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Including International Forest Carbon Incentives in Climate Policy: Understanding the Economics

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Cover photo: Rainforest on the Indonesian island of Lombok, courtesy of Andrey Narkevich

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Executive Summary

Deforestation and forest degradation currently account for 15% to 20% of global greenhouse gas emissions, exceeding the global emissions of the transportation sector (Intergovernmental Panel on Climate Change [IPCC] 2007). But efforts to curb deforestation and degradation have not yet been incorporated into the binding agreements to reduce GHGs such as the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC). Given the enormous scale of deforestation, and the realization that the world's remaining tropical forests are disappearing at an alarming rate, it is no longer a question of *whether* the prevention of forest carbon losses should be part of a global climate agreement, but one of *how*. Policymakers are now considering the inclusion of reduced emissions from deforestation and degradation (REDD) in the UNFCCC post-Kyoto climate agreements. At the same time, legislators in the United States Congress continue to craft proposals to cap greenhouse gas emissions, several of which include a role for reduced emissions or increased sequestration of international forest carbon stocks as part of the policy portfolio.

A dimension that can greatly influence how international forest carbon policies work is the source of financing to pay for emission reductions. Compensation will likely come either from using part of the global carbon market a flexible compliance mechanism for those countries that face a mandatory cap on their emissions, some other nonmarket transfer of funds to the country achieving the reductions (often called the *fund* approach), or a mix of the two. This report directly assesses the consequences of including demand from a compliance market as the source of international forest carbon compensation. This does not presuppose or advocate the policy outcome (market or fund); rather, it uses the results of economic modeling to inform the discussion, including how the inclusion of forest carbon might affect the carbon market price and the distribution of abatement efforts across sectors and countries.

Economic dimensions of international forest carbon payments

Whether the carbon market or other institutions provide the funds to drive the program, compensation to parties for reducing deforestation rates and corresponding GHG emissions lies at the heart of the current proposals. Thus the success of a forest carbon policy is ultimately tied to its economic viability. Viability applies at both the individual and the aggregate level. At the individual land-holding level, parties will opt in to a forest carbon program only if they expect the compensation will make the changes in land-use practices economically worthwhile for them—that is, the compensation exceeds the opportunity costs of forgoing the returns from clearing the land plus any additional costs (e.g., for planning, measurement, monitoring, verification, asset protection, and exchange) necessary to bring the credits forward to a buyer. Also at the local level, forest carbon compensation may affect the economic well-being of other parties (including indigenous people) who currently access forests for food, timber, firewood, and other goods and services that affect their livelihood.

At the aggregate (national, international) level, economic viability implies that there is demand for international forest carbon reductions—either from GHG compliance markets, voluntary markets, or various forms of nonmarket institutions (e.g., official development assistance or ODA)—matched by funds to make it happen. There must be sufficient supply capacity of forest carbon credits to meet this demand at a price that is competitive with other mitigation options. And there must be provisions put in place to address the possibility of emissions leakage caused by shifting of deforestation to sources not covered by forest carbon policies, and the potential impermanence of these reductions due to subsequent release of forest carbon into the atmosphere (e.g., if forests burn or are harvested). To make the policy work on the ground, infrastructure (technological, legal, and other) must be in place to ensure that reductions are properly quantified and monitored, that the rights to compensation are properly established, and that compensation flows through the appropriate channels.

Forest carbon must also be viewed as part of a multisector approach to mitigating GHGs. International forest carbon is seen by many as a potentially low-cost option relative to actions in other sectors, which drives its appeal as a possible component of a global compliance market for carbon (Bosetti et al. 2009; Richards and Stokes 2004). Low-cost options, if integrated into a market, will supplant some higher-priced mitigation actions from other sectors; that is how competitive markets work. However, this possibility has raised concerns in some corners that forest carbon and other forms of compliance offset mechanisms will "flood the market" and defer or even eliminate compliance actions from other sectors, such as energy, that are core to the GHG problem. While this should not necessarily be a problem as long as forest carbon mitigation is real, verifiable, and permanent, careful scrutiny is warranted to ensure that it meets these criteria.

Informing U.S. climate policy deliberations

The primary audience for this report includes those responsible for deciding whether and how to incorporate international forest carbon into a U.S. climate policy regime. We focus on the United States because of the momentum now building for a comprehensive climate bill emanating from the walls of Congress and the pronouncements of support for such an endeavor by the Obama Administration. Various proposals contain provisions for including forest carbon in the policy. There are many excellent papers already on the role of REDD as part of a global climate agreement under the UNFCCC, but not much has been written specific to the unique position that the United States holds in climate policy.[1] Not a signatory to the Kyoto Protocol commitments under the UNFCCC, the United States has nonetheless taken forward steps in recent years toward adopting a mandatory GHG reduction program of its own. The U.S. proposals with the most political resonance of late—The Boxer-Lieberman-Warner bill (S. 3036) taken to the Senate in the summer of 2008 and the Waxman-Markey draft bill (H.R. 2454, Waxman-Markey American Clean Energy and Security Act of 2009) passed by subcommittee in the U.S. House of Representatives in May 2009—both include international forest carbon, including REDD, as a potential source of offsets to meet U.S. compliance commitments. Thus a careful look at the economics of this potential source is clearly needed at this time. Debate, discussion, and undoubtedly new proposals will continue to surface as this report is being drafted in early to mid 2009.

Key take-home messages

A better understanding of the economics of international forest carbon mitigation can help the international community and U.S. Congress better decide how to include these options in the climate policy portfolio. Several studies have been conducted in the last few years that directly address the economic potential of forest carbon, how its inclusion might affect the compliance market for carbon, and how policy design issues like scope of coverage might affect outcomes. These studies have produced a wide range of cost estimates for REDD and other forest carbon mitigation activities, which can confuse the discussion. Some point to the lower-cost estimates as evidence that international forest carbon is a very inexpensive option which, given its other environmental co-benefits, should play a major role in climate mitigation strategy. Others, however, are concerned that these low-cost options will flood the market and divert mitigation from other key emitting sectors such as energy. These claims need to be put in proper context, which we attempt to do here. Taken together, the economic results provide helpful insights to inform the policy development process moving forward. Key findings and policy implications are highlighted below.

1 See, for example, Angelsen, A. (ed.), 2008, *Moving Ahead with REDD: Issues, Options, and Implications*, Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Economic models suggest that over the next 20 years, carbon prices of US\$10–\$30[2] per metric ton[3] of CO_2 (tCO_2) could generate reductions of 1–4 billion tCO_2/year globally through avoided deforestation. The models suggest that this amount could be as much as doubled if other options such as afforestation and forest management were credited.

Economic models can produce cost curves to indicate potential quantities of forest carbon reductions at different cost-per-ton levels. Forest carbon emission reductions, like other forms of mitigation, produce rising cost curves. Initial reductions can be quite inexpensive, perhaps as low as \$2–\$5/tCO_2 to reduce deforestation by the first 10% below baseline levels. Additional reductions, though, become progressively more expensive. If the program is focused on deforestation only, a central estimate of global reduction potential is 1.8–2.9 billion tCO_2 for carbon prices of \$10–\$30/tCO_2. Reductions in deforestation emissions, combined with increases in forest carbon stocks through afforestation and forest management in tropical regions, could amount to a significant boost in mitigation potential from the global forest sector. At the \$10–\$30/tCO_2 range referenced here, forest sector mitigation can offset 12%–20% of current global CO_2 emissions, a number that can make a substantial contribution to near-term reduction targets.

If compensation is based on future projected emissions potential, then the best purely economic opportunities from supply can be found in Africa.

Economic modeling suggests that future emissions from Africa are expected to rise more than in other regions. Moreover, opportunity costs of keeping land in forest are expected to be lower in Africa than elsewhere in the tropics. Taken together, this creates better potential forest carbon supply conditions for Africa. Economic modeling results suggest that at a price point of \$10/tCO_2, about half the global REDD potential comes from Africa. Africa's global potential share declines as the price rises, bringing in higher opportunity-cost reductions from South and Central America and Southeast Asia. However, governance reform, capacity building, and infrastructure needs may be greatest in Africa, suggesting that investment in these factors will be necessary to realize this potential.

If the United States includes international forest carbon reductions for compliance purposes, the supply of those reductions will depend on similar policy decisions by the rest of the international community as well as on the linkages between the U.S. market and other carbon markets.

Currently, the UNFCCC is negotiating the role that international forest carbon, through the REDD mechanism, will play in a post-Kyoto (post-2012) compliance regime. Options range from full use for compliance to no use, and variations in between. If the post-Kyoto framework allows for full use in compliance, this means that the United States will need to compete for these reductions on the open market, possibly raising costs of these credits in the U.S. market. However, if all countries are on board in the compliance market, this may provide the certainty and funding to ensure that the supplies will materialize in the first place, thereby bringing down costs for all buyers. This will depend not only on U.S. decisions on the applicability of forest carbon for compliance purposes, but also whether the rest of the world (via the UNFCCC) adopts international forest carbon (REDD) into its post-Kyoto compliance framework. Furthermore, even if other countries do not allow forest carbon for compliance purposes, their demand for reductions could still indirectly affect allowance prices in the U.S., depending on the linkages between the different markets.

Economic modeling shows that forest carbon as part of a global compliance market could lower the global allowance price more than 40%, depending on the scope of the program.

The success of international forest carbon as a compliance strategy will depend on its costs relative to mitigation in other sectors and locations. The greater the cost differential, the more of an impact including forest carbon will have on the carbon price. Evidence from economic modeling suggests that forest carbon

2 Unless otherwise specified, all dollars in this report are U.S. dollars.

3 All tons referenced in this report are metric tons, denoted by the abbreviation "t." Thus, the abbreviations "tCO_2" and "tCO_2e" refer to "metric tons of carbon dioxide" and "metric tons of carbon dioxide equivalent," respectively.

can substantially lower the aggregate costs of hitting a global target, reducing allowance prices by about 22% if deforestation only is included, and by about 43% if all international forest carbon is included.

The U.S. can play a significant role in global compliance demand for international forest carbon.

Estimated potential purchases by the U.S. for compliance purposes to meet targets in line with the proposed Waxman-Markey legislation are 1.9 billion tCO_2/year (valued at $32 billion) for deforestation only starting in 2013, rising to 2.2 billion tCO_2/year (valued at $52 billion) by 2020. The opportunities increase if the suite of creditable international forest carbon activities includes afforestation, reforestation, and changes in forest management. Our analysis estimates total U.S. forest carbon purchases from developing countries at 2.9 billion tCO_2 ($36 billion) in 2013 rising to 3.3 billion tCO_2 ($58 billion) by 2020. These estimates consider competition for forest carbon credits between the U.S. and other countries.

Allowance price reduction benefits need not cause flooding or substantial diversion of effort from other sectors. Inclusion of forest carbon in a global regime could help achieve a higher level of climate protection for the same cost as a regime without forest carbon.

As indicated above, the inclusion of international forest carbon can bring down the allowance price considerably as it substitutes for higher-cost mitigation alternatives on the margin. However, more than 70% of global abatement must still come from other sectors in order to achieve the global targets called for by various international and domestic policies, so the lion's share of the effort still falls elsewhere. Moreover, including international forest carbon for compliance allows policymakers to consider more aggressive targets than they might otherwise. At the global scale, including avoided deforestation as an emissions reduction option, with some limitations on trading prior to 2020, lowers the total costs of achieving a GHG stabilization target of 550 parts per million (ppm) CO_2 equivalent by up to 25%, with modest estimated impacts on incentives for investment and innovation in renewables, carbon capture and storage, and other energy technologies. The estimated cost savings from including avoided deforestation can enable a more stringent stabilization target of least 530 ppm CO_2e without an increase in the overall cost compared to a policy where deforestation is excluded from the carbon market. Estimated net savings of $2 trillion through global forestry mitigation could finance as much as a 10% stricter target or about 0.25°C less of warming over the century, depending on the modeled scenario.

When banking of allowances is allowed, the inclusion of international forest carbon can accelerate abatement.

According to modeling worked referenced herein, the United States could achieve 29%–33% of its targeted cumulative reductions for the 2012–2050 period by 2025, compared to 27% without international forest carbon from developing countries. Speeding the reductions provides additional climatic benefits by reducing the time that greenhouse gases persist in the atmosphere.

