 0 otherwise. The MODIS-based indicator values are the independent variables.

For all tropical countries except Brazil, the best identification of recent forest clearing has been published in the Proceedings of the National Academy of Sciences by Hansen, et al.[13] (2008), who estimate the incidence of forest-clearing for 500m parcels in the humid tropics. We calibrate FORMA using the map of forest cover loss hotspots (henceforth referred to as the FCLH dataset) published by Hansen, et al. for the period 2000-2005.[14]

Using the FCLH pan-tropical dataset for 2000-2005, FORMA fits the calibration model to observations on forest-clearing for 1 km^2 cells in each country and ecoregion. As we document in Hammer, et al. (2009), the model's predicted probability distribution provides a very close match to the spatial incidence of FCLH forest-clearing. FORMA then applies the fitted model to monthly MODIS indicator data for the period after December 2005. The output for each month is a predicted forest-clearing probability for each 1 km^2 parcel outside of previously-deforested areas, as identified in the FCLH map. FORMA selects parcels whose probabilities exceed 50%. We calculate the total number of selected parcels within a geographic area to produce an index of forest-clearing activity in that area. Even small

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[13] Hansen, M.C., Stehman, S.V., Potapov, P.V., Loveland, T.R., Townshend, J.R.G., DeFries, R.S., Pittman, K.W., Stolle, F., Steininger, M.K., Carroll, M., Dimiceli, C. 2008. Humid tropical forest clearing from 2000 to 2005 quantified using multi-temporal and multi-resolution remotely sensed data. PNAS, 105(27), 9439-9444. www.pnas.org/cgi/doi/10.1073/pnas.0804042105

[14] In Brazil, higher resolution estimates are also available annually from the INPE PRODES program. We have used these estimates to test the accuracy of our FCLH-based calibration methodology. For more information on PRODES, see Projeto PRODES: Monitoramento da Floresta Amazonica Brasileira por Satelite. http://www.obt.inpe.br/prodes/

geographic areas can include thousands of 1 km cells, so error-averaging ensures robust index values.[15]

[15] For example, a square area 50 km on a side contains 2,500 1 km cells.