International forest carbon could be used to induce broader participation in the global carbon market to achieve greater overall reductions.

For example, a bilateral agreement between the United States and Brazil allowing 80% of Brazil's deforestation reductions to be used for U.S. abatement exclusively until 2020 could reduce the allowance price by 4%. In addition to the 20% of deforestation emissions reductions that Brazil would not trade, the associated cost savings could allow the U.S. to reduce its emissions by 4%–10% below 1990 levels by 2020, compared to simply returning to 1990 levels by 2020 as proposed by President Obama, while keeping the costs of compliance to U.S. companies the same as in the case without forest carbon credits.

Broader participation is critical to prevent emissions leakage to countries that do not participate in a forest carbon program.

The effectiveness of an opt-in policy to reduce forest carbon emissions could be undermined by emissions leakage from sources that remain outside the purview of the policy. Avoiding deforestation in one place can simply shift it—and its emissions—to other places if proper incentives and accounting are not in place to prevent it. Economic analyses show that leakage can be substantial when policy incentives are isolated. This suggests that policymakers should make every effort to engage all major sources of forest carbon in an agreement in order to minimize leakage across countries. National accounting systems can help control for leakage within a country by ensuring that any leakage that does occur is captured within the national accounts. Absent national accounting, discounting or other credit adjustments will likely be necessary to adjust crediting to deduct for leakage problems.

Forests as a mitigation tool are complemented by their role in adaptation, suggesting that forests can pay a double dividend in combating climate change.

Tropical forests in particular provide natural insurance against many threats—drought, flooding, and vector-borne diseases, to name just a few. These risks could be exacerbated by climate change; thus, keeping forests intact or expanding forest areas can contribute positively to future adaptation efforts.

1. Introduction

The scientific community is issuing progressively stronger warnings about the emerging threat of climate change and the need to prevent the continued accumulation of greenhouse gases (GHGs) in the atmosphere. Recent projections suggest that to prevent dangerous levels of climate change from occurring (above 2°C), global concentrations of carbon dioxide (CO_2), the most prevalent GHG, must be stabilized at levels below 450 parts per million (ppm) by mid-century (IPCC 2007)—or perhaps even as low as 350 ppm (Hansen et al. 2008). Currently, CO_2 concentrations sit at approximately 385 ppm. They are projected to rise significantly, perhaps doubling or tripling that concentration by the end of the century without significant policy intervention (IPCC 2007). Modifying this concentration path clearly would require a multifaceted effort to reduce GHGs across as many sources as feasible starting as soon as possible.

CO_2 emissions from deforestation and forest degradation currently account for about 15%–20% of global GHG emissions (IPCC 2007), exceeding the global emissions of the transportation sector. Because of deforestation, as of 2000, Indonesia and Brazil were the third and fourth largest individual nations in terms of GHG emissions, after China and the U.S., respectively (World Resources Institute Climate Analysis Indicators Tool 2008). But efforts to curb deforestation and degradation have not yet been incorporated into the binding agreements to reduce GHGs such as the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC). Given the enormous emissions reductions task just described and the realization that the world's remaining tropical forests are disappearing at an alarming rate (United Nations Food and Agricultural Organization 2006), it is no longer a question of whether the prevention of forest carbon losses should be part of a global climate agreement, but one of how. Internationally, policymakers are now considering the inclusion of reduced emissions from deforestation and degradation (REDD) into the UNFCCC post-Kyoto climate agreements. Moreover, in parallel and specific to the focus of this report, the United States Congress is now considering GHG cap-and-trade legislation that would include mitigation incentives for international forest carbon, including REDD.

Terminology

Policy discussions about forest carbon principally refer to *deforestation* and *degradation*, the two processes under which forest carbon stocks can be emitted to the atmosphere. The other main components are *conservation*—which maintains forest carbon stocks—and *afforestation*, *reforestation*, and *forest management*—which can build carbon stocks by removing CO_2 from the atmosphere. The international community is actively working to develop policy mechanisms that will incorporate tropical forests into a post-2012 climate regime. The current terminology in that process uses the phrase ***reduced emissions from deforestation and forest degradation*** or ***REDD***. Negotiations are under way regarding whether REDD will include other forest sector and land-use activities such as those mentioned above. When referring to the full suite of forest activities including—but beyond—REDD, we will use the broader terms ***international forest carbon*** and ***forest carbon*** in this report.

The details of including international forest carbon in U.S. legislation or the UNFCCC climate agreement are still very much in flux at this time. They likely will remain in flux throughout 2009 as the global community deliberates the successor agreement to the Kyoto Protocol in Copenhagen at the end of 2009 and U.S. policymakers transition climate policy into a new political landscape. However, there are a few basic principles that seem likely to apply to any policy that emerges from these discussions:

- ***Obligation.*** Tropical forest countries will seek compensation for reducing their forest-related emissions below some reference level (or baseline), but will not likely take a hard cap mandating these reductions in the near term.

- ***Scope.*** To date, the main focus has been on deforestation and degradation (REDD), but there is considerable movement to consider factors other than the two Ds, including the enhancement of carbon stocks through afforestation, reforestation, and sustainable forest management (sometimes called REDD+, but what we refer to throughout this report as international forest carbon).

- ***Scale.*** There is a push to hold countries accountable for forest carbon mitigation performance at the national level to avoid compensation of subnational projects from simply shifting deforestation and emissions to other spots within the country (what is known as leakage; see Section 5). The institutions necessary to measure and account for forest carbon emissions and sequestration at the national level may take time to develop, however. Thus activity and transactions at the subnational (project or programmatic) level may be a primary emphasis until national systems are up and running. Moreover, even once a national system is up and running, there may still be a significant role for projects and subnational programs to actually deliver the national results.

- ***Compatibility with human rights.*** There is strong concern that international forest carbon policies must not harm, and preferably should benefit the people who directly depend on the forests for their livelihood, especially indigenous populations with limited access to resources and political power. Policies will need to be designed to ensure that revenues flow to the affected parties in order for them to be fair and effective in combating the root causes of forest loss.

- ***Consistency with broader environmental objectives.*** Protecting and enhancing terrestrial carbon stocks necessarily affects the flow of all ecosystem services from the landscape. Forest carbon policies need to be viewed in the broader context of the range of affected services, including biodiversity and water resources. Ideally there would be markets for all ecosystem services, and those market signals would determine the efficient mix, complementarities, and tradeoffs between carbon and the other services. But since ecosystem service markets are incomplete, these tradeoffs and synergies may need to be addressed either through a broader statement of principles or product standards, or through case-specific applications.

Another dimension that can greatly influence how forest carbon policies work is the source of financing to pay for them. Compensation will come either as part of the global carbon market being used as a flexible compliance mechanism for the U.S. and possibly other countries that face a mandatory cap on their emissions, some other nonmarket transfer of funds to the country achieving the reductions (often called the fund approach), or a mix of the two. This report directly assesses the consequences of including demand from a compliance market as the source of forest carbon compensation. This does not presuppose or advocate the policy outcome (market over fund); rather, it uses the results of economic modeling to inform the discussion, including how the inclusion of international forest carbon might affect the carbon market price and the distribution of abatement efforts across sectors and countries.

1.1. Economic dimensions of forest carbon payments

Whether the carbon market or other institutions provide the funds to drive the program, compensation to parties for reducing deforestation rates and corresponding GHG emissions lies at the heart of the current proposals. Thus the success of a forest carbon policy is ultimately tied to its economic viability. Viability applies at both the individual and aggregate level. At the individual level, parties will opt into a forest carbon program or project only if they expect that the compensation will make the changes in land-use practices economically worthwhile for them—that is, the compensation exceeds the opportunity costs of forgoing the returns from clearing the land plus any transaction costs (for planning, measurement, monitoring, verification, asset protection, and exchange) necessary to bring the credits forward to a buyer. Also at the local level, forest carbon compensation can affect the economic well-being of indigenous people and other parties affected by access to the forest in ways that not only affect the equity of the economic outcomes, but perhaps the viability and sustainability of the enterprise.

At the aggregate (national, international) level, economic viability implies that there is demand for the forest carbon reductions—either from GHG compliance markets, voluntary markets, or various forms of nonmarket institutions (e.g., official development assistance or ODA)—matched by funds to make it happen. There must be sufficient supply capacity of international forest carbon credits to meet this demand at a price that is competitive with other mitigation options. And there must be provisions put in place to address, resolve, and otherwise account for the possibility of emissions leakage caused by shifting of deforestation to sources not covered by the forest carbon policies, and the potential impermanence of these reductions due to subsequent release of forest carbon into the atmosphere. To make the policy work on the ground, infrastructure (technological, legal, and other) must be in place to ensure that reductions are properly quantified and monitored, that the rights to compensation are properly established, and that compensation flows through the appropriate channels.

International forest carbon must also be viewed as part of a multisector approach to mitigating GHGs. Forests in general, particularly in the tropics, are seen by many as providing a number of potentially low-cost options relative to actions in other sectors (Fisher et al. 2007; Tavoni et al. 2007; Richards and Stokes 2004), which drives their appeal as a possible component of a global compliance market for carbon. Low-cost options, if integrated into a market, will supplant some higher-priced mitigation actions from other sectors. That is how competitive markets work. However, this possibility has raised concerns in some corners that international forest carbon and other forms of compliance offset mechanisms will flood the market and defer or even eliminate compliance actions and technological innovation in other sectors, such as energy, that are core to the GHG problem. If the long-term emissions targets were set appropriately and anticipated by market participants, and if international forest carbon mitigation were real, fully verifiable, and permanent, then the right incentives would be in place and flooding the market would not present a problem. However, many policymakers and scientists recognize that the established targets and frameworks may fall short of providing the long-term signals needed to drive the economic and technological transformation to address the climate imperative. They also recognize that there are important challenges in structuring an effective market mechanism for crediting forest carbon sinks or REDD actions. Careful scrutiny of the potential implications of international forest carbon is thus warranted before policy action is taken.

1.2. Purpose of this report and its intended audience

Developing an efficient and equitable international forest carbon mechanism requires a sound understanding of its economic dimensions. Nothing quite like an international forest carbon market, operating at a large scale and including REDD, is in existence at this time. Therefore the economic understanding must come from a synthesis of what we know about the core elements of the system—supply, demand, and market structure, including distributional impacts and institutional infrastructure. Toward that end, we have prepared a report that synthesizes and builds upon existing knowledge of these core system elements.

The primary audience for this report is the parties responsible for deciding whether and how to incorporate international forest carbon activity into a U.S. climate policy regime. We focus on the United States because of the momentum now building for a comprehensive climate bill from inside the walls of Congress and the Obama administration. Various legislative proposals include provisions for including international forest carbon reductions such as REDD in the policy. There are many excellent papers already on the role of REDD as part of a global climate agreement under the UNFCCC (see for instance, Angelsen [ed] 2008), but not much has been written specific to the unique position that the United States holds in climate policy. Not a signatory to the Kyoto Protocol commitments under the UNFCCC, the United States has nonetheless taken forward steps in recent years toward adopting a mandatory GHG reduction program of its own. The U.S. proposals with the most political resonance of late—The Boxer-Lieberman-Warner bill (S. 3036) taken to the Senate in the summer of 2008 and the Waxman-Markey draft bill introduced in the U.S. House of Representatives in March 2009—both include international forest carbon, including REDD, as a potential source of offsets to meet U.S. compliance commitments. In January 2009, the U.S. Climate Action Partnership (USCAP) called for the United States to cut greenhouse gases 80% by the middle of the century using a cap-and-trade system (USCAP 2009). This would set a firm cap on greenhouse gases but give businesses the flexibility to meet this cap by trading the right to emit these pollutants among themselves and through the use of emission reductions from uncapped domestic sectors (called offsets) or credits for emissions reductions in other countries. USCAP envisions that a prominent potential source of those international credits is through REDD from developing countries, and thus a careful look at the economics of this potential source is clearly needed at this time. Debate, discussion, and undoubtedly new proposals will continue to surface as this report is being drafted in early 2009.

1.3. Adaptation benefits of forests

The focus of this report is on forests as a climate mitigation tool, but forests also provide a means by which those most directly impacted by climate change can adapt to it. Thus preserving and enhancing forests can provide dual benefits—reducing the probability of dangerous climate change in the first place by removing CO_2 from the atmosphere and providing a form of "natural insurance" against climate change that does occur. Table 1.1 provides a summary of the natural insurance benefits of forests in a changing climate, drawing from an extensive set of studies reviewed in the companion report (Olander et al. 2009).

Table 1.1. Types of "natural insurance" forests provide that could facilitate adaptation to climate change.

Predicted impacts of climate change	Natural insurance provided by forests
Reduced agricultural yields in seasonally dry and tropical regions. Crops near the warm end of their suitable growth range or rain-dependent will face challenges. Ex: Rain-fed agriculture in Africa could be reduced by 50% by 2020.	**Food and economic security for the rural poor** – Hundreds of millions of people depend on forests for subsistence and income needs, collecting food, medicine, and fuelwood from the forest. Numerous studies find that the rural poor increase their collection of wild foods and other products from the forest in response to reduced agricultural yields and other economic shocks.
Disruption of rainfall patterns is predicted to cause more extreme rain events making water management more difficult.	**Regulation of water flow and water quality** – Forest ecosystems store water; regulate base flows; mitigate floods; and reduce runoff, erosion, and sedimentation. Forests can reduce landslide risk, improve local and downstream water quality, maintain aquatic health and fisheries, and maintain coastal water quality and clarity.
Increase in extreme weather events predicted – specifically an increase in the intensity of tropical cyclones and hurricanes.	**Protection of coastal areas** – Mangrove and coastal forests provide protection from flooding and erosion, and buffer coastal areas from storms.
Increased prevalence of vector-borne diseases is predicted as the range and breeding habit of disease-carrying agents such as mosquitoes expand. As a result, malaria, dengue, and other vector-borne diseases are projected to spread and increase. In addition, parts of Asia are expected to experience an increase in diarrhoeal disease and related death associated with increased floods and droughts caused by changes in the hydrological cycle.	**Forests may reduce spread of these diseases** – Deforestation is linked to the spread of malaria, dengue, and other vector-borne diseases. A recent study considered the projected increases in vector-borne diseases in the Brazilian Amazon due to climate change and found that if forests are conserved, disease prevalence in local populations would be lower than what it would be if forests are cleared.
Increase risk of fire is predicted as the frequency of heat waves increases and the areas affected by drought expand.	**Protection from forest fires** – It is harder for fires to penetrate intact moist forests. Deforestation and degradation open up the forest lowering shade and humidity, exacerbating local climate variation, increasing drought, desertification, and susceptibility to fires.

Source: Olander, L.P. et al. Responding to concerns and questions. In *International Forest Carbon and the Climate Change Challenge: Issues and Options*. Nicholas Institute for Environmental Policy Solutions, Duke University. See the original for the specific references to the underlying research studies.

Forests provide a buffer for rural land dwellers who depend on both forests and agriculture as a source of food, fuel, fiber, medicine, and income derived therefrom. When weather fluctuations negatively impact agricultural yields, land dwellers turn to the forests to sustain them (e.g., as a source of bushmeat, fuel, and other non-timber forest products). With climate change portending greater climate variability, this buffering may be more valuable to these individuals in the future. Likewise, forests provide protection against extreme weather events such as droughts, flooding, and fire, all expected to increase in intensity under a changing climate (IPCC 2007). A warming climate, wetter in some places, can also provide more favorable conditions for malaria and other vector-borne diseases, a situation that can be exacerbated by deforestation (Pattanayak and Yasuoka 2008).

Adaptation benefits complement mitigation benefits of forests, thereby suggesting that protecting forests can pay a climate change double dividend. However, the dual mitigation and adaptation benefits of forests also enlarge the potential threat of the third dimension of climate change: impact. The IPCC Fourth Assessment Report reports a mixed story for forest impacts under future climate conditions, with some temperate regions possibly enjoying enhanced forest growth conditions, but other regions such as the tropics potentially suffering severe negative effects from climate feedbacks (Easterling et al. 2007). This suggests an element of uncertainty about the future mitigation and adaptation benefits of forests as climate change unfolds that, while outside the scope of this report, warrants further consideration.

1.4. Organization of this report

The report will continue next with a section on the potential supply of international forest carbon mitigation opportunities, describing the nature of the underlying costs of reducing forest carbon emissions and increasing forest carbon stocks, the regional distribution of supply opportunities across the globe, and a synthesis of supply function estimates from recently conducted economic studies. The supply potential is also affected by a number of institutional and legal factors such as property rights and governance reform that could well affect the ability to deliver credits.

The report then addresses the demand and sources of financing for international forest carbon mitigation, focusing primarily on the compliance market. We incorporate the role of compliance demand from the United States, as well as assumed compliance demand from other developed countries, such as those in Annex I countries under the Kyoto Protocol (i.e., EU, Russia, Japan, Australia, New Zealand, Canada) under the assumption that they may all constitute demand in an integrated global carbon market starting in 2013. Over the longer term, we also consider the impacts of developing countries gradually taking on emissions-reductions commitments and linking to this global market.

Market equilibrium determines the market price and the quantity of reductions distributed across the regions and sectors covered. This allows us to examine how much international forest carbon can contribute to a cross-sector strategy to mitigate GHGs and whether market-flooding is a real concern. The related topic of leakage is also examined, including an assessment of the degree of leakage threats and policy design features that can be added to minimize the threats.

The report ends by summarizing the conclusions that can be drawn from the findings within and how those conclusions can be used to guide wise policy development.

2. Supply: Costs of International Forest Carbon and Distribution of Economic Supply Potential

2.1. The nature of forest carbon mitigation costs

The economic costs of reducing carbon emissions from deforestation and forest degradation or enhancing carbon stocks through afforestation, reforestation, and forest management are measured by the resources society diverts from other activities. Several types of cost are important to consider: opportunity costs, transactions costs, implementation costs, and capacity-building costs. When reviewing forest carbon mitigation cost estimates it is important to determine what assumptions the researchers have made with respect to these different categories of costs.

Opportunity costs are the value of the next best alternative to the action taken. For forest carbon mitigation in the tropics, opportunity costs are the value of the alternative crop, livestock, or other extractive operation that would occur on the land otherwise being kept in forest. Or if land-use change is not the issue, it could be the alternative revenue streams that could be generated through alternative forms of forest management, some of which might cause degradation. To illustrate this for avoided deforestation, consider the example of a landowner in the Amazon who is planning to convert a 25,000-hectare plot of rainforest into pasture. If another party approaches the landowner and proposes to pay him or her to avoid that land conversion as part of a carbon payment system, the question becomes, What is a fair price? In this case, the land has two potential values. One value comes from holding the forests intact and receiving the offered carbon payment, and a second value is the return associated with converting the land to pasture. For simplicity, we ignore any implicit or explicit value the landowner may receive for the intact forest's biodiversity or other environmental values, although we recognize that these other values may be very important in many cases.

To determine whether to sell the right to convert the forestland to pasture, the landowner needs to determine how valuable the land would be in pasture. Suppose he or she determines that the potential net return is $50/hectare/year in livestock production. In this case, the opportunity cost associated with maintaining the land in forest cover is the $50/hectare/year the landowner could have obtained by converting the land to pasture. The landowner will require that the person interested in carbon pay him or her at least that amount to maintain the land in forests.

Economists use a range of methods to measure opportunity costs. In some cases, they can measure the costs directly in specific locations using survey or census data (e.g., the U.S. Agricultural Census) or infer them from landowners' behavior using statistical techniques (Lubowski et al. 2006). In other cases, opportunity costs are measured using algorithms that translate land productivity into land values (e.g., Rokityanskiy et al. 2007; Kindermann et al. 2006). Another way is to calibrate a cost function with a combination of local data and estimates from the economic literature (e.g., Sathaye et al. 2005, 2006; Sohngen and Mendelsohn 2003). Yet another is to solicit cost estimates directly through survey methods that determine willingness to accept money to forgo the opportunity.

The act of developing and executing contracts to avoid deforestation will create transactions costs. Transactions costs are important yet are often ignored by researchers who model policy-induced land-use change. There are several categories of transactions costs including the costs of:

- searching out and discovering appropriate places where deforestation can be avoided or non-forest land can be converted to forest,
- negotiating and writing a contract,
- learning about contracts (both buyers and sellers), and

- monitoring, verifying, and enforcing the contract once it is in place (for a general discussion of transactions costs in economics, see Dahlman 1979).

All of these costs could be important when it comes to measuring the full costs of forest carbon mitigation.

Search costs are associated with buyers and sellers finding each other. For avoided deforestation contracts, a number of factors may increase search costs compared to other types of contracts. One issue relates to the sheer size of the area over which deforestation occurs and the resulting costs associated with finding individuals engaged in the deforesting activities. The Amazon Basin, for example, is 8.2 million square kilometers, and it contains a large number of potential agents of deforestation. Searching for individuals to participate in contracts may be fairly time-consuming and difficult with such large areas of land.

In addition to searching over large areas, finding individuals who control the land may be difficult in many locations, particularly where land ownership, or tenure, is not well-defined. Where land ownership is unclear, it may be very difficult for the buyers to determine which sellers can actually produce the carbon reductions and legally receive the credits. It could also be difficult to determine which land-use actions are actually imminent, and therefore worthy of contract consideration as a mitigation activity. When developing contracts, the agents will likely need to show that the land under contract would have been used or managed another way (e.g., cleared) and therefore that the intervention provides real and additional carbon reductions. Finding such pieces of land could take substantial effort and research. On the other hand, other government policies could have large impacts on deforestation, without requiring identifying and contracting with dispersed private individuals. Such approaches include establishment and management of protected areas, reforming land tenure laws, improved enforcement of environmental legislation, and strategic planning of roads and other infrastructure.

While the buyer's perspective is important, search costs also accrue to sellers, who must learn about the value of their carbon asset. Many landholders may be unaware that their property actually contains substantial climate mitigation asset value as a warehouse of carbon. Learning how to physically assess and monetarily value the carbon and sell it could be a substantial learning process that takes time and educational effort, perhaps involving a network of agents from the public or private sector to deliver this information. If, as some arrangements might allow, the landholders decide to lease their carbon rather than sell their land, they may also have to live up to a number of contractual obligations (perhaps related to harvesting timber, harvesting medicinal plants and firewood, or reporting of disturbances, etc.). In short, landowner efforts to learn about carbon contracts create transactions costs that potentially could be large.

Negotiating and writing a contract are important and potentially costly activities as well (Davis 2000). For example, both the individuals purchasing the emission reductions and the landowners or entities selling them may wish to engage legal representatives to assess the contract. It is reasonable to expect that standard contracts for avoided deforestation will emerge as more contracts are written, thereby bringing down contracting costs. But circumstances will vary widely from country to country and site to site, depending on the respective property rights regimes and any restrictions on whom may enter into a contractual agreement, so developing a universally accepted contract applicable in all or most cases could prove challenging.

A program to reduce emissions from deforestation will work only as long as there is confidence in the monitoring system. Valid measuring, monitoring, and verification (MMV) systems for the goods to be bought and sold are critical to the functioning of any market. With respect to carbon retained in forests through reduced deforestation efforts, these costs may be substantial in the near term. Such systems provide protections both for landowners and those purchasing the carbon, although they will also drive up the costs of implementation. A recent report estimates that establishing forest inventories in a sample of 25 countries would require \$50 million upfront and \$7–\$17 million per year to administer (Eliasch 2008). While these costs are small relative to the potential size of a global forest carbon market, these entail upfront costs for traditionally under-resourced countries. Capacity-building efforts are now being targeted for these types of activities, as discussed below.

There are not many estimates of the transactions costs of forest carbon projects. Antinori and Sathaye (2007) suggest that these costs could range from 1%–20% of the total costs of forest carbon projects, or \$1–\$3/tCO_2. Sohngen (2007) examined an established land-use change program in the United States and concludes that transactions costs for a similarly constructed carbon program would be around \$1/tCO_2 to administer and run the program. This estimate, however, does not include all the additional costs that landowners bear to get involved in the program. Cacho and Lipper (2007) suggest substantially higher costs of \$5–\$7/tCO_2. Their estimates include more cost categories than considered by either Antinori and Sathaye (2007) or Sohngen (2008). Grieg-Gran (2008) estimates that administrative costs of a program to halve global deforestation through payments to private landowners would entail \$233–\$500 million/year (reported in Eliasch 2008), which is well below \$1/tCO_2/year globally, though this is for administrative costs only.

Other implementation costs could arise with avoided deforestation programs, such as educational costs, the one-time costs of developing new bureaucracies, educational programs, advertising costs, etc. This, in addition to the MMV and infrastructure costs alluded to above, are forms of capacity-building costs. One-time needs for capacity-building policy reform for REDD in 40 countries were recently totaled at \$4 billion over five years (Eliasch 2008). These capacity-building costs are an important component of any plan to reduce deforestation, but they are difficult to assign (and thus charge) to specific transactions. The extent to which capacity-building costs are borne by the private parties to the transaction remains to be seen. There are a number of broad international initiatives now under way, such as the World Bank's Forest Carbon Partnership Facility, that are funneling resources toward building capacity to develop the foundation for these REDD transactions.

There is an upfront and somewhat fixed nature to many of these transaction costs—developing infrastructure, establishing monitoring systems, educating market participants, and bringing together buyers and sellers. While important, these initial costs will presumably diminish over time and the fixed costs become less relevant as the scale of the market increases.

2.2. Sources of deforestation and potential reductions in deforestation

Since 1850, over 800 million hectares of forestland globally have been cleared for agricultural uses, causing the emission of over 150 billion tCO_2 (550 billion tCO_2e) (Houghton 1999, 2003). In recent decades, most deforestation has occurred in tropical countries of Africa, Southeast Asia, Central America, and South America. Between 1990 and 2005, the United Nations Food and Agricultural Organization (UNFAO) (2006) estimates that an around 168 million hectares were deforested in these regions, or around 11 million hectares per year (Table 2.1).

Table 2.1. Deforestation estimates.

	1990 forest area	2000 forest area	2005 forest area	1990–2000 forest loss	2000–2005 forest loss	2000–2005 forest loss
	1,000 ha	1,000 ha	1,000 ha	1,000 ha/yr	1,000 ha/yr	%/yr
Africa	699,361	655,613	635,412	−4,375	−4,040	−0.6%
South and Southeast Asia	323,156	297,380	283,127	−2,578	−2,850	−1.0%
Central America	27,639	23,837	22,411	−380	−285	−1.2%
South America	890,818	852,796	831,540	−3,802	−4,251	−0.5%

Source: UNFAO 2006.

Brazil and Indonesia are the two countries with the largest area of land deforested in the last five years (Table 2.2). Five of the top ten countries in terms of area deforested, however, lie in Africa, namely Sudan, Zambia, Tanzania, Nigeria, the Democratic Republic of Congo, and Zimbabwe. Nigeria, in fact, has one of the largest proportional losses in forestland of all countries worldwide.

Table 2.2. Ranking of countries in terms of annual deforestation from 2000–2005.

Rank	Country	2005 Forest area	Annual forest loss	% Lost per year	Rank in % lost/yr
		1,000 Ha	1,000 Ha/yr	%/Yr	Rank
1	Brazil	477,698	−3,103	−0.6	18
2	Indonesia	88,495	−1,871	−2.0	2
3	Sudan	67,546	−589	−0.8	13
4	Myanmar	32,222	−466	−1.4	6
5	Zambia	42,452	−445	−1.0	9
6	Tanzania	35,257	−412	−1.1	7
7	Nigeria	11,089	−410	−3.3	1
8	D.R. Congo	133,610	−319	−0.2	28
9	Zimbabwe	17,540	−313	−1.7	4
10	Venezuela	47,713	−288	−0.6	19

Source: UNFAO 2006.

2.3. Methods for estimating land and carbon supply

Numerous approaches have been developed to examine the process of land-use change, ranging from survey approaches to empirical models estimated with historical data to process modeling that project future outcomes. This section briefly reviews several of the more common approaches taken to date.

Empirical approaches typically estimate statistical models that relate land use or land-use change to other observable factors, such as economic returns to land (rents), commodity prices, population, road density and quality, distance from markets, distance from export centers, and other factors. Many empirical studies use data within one country or specific regions of countries, e.g., studies by Chomitz and Gray (1996), Nelson and Hellerstein (1997), and Pfaff (1999) in developing countries, and Lubowski et al. (2006) in a developed country. A review of empirical studies on deforestation in tropical countries by Angelsen and Kaimowitz (1999) suggests that existing empirical research into land-use change has provided reasonably good evidence that the following factors clearly affect land-use change: agricultural commodity prices, off-farm employment and wages, land access, and population change. Angelsen and Kaimowitz (1999) conclude that the evidence is less determinate on the influence of technological change, land tenure, timber prices, and income on rates of deforestation. Moreover, these factors can differ substantially by region.

In recent years, Geographic Information System (GIS) models have been used in most regions of the world to assess land use. Many of these GIS models have been constructed to assess potential deforestation in tropical regions, for example, Soares-Filho et al. (2004, 2006), Brown et al. (2007), Harris et al. (2008). While many of the economic analyses described above also utilize GIS systems as a data platform, the economic models focus on testing specific economic drivers, such as prices, land rents, or accessibility. Pure GIS models focus less on the economic theory to structure them and more on other social, physical, or biological factors that can be correlated with historical change in land use. The GIS studies are often of greater spatial predictive value than explanatory value in attributing the changes to their underlying causes.

One large-scale GIS approach that is integrated within an economic theory framework is the International Institute for Applied Systems Analysis (IIASA) Integrated Model of Forestry and Other Land Use, or DIMA (Benítez and Obersteiner 2006; Rokityanskiy et al. 2007; Kindermann et al. 2006). This model is global in scope, utilizing data at the 0.5° grid level for the entire world. DIMA makes predictions of land-use change based on adjustments in the present value of land. The model is calibrated to current land uses in agriculture and forestry, and adjusts uses in the grid cells based on adjustments in the value of land driven by policies or changes in demographic or technological factors.

Other modeling approaches use data that are much more aggregated than utilized by the GIS or empirical economic models described above, for example at the regional scale within a country. These aggregated approaches focus on modeling forestry and/or agricultural production and consumption, as well as the market for land. They account for the derived demand for land and the underlying resource constraints on different land uses. Aggregate market models typically do not attempt to model land use at fine levels of spatial resolution. Examples of aggregate models include the Forest and Agricultural Sector Optimization Model–Greenhouse Gas version (FASOMGHG) for the United States (Adams et al. 1999; and Murray et al. 2005), the Global Timber Model (GTM) (Sohngen et al. 1999; Sohngen and Mendelsohn 2003), and the Generalized Comprehensive Mitigation Assessment Process (GCOMAP) model (Sathaye et al. 2005, 2006). Computable general equilibrium (CGE) approaches that integrate land use in with the rest of the economy have also been used to assess land-use questions (e.g., Hertel et al. 2007).

One important difference between the fine grid-scale approaches described above and the more aggregated modeling approaches involves their assumptions about price effects. Empirical models based on gridded data often assume that market prices are exogenous, or given, while aggregate approaches, because they operate at a larger scale, attempt to solve for prices by equilibrating market supply and demand in response to the changes in land use simulated. This may have important implications for estimates of carbon sequestration costs since accounting for these price effects can increase cost estimates for avoided deforestation (see for instance, Kindermann et al. 2008). But if the policies themselves are operating on such a large scale, they will affect market fundamentals and modify behavior. Thus capturing the market feedback adds an important element of realism.

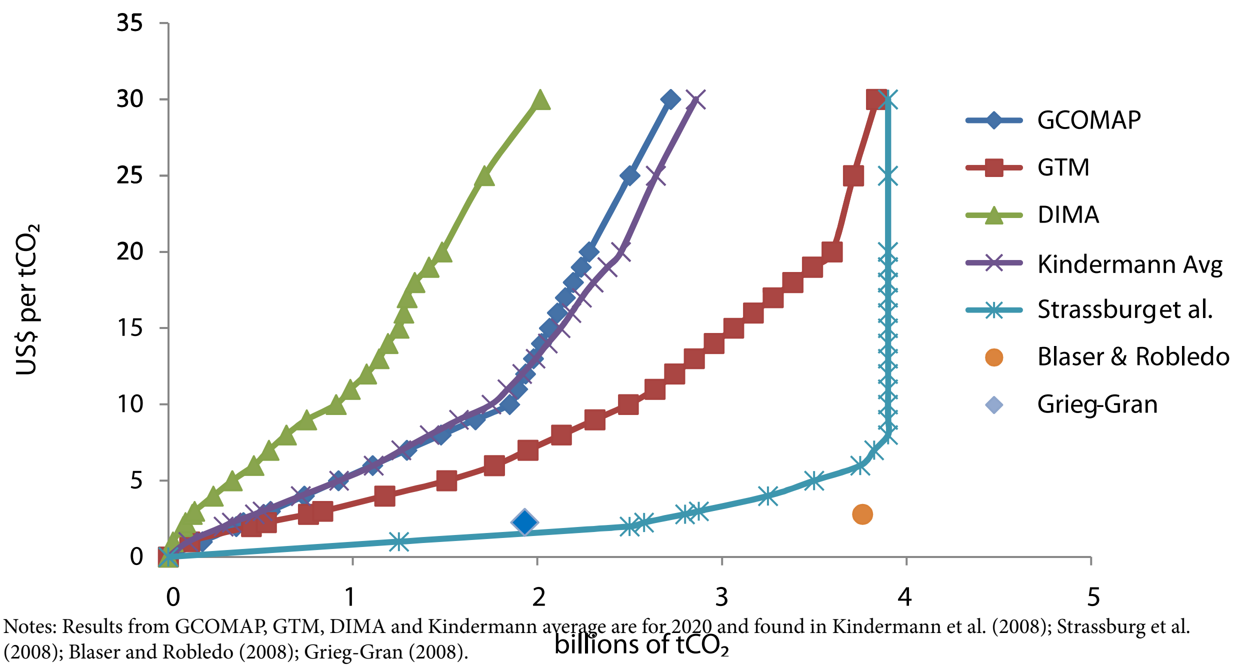
2.4. International forest carbon mitigation cost estimates

A number of studies have now estimated marginal cost functions (curves) of forest carbon mitigation activities at the global level. A marginal cost curve traces out the cost of generating successively higher levels of mitigation, starting with the cheapest reductions first and moving toward the more expensive reductions after that. Much of the empirical emphasis has been on the cost of the avoided deforestation component of REDD, which we highlight below, but we also present some evidence on cost curves for all forest carbon mitigation including afforestation, reforestation, and forest management.

2.4.1. Global marginal cost curves for reduced emissions from deforestation

Figure 2.1 presents various estimates of a global marginal cost curve for emission reductions from deforestation as of 2020. The estimates are presented for 2020, given that it may take a number of years to get an actual policy to reduce deforestation fully in place.

Figure 2.1. Marginal cost estimates for REDD activities from six different models that have made estimates at the global level. Costs given in 2005 US$.



Notes: Results from GCOMAP, GTM, DIMA and Kindermann average are for 2020 and found in Kindermann et al. (2008); Strassburg et al. (2008); Blaser and Robledo (2008); Grieg-Gran (2008).

Kindermann et al. (2008) used three models (GTM, DIMA, and GCOMAP) to estimate global emission reduction supply functions from deforestation. The average of these estimates (shown in Figure 2.1) indicates that by 2020, around 1.8 billion tCO_2 of emissions from deforestation could be abated for less than \$10/tCO_2, around 2.5 billion tCO_2 could be abated for less than \$20/tCO_2 and around 2.9 billion tons for \$30/tCO_2. The estimated potential for low-cost reductions (in tons reduced) in these models is substantially less than many other estimates in the literature. For instance, Strassburg et al. (2008), also shown in Figure 2.1, suggest that up to 3.9 billion tCO_2 could be obtained for less than \$10/tCO_2; Blaser and Robledo (2008) provide a point estimate that 3.8 billion tCO_2 would be available for around \$2.80/tCO_2; and likewise Grieg-Gran (2008) estimates that 1.9 billion tCO_2 is available for around \$2.30/tCO_2.

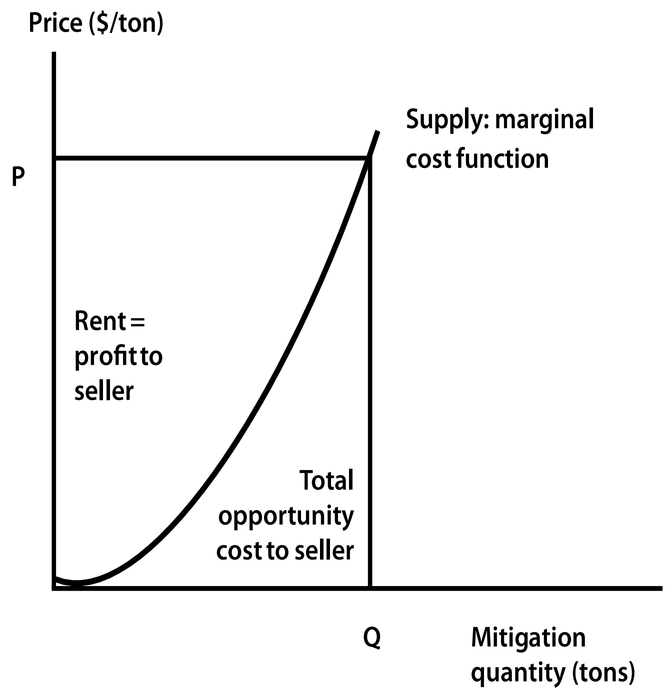
Even though the foregoing comparison suggests that the studies referenced in Figure 2.1 are on the high end of costs compared to other studies, they still generally underestimate the full costs of deforestation reductions because they focus on land opportunity costs and ignore other costs discussed above (e.g., transaction costs). Further, the studies finding lower costs, including analyses by Strassburg et al. (2008), Blaser and Robledo (2008), and Grieg-Gran (2008) get the lower costs in part due to how they define costs and the methodology they use to estimate

Marginal Cost and Supply Functions

Economic models can generate estimates of the marginal cost of achieving different levels of forest carbon emission reductions. Marginal cost is the cost of producing one additional unit of reductions. When depicted graphically, marginal cost curves "slope upward," meaning that some initial reductions can be accomplished at a very low marginal cost, but further reductions are progressively more expensive. Deforestation efforts would naturally move from the cheap (low-hanging fruit) to the more expensive as the scale of the effort expands. When viewing this in a market setting, the marginal cost function is also referred to as a "supply function" that traces out the correspondence between a price being offered for the good (in this case for a tradable emission reduction) and the amount offered. The notion is that the market will supply reductions up to the point that the marginal cost of the last unit just equals the market price. Higher prices call forth more supply. This is why the terms ***marginal cost function*** and ***supply function*** are often used interchangeably, as they are here. As is discussed in this section, however, the prospect that forest carbon may be transacted via government-funded lump payments rather than through a market can blur the distinction between marginal cost and supply.

them. For instance, the lower-cost studies tend to only consider the opportunity cost of the reduction and not the rents that accrue to the seller. Figure 2.2 provides an illustration. The area below the marginal cost curve represents the cost of achieving the mitigation quantity, *Q*. This captures the total opportunity cost of the reduction. Some of the studies take this total and divide by *Q* and refer to this as the average cost per ton of achieving *Q*. If the buyer countries could figure out a way to only pay the seller countries their exact opportunity cost, then this might give a reasonable approximation of what needs to be paid to realize these reductions. But this is not typically the way things work in a market setting, where the dual forces of supply and demand counter each other until a market clearing price emerges—in this case, *P*. Typically all buyers in the market must pay the market clearing price—which equals the marginal, not the average, cost—and all sellers receive it. This means that the sellers collectively receive a producers' surplus, also called rent, or simply profit, which equals the total value of market payments (revenues to them) minus the opportunity costs. This is represented in Figure 2.2 by the area above the marginal cost curve and below the price line. In this example, the buyers end up paying (much) more for the reductions than just the opportunity cost, but this reflects market reality. Some REDD policy proposals have suggested means by which buyers could pay closer to the opportunity cost than a competitive market, which resolves to a single price, as shown in Figure 2.2. We further explore the implications of these alternative payment schemes in Section 2.5.

Figure 2.2. Revenues vs. opportunity costs vs. rents to seller(s).



Another factor driving differences in the cost estimates is that some studies do not account for commodity market price adjustments that would raise the opportunity costs of the land-based mitigation options such as REDD. For example, programs that shift large quantities of land from one use to another would be expected to have some market price impacts, raising prices in either in forestry or agricultural markets or both. These additional price impacts would drive up overall costs, as they reflect additional forgone profits by those who forgo clearing land for commodity production. The studies in Kindermann et al. (2008) do account for some of these adjustments, thereby providing a more complete estimate than the average opportunity cost "bottom-up" measures estimated, without incorporating any market feedback effects at all.

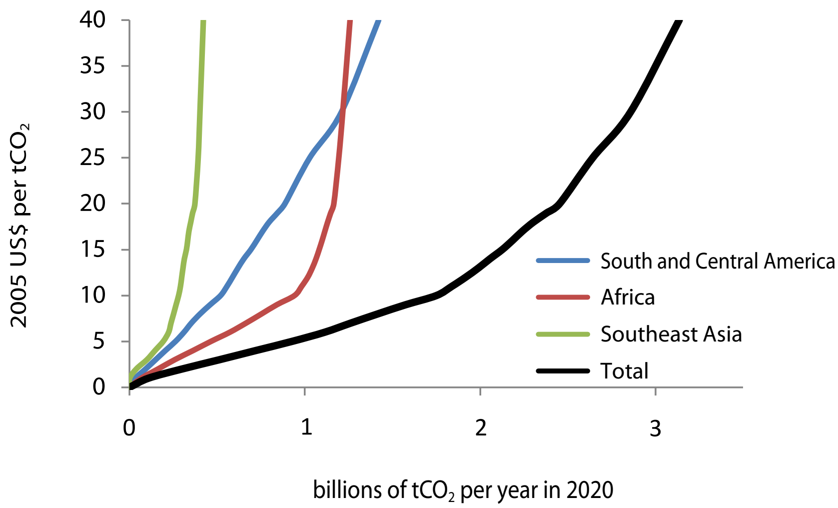
2.4.1.1. Regional distribution of supply

The global cost/supply functions above indicate the potential magnitude of a REDD supply opportunities at different price points, but it is at least equally important to understand where in the world these reductions are projected to occur.

Figure 2.3, drawing from the averages of the three model estimates in Kindermann et al. (2008), presents the cost/supply function for the three main tropical regions of the world—South and Central America, Southeast Asia, and Africa. The three models indicate that the lowest-cost reductions in emissions lie in Africa, up to the $30/tCO_2$ price point (Figure 2.3). Beyond that point, Africa and South America have similar costs. Costs are estimated to be the greatest in Southeast Asia. These results are not too surprising.

Although Africa has a smaller share of tropical forests than South and Central America (see Table 2.1 above), quite a lot of deforestation is predicted to occur there in the future business-as-usual (BAU) baseline, and all three of the models used in Kindermann et al. (2008) assume that the opportunity costs of land are lowest in Africa. These two factors—high projected deforestation rates combined with low land opportunity costs—suggest more abundant low-cost opportunities. In contrast, the models suggest that costs are highest in Southeast Asia. While Southeast Asia also has fairly high deforestation rates, land opportunity costs there are assumed to be higher in the models, and this drives up their marginal costs of reducing deforestation.

Figure 2.3. Marginal cost function for reduction in deforestation in 2020 for three regions in Kindermann et al. (2008). Average of three model results (2005 US$).



The regional-scale estimates provided above can, in the case of most of the models, be broken into smaller geographical units. In some instances, supply curves can be provided for individual countries. Individual country-level estimates are probably most useful for national policymakers and market makers. This may be particularly true if only some of the countries ultimately develop the capacity to reduce deforestation or enter into policy or market agreements to engage in reductions in deforestation.

The results in Figure 2.3, while not at the country level, provide some indication about what country-level supply functions would look like. For most countries, the country-level supply functions would lie to the left of (i.e., less reduction at any given marginal cost/price level) the Southeast Asia supply function shown in Figure 2.3. One reason for this is practical—most individual countries are small compared to these large regional aggregates, or at least they have smaller areas of deforestation occurring. An exception to this is Brazil, which is the largest tropical forested country, with one of the largest total areas of deforestation. Brazil constitutes a large share of the South American regional supply function shown in Figure 2.3. Thus, the supply function for Brazil alone would lie to the left of the supply function for South America in Figure 2.3, but because Brazil is so large, the supply function for Brazil alone likely lies to right of (is larger than) the supply function for Southeast Asia.

Another reason for individual country supply functions to lie to the left of the supply functions shown in Figure 2.3 is that low-cost options for individual countries will be depleted fairly quickly. That is, while some individual countries will undoubtedly have a number of very low-cost alternatives for reducing emissions from deforestation, their marginal costs ultimately will rise as these low-cost opportunities are depleted. As reductions in deforestation occur, land opportunity costs will rise as competition for the remaining resources dedicated to commodity production becomes more intense.

It is useful to compare cost estimates in the literature for particular countries or regions (Table 2.3). Again, many of these individual country estimates are actually average cost estimates for the country overall rather than marginal cost functions as shown in Figures 2.1 and 2.3. Most of the country-level estimates in the literature to date are point estimates that are based on average estimates of land opportunity costs for the countries, and historical estimates of deforestation rates (see discussion about Figure 2.2 above). One exception to this is the study by the Woods Hole Research Center (WHRC 2007), which calculates a marginal cost function for the Brazilian Amazon similar to the marginal cost functions shown in Figure 2.3 above. That study was conducted for the entire Brazilian Amazon basin, which constitutes a large portion of the total potential reduction in deforestation available for South America.

Table 2.3. Carbon sequestration cost estimates from country-level research studies. The studies are for various years, although they focus on the period 2005 to 2020 in general.

Study	Region	US$/$tCO_2$	Total/cumulative (million tCO_2)	Million tCO_2/yr (annualized)
WHRC (2007)	Brazilian Amazon	$1.60	22,020	1,4821
Kerr et al. (2003)	Costa Rica	$4.90	12.5	1.02
Potvin et al. (2008)	Panama	$1.38	46.8	3.323
Bellassen and Gitz (2008)	Cameroon	$3.85	112.0	6.134
Osafo (2005)	Ghana	$8.07	88.1	5.731
Silva-Chavez (2005)	Bolivia	$2.59	110.1	7.161

1) Assume 30 years, 5% interest rate; 2) assume 20 years, 5% interest rate; 3) assume 25 years, 5% interest rate; 4) assume 50 years, 5% interest rate.

Taken together, the studies described in Table 2.3 do suggest that large reductions in emissions are possible for fairly low costs across the tropics.

2.4.1.2. Sensitivity of cost estimates

The estimates of reduced emissions from reductions in deforestation above are sensitive to a number of other factors (see Table 2.4). One important issue is that most of the studies above assume that carbon prices will be constant over time in real (inflation-adjusted) terms. Although the deforestation processes the authors study are assumed to unfold over a 20- to 50-year future period (because the baseline is moving), the authors typically assume that carbon prices will be constant over this future time period when making their estimates. In reality, though, one might expect carbon prices to rise in real terms if society continues to put more and more effort into reducing overall CO_2 emissions and if the cap-and-trade programs being used by countries to reduce emissions, and thereby potentially drive the demand price for REDD credits, allow for banking and borrowing of allowances over time. Estimates of the marginal costs of reducing deforestation would be higher, however, if carbon prices were rising.

For example, Sohngen and Sedjo (2006) examined how different carbon price paths would affect reductions in deforestation. They found that an increase in the rate of growth of real carbon prices from 3%–5% per year would slow reductions in deforestation by 60%–85% over the next 20 years. Because later periods have higher prices, increasing carbon prices give individuals an incentive to wait until later periods to enroll their land in the carbon program. If carbon prices do rise, actual costs could turn out to be substantially higher than most of the estimates of marginal costs presented above because the modelers have made simplifying assumptions that carbon prices are constant.

A second issue that could affect deforestation reduction costs is other exogenous shocks to the market. For example, agricultural land values rose worldwide in recent years as energy prices rose, global food demand rose, and increased attention shifted towards biofuels. Anything that raises land values would increase land opportunity costs, and hence the costs of reducing emissions from deforestation. Other exogenous perturbations to the market would include rapid advancements in crop yields (e.g., increases that go substantially beyond historical rates of change, which would raise land opportunity costs at any given set of commodity prices), shifts in interest rates (higher rates would lower land opportunity costs), changes in the value of forest products, etc. It is important to recognize that while recent years have seen run-ups in commodity prices and land values, this is a departure from the historical trend. Commodity prices have historically been falling over the long run, and land prices in developed countries have been fairly stable over time. Indeed, the experiences in 2007–2008 should provide evidence that commodity prices may have been artificially high, as many prices plummeted in late 2008 as the global economic crisis took hold and substantially dampened expectation about rapidly rising future demand.

Table 2.4. Exogenous factors that could influence cost of reduced deforestation.

Factor	Effect on reduced deforestation costs
Rate of growth of carbon prices	Faster rates of CO_2 price growth increase marginal costs
Increase in agricultural land values (due to biofuels, rising food demand, etc.)	Increase marginal costs
Increases in the value of forest outputs	Increase marginal costs
Uncertainty in growth or carbon density factors	Increase uncertainty
Increased agricultural productivity	Increase marginal costs

A third issue involves general uncertainty in parameters related to the quantity of carbon on forested sites. Most of the models and estimates described above assume that the quantity of carbon on forest sites is known with certainty, when in fact there are large uncertainties associated with carbon storage in tropical forests. It is difficult to model this uncertainty and include it in marginal cost functions, so most studies to date have not included it and use central values (e.g., mean) rather than a range. This increases overall uncertainty in the results, but does not systematically bias results either upward or downward.

2.4.2. Expanding beyond REDD to all forest carbon: Model results

Because the estimates above focus only on deforestation, they understate the global potential for all forest carbon mitigation. To the extent that reducing degradation, enhancing forest management, and increasing afforestation become compensable activities in a climate regime, more total carbon should be available for any price. In fact, the same models as used in Figures 2.1 and 2.3 have been used to calculate the potential from all sources of forest carbon, whether sequestration activities or avoided emissions. Deforestation turns out to be only 40%–70% of the total potential carbon mitigation in the three important regions where deforestation is occurring (Table 2.5). Reduced deforestation is a larger share of the mitigation mix at lower prices, because of the low opportunity cost nature alluded to above. But at higher prices, afforestation becomes more attractive and makes up a larger part of the portfolio.

Table 2.5. Estimated share of total forest carbon mitigation from reduced deforestation.

	US\$ per tCO_2		
Region	\$20	\$50	\$100
Central and South America	85%	70%	56%
Africa	89%	88%	78%
Asia	58%	47%	39%
Global	70%	63%	51%

Estimates from the Global Timber Model (GTM) described in Sohngen and Mendelsohn (2007).

2.5. Payment design issues

It is important to recognize that the marginal cost functions presented in Figures 2.1 and 2.3 represent the cost of reducing deforestation emissions below the levels projected to occur in the future under BAU scenarios. Each model projects BAU levels of deforestation (and emissions) based upon assumptions about future commodity market demands, population growth, productivity in the forestry and agricultural sectors, and other factors. What you see in Figures 2.1 and 2.3 are departures from the BAU emissions levels simulated when a price for carbon ($/t$CO_2$) is incorporated into the model. The higher the price, the greater the reduction in emissions.

2.5.1. Single market price vs. opportunity cost compensation

Many different payment mechanisms could be designed to achieve reductions in emissions. For the purpose of these examples, consider South America as if it were a single country supplying reductions, following the supply function shown in Figure 2.3. Consider the following two payment systems, which use actual numbers to reflect the situation first illustrated in Figure 2.2 and described above:

- **Payment System 1: All forest holders are paid $20/t$CO_2$ to maintain forests.**
  According to the supply function in Figure 2.3, this level of payment would reduce South America's emissions in 2020 by 887 million tCO_2 in that year. The total payments would be $20*887 million t$CO_2$ = $17.7 billion per year. This is the area A + B in Figure 2.4.

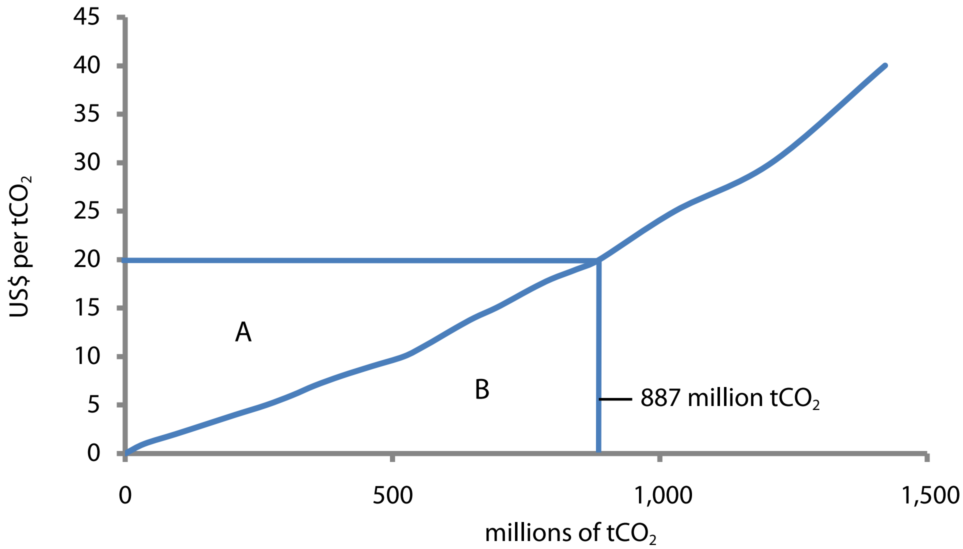
- **Payment System 2: Pay only for the opportunity cost to achieve given reductions.**
  Rather than paying the full amount of $20/t$CO_2$, it also would be possible in theory to subsidize along the marginal cost curve, paying only the area underneath the marginal cost curve to achieve the same level of reductions. This would amount to total costs of around $8.7 billion, or just under half the payment under the single price payment system. This is the area B in Figure 2.4. This reflects the fact that the marginal cost is twice the average cost. Again, think about the estimates from the studies above and the generally lower cost-per-ton estimates coming from studies estimating average costs rather than marginal costs.

In practice, targeting the payments via System 2 would be difficult to achieve as it would require either perfect information on the part of the buyer or for all sellers in the market to reveal exactly what their opportunity cost is, which they will not have the incentive to do. Either way, it is essentially a form of price discrimination that moves the benefits of the exchange from the seller to the buyer, which raises a number of equity issues for international transactions of this nature.

2.5.2. The critical role of the baseline (reference scenario)

For the most part, international negotiators appear to be focusing on systems that subsidize countries, or regions, to reduce their emissions from deforestation. Payments will be tied to some calculation of the baseline. To avoid confusion with project-level baselines under the Clean Development Mechanism (CDM), many are referring to the national baseline as a national reference scenario. Because any future projections of land-use change, deforestation, and the emissions from them are inherently uncertain, policymakers may use some basic rules of thumb to simplify the process. One prominent example at this time is the use of historical emission trends as the future reference scenario. While alluring in its simplicity, it bears mentioning that doing things this way can cause some problems, which we highlight here.

Figure 2.4. Marginal cost function and total costs for alternative methods to reduce deforestation in South America.



Again, using the case of South America as a representative "country," suppose that the historical deforestation emissions rate for baseline establishment was 2 billion tCO_2/year and that future emission reductions will be judged relative to this reference scenario. The economic modeling referenced above projects emissions level of 1.5 billion tCO_2 for 2020 under BAU. That is, the historical trend exaggerates actual emissions, perhaps because of accelerated migration out of rural areas. If that projection is accurate and if the reference scenario for reductions is 2 billion tCO_2, then South America will be credited with a 519-million-ton CO_2 improvement under BAU. If the global carbon price is \$20/tCO_2, then South American countries would get payments on the order of 519*20, or \$10.4 billion in 2020 for status quo activity.

Alternatively, suppose that the South American reference scenario is set at 1 billion tCO_2/year. Again, this is done to illustrate the centrality of the reference scenario assumption, not to comment on South America's position in the market. In that case, South American countries would get credit only if they achieve emissions less than 1 billion tCO_2/year. This presents a substantially more difficult dilemma for South American countries because the BAU projections suggest that they will emit 1.5 billion tCO_2 in 2020. Thus, if they would like to get any credit, they would have to reduce emissions by 481 million tCO_2 on their own before they receive any payment. Based on the marginal cost curve in Figure 2.4, the costs to South American countries to reduce emissions by 481 million tCO_2 on their own in 2020 would be \$2.9 billion. This means that any rents that South America earns through these exchanges would presumably need to exceed \$2.9 billion in order for them to participate, since this is still envisioned as a voluntary opt-in for tropical countries. Referring back to the payment systems discussion in the previous section, this would suggest that payments that try to avoid the generation of rents to the seller country could undermine participation. Another way to view this may be that at some point in the future, tropical forest countries may agree to take on their own binding commitments as part of their "common but differentiated responsibilities" under the UNFCCC Berlin Mandate by agreeing to a national target that is below their BAU emissions, but for now participation is optional.

Several key points emerge from the foregoing discussion. First, there are enormous financial incentives to get the national reference scenarios right. The credits countries or regions receive will rely on these decisions and large sums of money are at stake. Second, if developed countries want participation from developing countries, they may well have to live with baselines that provide them with opportunities for significant profit. In some cases, this could lead to payments that are not associated with net gains in carbon in forests.[4] Third, baselines will need to be re-evaluated and possibly updated over time. This could enable a more efficient and equitable crediting program over time and would also be consistent with countries taking on more of their own responsibility for reductions over time if that is a direction that emerges from future policy deliberations.

4 On the other hand, Brazil has announced its deforestation target and is seeking contributions of about $21 billion over 13 years (see Section 3), which is much less than we have estimated it could get from a carbon market based on historic emissions rates.

3. International Forest Carbon Demand and Financing

3.1. Where will the money come from?

An essential element for the success of international forest carbon policies will be the ability to tap sufficient sources of financing to cover the costs of meaningful reductions in forest sector emissions. Over the past decades, traditional financial transfers through public overseas development assistance (Official Development Assistance or ODA; e.g., foreign aid), supplemented by private NGO and philanthropic efforts, has proven inadequate to the task of protecting the world's forests. The need to mobilize a reliable stream of finance at a scale to significantly impact forest emissions has led to proposals for mobilizing funding by direct or indirect links to a compliance market for GHG reductions credits.

Climate policy choices at international, national, and regional levels will affect the potential for scaling up current and new financing opportunities for forest carbon, including the ability to tap the demand for GHG emissions reductions through existing and emerging carbon markets. This section reviews different institutional options for financing international forest carbon and addresses ongoing debates over that financing. Given the focus of this report on U.S. policy, we devote special consideration to a market system in which regulated entities could use tradable international forest carbon credits to satisfy compliance obligations as part of a mandatory cap-and-trade program consistent with recent proposals for U.S. climate legislation.

Debates over the design of international forest carbon policies have largely focused on the potential sources of funding and the structure of financing mechanisms. At the international level, debate has centered on whether forest carbon should be financed through a market-based trading system for forest carbon credits or through a separate fund drawn from dedicated tax revenues, proceeds from GHG emissions allowance auctions, or voluntary government contributions (e.g., Karousakis and Corfee-Morlot 2008; UNFCCC 2007). Governments and NGOs have put forth multiple proposals for such funds as well as alternative market-based approaches with varying degrees of fungibility (i.e., tradability) between forest carbon credits and GHG reductions in other countries and sectors. Parker et al. (2008) provide a user-friendly guide to the most recent and influential proposals for REDD, including the alternative financing options.[5]

Although this report is focused on policy deliberations in the United States, many of the core issues that are being debated there have direct parallels in the international arena for REDD—the UNFCCC. In the international negotiations under the UNFCCC, political consensus appears to be emerging that there should be no one-size-fits-all approach in terms of REDD financing. The Coalition for Rainforest Nations (CfRN), an alliance of governments of more than 40 tropical forest countries, has proposed a three-stage system in which countries would voluntarily sort themselves into a readiness category for capacity-building activities financed by voluntary contributions; a scaling-up category funded by additional voluntary contributions and/or pilot market-based trading; and a third category of financing through participation in future carbon market trading.[6] Policy analysts have also argued that a combination of approaches is needed to finance different types of REDD activities and to accommodate varying political and institutional environments and forest sector circumstances (Boucher 2008).

While carbon markets likely offer the opportunity to finance forest conservation on the largest and most consistent scale, voluntary markets and other voluntary financing public and private financing sources approaches are currently playing and, will likely continue to play, an important role that could combine with payments from compliance markets for reducing deforestation emissions. Voluntary approaches, including

5 See http://www.globalcanopy.org/themedia/file/PDFs/LRB_lowres/lrb_en.pdf.

6 UNFCCC Document Code FCCC/SBSTA/2006/MISC.5, FCCC/SBSTA/2007/MISC.2, FCCC/SBSTA/2007/MISC.14, FCCC/SBSTA/2008/MISC.4/Add.1.

ODA, are helping to develop the institutional capacities that are the upfront startup costs for REDD efforts. In addition, such approaches may be critical to facilitate the transition to compliance markets as well as to provide funding for activities and situations that compliance markets may not be well tailored to cover. For example, public financing may be needed for early demonstration projects as well as to improve environments in frontier regions and countries with weak governance systems where risks may be too high for private investors (Dutschke et al. 2008).

If baselines for crediting are set according to historical emissions, markets will provide little incentive to avoid increases in emissions, from leakage and other factors, in tropical forest nations with historically low rates of emissions. Various options have been proposed for providing these incentives through alternative crediting systems as well as fund-based mechanisms (Parker et al. 2008; also see Section 2). For example, the Waxman-Markey draft bill proposes a set-aside of allowances that would finance leakage prevention (see Section 5), among other forest carbon activities. While the ultimate power of a carbon market system to finance forest carbon mitigation is widely acknowledged, there is also a recognition that carbon markets will take some time to develop. As a result, the Prince of Wales' Rainforest Project has called for an emergency package to fund conservation of tropical forests during the transition to a market-based REDD mechanism. Proposed funding would derive from public sector resources in developed nations, including resources from government-backed rainforest bonds, possibly issued through the World Bank, that could tap into private capital markets (Prince's Rainforest Project 2009). Under one scenario with limitations on carbon market trading, Eliasch (2008) estimates that a carbon market would supply around $7 billion per year in 2020 but an additional $11–$19 billion would be needed to meet the goal of halving tropical deforestation. This modeling did not take into account the possibility of banking permits for future use which, as discussed in Section 4, could greatly increase demand for forest carbon in the early years of a cap-and-trade program. There will still likely be an important role for additional sources of funding to fill the gap while the compliance markets mature. In addition, government funding, perhaps in combination with private funding in voluntary and pre-compliance markets, could help to develop pilot projects and scale-up activities that would generate tradable credits for the compliance market (Eliasch 2008).

Different institutional arrangements for financing REDD and other forms of international forest carbon enhancement and the relative scale of potential funding are described further below.

3.1.1. Voluntary funds/Official Development Assistance (ODA)

The scale of traditional sources of bilateral and multilateral development financing for global forestry as a whole, including avoided deforestation, has been rising, but it still falls short of the tens of billions that analysts have estimated are needed to achieve significant reductions in forest loss (e.g., Kindermann et al. 2008). Not accounting for inflation, total flows of ODA for forestry rose about 50% from 2000 to about $2 billion/year over the period 2005–2007, with the majority of the increase coming from multilateral sources and two-thirds of the funding flowing to Asia; this figure includes about $700 million/year for forest conservation (World Bank 2008).

In addition to traditional ODA and charitable donations from private individuals and nonprofit organizations, public and private sources have contributed to a series of new funds to support the development of international forest carbon programs since the December 2007 decision at the UN climate conference in Bali to include REDD on the agenda for an international climate agreement to succeed the Kyoto Protocol (Table 3.1). Initiatives launched at Bali include the Forest Carbon Partnership Facility (FCPF) of the World Bank, which has a targeted volume of $300 million, and the Norwegian Rainforest Fund, which has pledged about $3 billion over five years to promote REDD. The Norwegian Fund has supported multilateral REDD efforts such as a Congo Basin Fund, administered through the African Development Bank; the FCPF of the World Bank; and UN REDD, a joint program of FAO, UNDP, and UNEP, to conduct coordinated capacity-building efforts for REDD in developing countries. Norway has also pursued bilateral agreements to establish REDD strategies in Tanzania and countries. With the exception of Norway's agreement with Brazil discussed below, which includes payment terms for actual reductions, the initial focus of these voluntary efforts is on providing the startup capital for readiness; this entails developing the monitoring and institutional capacities to generate forest carbon credits that would later be financed through a future climate policy regime.

In August 2008, the government of Brazil also established a fund to protect the Amazon forest with the goal of raising $21 billion in international contributions over the next 13 years. While these funds would be used for compensating reductions in Brazil's deforestation, Brazil has opposed using these reductions to generate credits that could be used to satisfy commitments to reduce GHG emissions in industrialized countries (e.g., through a global GHG compliance market). Brazil has secured a pledge of up to $1 billion through 2015 from the Norwegian fund, contingent on continuing progress in reducing deforestation over this period. At the UN climate conference in Poznan, Poland, in December 2008, Brazil further announced a voluntary commitment to reducing its deforestation by 70% over the period 2006–2017 relative to the average deforestation levels over the previous 10 years. These reductions would be phased in over three interim periods and result in an estimated cumulative reduction in emissions of 4.8 billion tCO_2, an amount greater than the entire combined target agreed by all nations under the Kyoto Protocol. Brazil is seeking international contributions for the purposes of achieving this target (Government of Brazil 2008).

The significant voluntary funding pledged for REDD to date are likely to play an important role in financing the capacity-building component of forest carbon costs, but are not generally intended to provide a long-term term source of demand for forest carbon activities. Voluntary government contributions have not yet reached the tens-of-billions-of-dollars scale and are vulnerable to myriad competing demands and the vagaries of government budgets, or are dependent on factors such as oil and gas prices, which drove Norway's budget surplus prior to the current economic crisis.

Table 3.1. International forest carbon funds launched in the wake of the Bali decision.

Fund	Description/Objective	Amount (millions of US$)
Traditional sources REDD funds established after Bali COP 2007. Converted to US$ from Euro €1 = US$1.56 (exchange rate June 20, 2008)		
	Bilateral funds	
Pledge by Norway	REDD actions over five years	2,808
NORAD Rainforest Initiative (Norway)	Support conservation of rainforests by promoting large-scale forest protection and the development of forest-based carbon management – likely to focus on the Congo Basin, the Amazon, and Southeast Asia.	638.04
International Forest Carbon Initiative (IFCI) (Australia)	To facilitate global action to address emissions from deforestation through capacity building and pilot REDD projects ($9.36 million capacity building in Indonesia; $28 million Kalimantan Forests and Climate Partnership and $3 million research partnership with CIFOR) – includes Indonesia-Australia Forest Carbon Partnership which will promote including incentives for REDD in any future international agreement on climate change	200
Pre-assigned ODA (Denmark)	REDD projects in Madagascar, Cameroon, Laos, and Bolivia	101.4
Pre-assigned part of the International Environmental Transformation Fund (UK)	Sustainable forestry in the Congo Basin	109.2
Pledge by France	Financing forestry projects in Gabon through debt cancellation	78
German Life Web Initiative (pledge by Germany)	Protected Areas support	780
The German International Climate Initiative	Earmarking of proceeds from EU allowance auctioning to international and national climate initiatives out of which $187.2 million should go to private sector project to leverage further financing	93.6 (earmarked for biodiversity and forestry)
	Multilateral Funds	
FCPF (contributors: France, Finland, Denmark, UK, Switzerland, Australia, Netherlands, Japan, TNC)	$101.4 million for capacity building, $202.8 million to generate VERs from pilot REDD programs in 5 countries	304.2
Earth Fund (GEF, IFC, others expected)	Environmental Innovation, including the forestry sector	202.8
The GEF Tropical Forest Account (TFA)	Financial incentive mechanism associated with the existing GEF SFM Program, aimed at motivating tropical forest countries to invest country resources in SFM – target regions are Amazonia, the Congo Basin, and Papua New Guinea/Indonesia	49.92 in first round
UN REDD Collaborative Program	Capacity building at the national level and payments for REDD initiatives	TBD
National Pact for the Valorization of the Forest and for the End of the Amazon Deforestation (TBD)	REDD actions in Brazil	577.98
The Prince's Rainforest Project (multiple corporate donors)	Work with the private sector to fight deforestation	TBD
Rainforest Fund (Norway, others to be confirmed)	National REDD program in Brazil	202.8
Congo Basin Forest Fund (Norway & UK)	Projects that avoid deforestation and contribute to poverty alleviation	197.73
World Bank Forest Investment Fund	Government efforts to reform the forestry sector or private action to protect major stands of forests	304–507

Table 3.1 (continued)		
Illustrative list of current public funds		
ODA – forestry In principle, ODA includes all funds listed below.	Channeled through loans and grants	$1,910 (2005–2007) which presents a 47.6% increase compared to $1,294 (2000–2002)
IFC	Funding for private sector	$65/year
ITTO	Funding for forest management	$1.5 (in 2006)
Global Environment Facility	Funding in forestry sector for (i) forest conservation, (ii) sustainable forest use, and (iii) sustainable forestry management	$1.25 billion (since 1997); leveraged cofinance: $3.45 billion
NFP-Facility, FAO	NFP Facility has programs in approximately 50 countries, each of which receives $300,00 over 3 years.	$17.3 over 5 yrs (2002–2007), of which 12.5 is committed
Private		
Private funds from domestic investors		N/A
Foreign Direct Investment		N/A
Nonprofit		N/A (maybe available in WB 2008 text)
Innovative sources		
Carbon markets (AR)	CDM and voluntary AR projects	N/A
Carbon markets (REDD)	Market-based national REDD systems (as modelled in Eliasch Review)	$7 billion/year in 2020
ETS auction revenues	Use of proceeds from auctioning ETS emissions allowances (assuming 3%–5% used to fund forest carbon initiatives)	$2.3–$3.9 billion
International air travel levy	Per passenger charge on international and/or domestic flights	$10–$15 billion
Tobin tax	0.01% tax on wholesale currency transactions	$15–$20 billion
Extension of CDM levy to other carbon market transactions	Extend levy on CDM to international transfers of Emissions Reduction Units (ERUs), Assigned Amount Units (AAUs), and Removal Units (RMUs)	$10–$50 (depending on size of C market)

Source: Mission Climat, Caisses des Dépôts (adapted from Bellassen et al. 2008).

3.1.2. Voluntary and pre-compliance markets

The only setting in which credits for avoided deforestation and forest degradation are actually traded currently is on the voluntary markets, where credits are transacted by companies and individuals according to a variety of different of voluntary standards in the absence of any regulatory requirements. These markets currently entail a small source of demand relative to the potential from compliance markets, but have driven the development of various methodologies for crediting REDD and other land-based activities which could be useful for developing rules in a compliance framework (e.g., the Voluntary Carbon Standard). Some portion of activity in these markets is also largely transitional—comprising pre-compliance activities carried out in anticipation of being able to receive early action credits under California's AB32 GHG regulation and other future compliance markets—and is likely to decline as mandatory compliance markets come on line (Capoor and Ambrosi 2008).

The voluntary markets include the Chicago Climate Exchange (CCX), a voluntary cap-and-trade program with a dedicated exchange, as well as the more diffuse over-the-counter market (OTC) that is not linked to an emissions cap. These markets transacted a total of 65 million tCO_2, with a value of $72 and $258 million for the CCX and OTC markets, respectively (Hamilton et al. 2008). Forestry represented less than 0.25 million tons in CCX in 2007 but about 7 million tons are expected to have been traded in 2008. Avoided deforestation comprised just 5% of the total land-based tons on the CCX. Forestry credits, including REDD, comprised about 6 million tons or about 15% of the OTC market, with avoided deforestation comprising almost 30% of the forestry component (Hamilton et al. 2008).

3.1.3. Compliance markets

Although REDD credits are currently not permitted in any of the compliance markets for GHG emissions in operation today, and other forest carbon activities such as afforestation and reforestation which are allowed into compliance markets through the Clean Development Mechanism (CDM) of the Kyoto Protocol are extremely limited, the compliance markets appear to represent the largest potential source of demand for international forest carbon credits in the future. There are various proposals for linking to carbon markets, including:

- direct trading of emissions credits from international forest carbon that can be fully exchanged for (are completely fungible with) any other source of emissions reductions,
- creating a parallel market for international forest carbon credits that could be partially fungible with other sources of emissions reductions (Ogonowski et al. 2007), and
- establishing a completely independent market, subject to its own targets for international forest carbon reductions (Hare and Macey 2007).

Other proposals include market-linked approaches that exclude the trading of international forest carbon credits but still tap revenues generated through the compliance carbon market. One proposed option is to tax transactions in the carbon market as a source of forest carbon financing. For example, Norway has proposed a 2% tax on Assigned Allowance Amounts (AAUs) under the Kyoto Protocol to finance REDD, which would generate an estimated \$15–\$20 billion/year (Parker et al. 2008). Taxes have also been proposed on the market for CDM credits, currently valued at \$7 billion annually (Capoor and Ambrosi 2008). Such levies would raise revenues at the expense of increasing transactions costs in the compliance market, thus decreasing incentives for generating credits and trading emissions reductions (Bellassen et al. 2008).

Another suggestion is to dedicate resources to international forest carbon from the public distribution of emissions allowances. An example from the U.S. policy arena is the 5% allowance allocation proposed as part of the Waxman-Markey American Clean Energy and Security Act of 2009 for reduced deforestation activities. This could generate about \$4–\$5 billion/year, which is a substantial share of the financing necessary to reduce emissions by roughly half, as discussed above. Similarly, a 5% allocation of the allowance proceeds of the European Union's Emissions Trading Scheme (EU ETS) would generate an estimated \$2–\$3 billion in 2020 (Commission of the European Communities [EC] 2008).

Free (unlimited) trading of international forest carbon credits on a GHG compliance market opens it to the largest potential demand determined by the total demand for emissions reductions under the system. There are also important implications for the price that is paid for international forest carbon credits. In a free market, a single price will be paid for emissions reductions from all sources so that the price received for international forest carbon will be determined by the demand for it as well as the demand for other sources of abatement. At the same time that the demand for other emissions reductions will affect the price for forest carbon, the supply of forest carbon will affect the price in the broader GHG allowance market. Including international forest carbon in a compliance market thus offers a potential means of cost containment by providing greater flexibility to reduce the costs of compliance for regulated entities.

Under some circumstances, however, the price paid for forest carbon may fall below the market price for other emissions allowances if trading is restricted or limited to a parallel market, or if international forest carbon activities are financed separately through a fund. In a market with a limited number of buyers, a fund or other separate vehicle for purchasing international forest carbon credits could potentially exert its bargaining power to offer different prices to different sellers and thus achieve the same quantity of reductions at lower cost.[7] Such a discount and the potential for price discrimination may reduce the price paid for REDD, but this raises distributional equity issues and provides lower incentives for developing countries to participate in the system and bring their own emissions reduction commitments to the negotiating table.

In theory, an open market for international forest carbon and other sources of emission reductions also has the economic advantage that the market can determine where across the economic and physical landscape emissions reductions are achieved in the most cost-effective manner. Separately choosing a funding target for international forest carbon reductions risks achieving too few (or too many) reductions from international forestry relative to the potential least-cost mix of abatement across sectors.

7 The opposite could be the case if a limited number of sellers could exert monopoly power to restrict supply and raise the price.

While discussions of markets for tropical forest carbon typically focus on the role of credits that can be directly used for compliance with emissions reduction obligations, recent research has also examined the potential role of options to purchase REDD credits at a future date, depending on the carbon prices prevailing at that time. Even if REDD credits could not currently be used for compliance purposes, such options could provide an additional transitional source of financing for deforestation reductions while hedging firm-level risks associated with development of new energy technologies such as carbon capture and storage (Golub et al. 2008).

Policy concerns over the environmental integrity and equity of the program's design are often directed towards market-based approaches (see leakage discussion in Section 5). The same concerns over issues such as emissions leakage (see Section 5) could apply in much the same manner to the design of funds and other nonmarket approaches because it is the land-use change itself that drives leakage through land and commodity markets not the fact that a compliance market is purchasing the credit. Another related set of concerns surrounds the extent to which introducing forest carbon into a carbon market would detract from necessary efforts to reduce emissions in other countries and sectors. From an economic perspective, lowering the costs of climate change protection by protecting forests is an overall gain for society and can enable more ambitious climate protection efforts, if governments so choose. From the perspective of the atmosphere, the fundamental questions are whether the emission reductions are genuine and whether the overall targets for reducing emissions are sufficient to achieve the desired environmental goals.

The consequences for the atmosphere of including international forest carbon in a market-based system fundamentally will depend on program design and the supply of tradable forest carbon credits relative to the demand for reductions determined by the overall climate policy architecture. Critical elements include the standards for awarding credits, the degree to which both industrialized and developing countries are willing and able to contribute their own by self-financing resources towards net reductions in their forestry emissions, and the stringency of the overall targets for GHG reductions. These factors will determine the environmental integrity of international forest carbon credits and whether their inclusion in a carbon market serves as an international offset of emissions in capped countries, analogous to the Kyoto Protocol's CDM, or whether instead their inclusion leads both sets of countries to adopt more ambitious emission-reduction trajectories. An international offset system lowers the cost of climate protection by shifting environmental protection from developed to developing countries, for a price, while keeping overall global reduction targets unchanged. Such concerns have led negotiators, especially from developing countries, to argue that the use of international forest carbon credits in an emissions compliance market should be supplemental to domestic commitments to reduce emissions in industrialized countries. A more favorable view is that including international forest carbon in the carbon market has the potential to leverage participation in GHG reduction efforts from both developed and developing countries to achieve deeper global emissions cuts as well as net GHG reductions within both sets of countries.

In Section 4, we discuss in detail the potential of international forest carbon mitigation to lower costs and market risks and enable emissions to decrease in both the buyer countries (e.g., U.S. or other developed countries) as well as the host tropical forest countries. In addition, forest carbon mitigation could provide an important bridge strategy for reducing near-term emissions while buying time for the world energy system to transition to a low-carbon future (e.g., Chomitz 2006). We also discuss the factors affecting the balance between supply and demand in the carbon market, the role that international forest carbon can play in filling the gap, and the implications for the price signal and associated incentives for technological innovation.

3.1.4. Forest carbon in the European Union's compliance market

The world's largest compliance market for GHG credits by far is the European Union's Emissions Trading Scheme (ETS), operating since 2005 and covering about 10,000 regulated entities in the industrial and energy sectors, with a market volume of approximately 3.1 billion tCO_2 and a traded value of almost $100 billion (67 billion euros) in 2008, almost twice the value as in 2007 (see Table 3.2).[8] This constituted over 60% of the volume of all global carbon market transactions. Over 2009, the volume of the ETS is expected to rise about one-quarter, representing about 65% of the global carbon trade, although the ETS's value is forecast to fall by one-third due to the current economic crisis (Point Carbon 2009). The EU ETS is currently the world's largest market for emissions reductions activities in developing countries, absorbing almost 60% of reductions credited via the CDM. While reductions in deforestation were not creditable under the Kyoto Protocol, afforestation and reforestation activities in developing countries can in theory generate tradable credits under CDM, though in practice they represented just 0.1% of the market in 2007 and traded at just one-third to one-fifth the value of other CDM credits (Capoor and Ambrosi 2008). Among various reasons hampering demand, the principal reason for the lack of interest in CDM forestry projects is the fact that they have been excluded from use in the EU's ETS (Bellassen et al. 2008). Another is that they are valued as temporary credits that must be replaced in the future due to permanence concerns, which brings down their value to the buyer and brings with it another (future) compliance obligation to replace the credits.

The EU ETS has a maximum quota on CDM credits of 280 million tCO_2 for the period 2008–2018, representing approximately $4 billion/year, assuming an average price of 20 €/ton.[9] This gives an indication of the potential scale of demand that might be available for REDD if international forestry credits were allowed to compete in the ETS under terms similar to the current CDM quota (Bellassen et al. 2008). Eliasch (2008) estimates that relaxing this quota and including tradable REDD credits in ETS alongside CDM could generate an annual demand of $7 billion for REDD in 2020 without significantly affecting the price of ETS allowances.

On December 17, 2008, the EU Parliament reached agreement on a new Climate and Energy package setting the rules for the third phase of the ETS from 2013 to 2020. While opening the EU to REDD credits was considered, the EU voted to keep its market closed to international forest carbon credits, though member states must allocate at least 50% of revenues from allowance auctions to a fixed set of priorities, including REDD and adaptation.[10] This means that REDD funding depends on voluntary allocation by member states within some general guidelines. REDD credits cannot be used as a cost containment measure by the covered sectors as is the case with project-based credits under CDM. According to the European Commission's estimates of carbon prices, the Parliament's decision implies total auction rev-

8 The next largest compliance trading system is the Greenhouse Gas Abatement Scheme (GGAS) covering the electricity sector in Australia's New South Wales, with a value of $224 million in 2007 (Capoor and Ambrosi 2008).

9 Conversions from euros are based on an estimated exchange rate of 1.35 $/€.

10 While this share was higher than the European Commission's recommended 20% share, the total amount of allowance auctions was reduced by relaxing the transitional free allocation of allowances for the covered sectors other than the power sector and by introducing a new measure that establishes a transitional free allocation for the modernization of the power sector in the least developed EU Member States. As a result, the total amount of allowance auctions is reduced by 15% and 10% in 2013 and 2020, respectively. Also, the scope of the measures to be funded was expanded to include, among other activities, research and development in energy efficiency and clean technologies in the covered sectors; measures to encourage a shift to low-emission and public forms of transport; forestry sequestration in the EU; and regarding international forestry, a broader scope of activities including afforestation and reforestation in addition to avoided deforestation as well as expanding the geographical preference beyond developing countries to all signatories of the future international agreement.

enues earmarked for climate change activities of about €13.5–€22.5 billion in 2020 (EC 2008).[11] If 10% of these funds were dedicated to REDD, for example, this would provide about €1.35–€2.25 billion of REDD funding in 2020 from the EU. To put this in context, the EC estimates that halving global deforestation would require €15–€25 billion/year by 2020.

Table 3.2. Transaction volumes and values, 2006 and 2007.

Markets	Volume (millions of tCO_2)		Value (millions of US$)	
	2006	2007	2006	2007
Voluntary OTC market	14.3	42.1	58.5	258.4
CCX	10.3	22.9	38.3	72.4
Total voluntary markets	**24.6**	**65.0**	**96.7**	**330.8**
EU ETS	1,104	2,061	24,436	50,097
Primary CDM	537	551	5,804	7,426
Secondary CDM	25	240	445	5,451
Joint implementation	16	41	141	499
New South Wales	20	25	225	224
Total regulated markets	**1,642**	**2,918**	**31,051**	**63,697**
Total global market	**1,667**	**2,983**	**31,148**	**64,028**

Source: Ecosystem Marketplace, New Carbon Finance, World Bank.

Despite its recent decision, the EU continues to offer significant potential as a future market for international forest carbon credits, particularly if the U.S. and other countries also provide significant sources of demand under a successful agreement on an international emissions trading system. The European Parliament's climate package kept the door ajar for REDD in the ETS by approving a placeholder that allows inclusion of international forestry credits, including avoided deforestation and degradation, to be reconsidered in the event of approval of a future international climate agreement.[12]

3.1.5. Forest carbon in emerging regional compliance markets in the United States

Emerging regional markets in the United States also offer potential as a direct or indirect source of demand for international forest carbon credits. The largest current market is the Regional Greenhouse Gas Initiative (RGGI), which involves ten Northeastern states and had forward sales of 339 tCO_2 in 2008 (Point Carbon 2009). RGGI recognizes afforestation and manure management activities as valid offsets but does not currently allow avoided deforestation as a form of compliance. In contrast, the potential use of international forest carbon and a broad range of offset credits generated through forestry and other activities is under evaluation for inclusion in a cap-and-trade system to start in 2012 under California's greenhouse gas reduction program under Assembly Bill 32. The preliminary estimate of the size of the cap is 365 tCO_2 in 2020 (California Air Resources Board [CARB] 2008). This is being envisioned as part of a potential cap-and-trade system under the Western Climate Initiative involving six other U.S. states and four Canadian provinces. At the Governors' Global Climate Summit hosted by California governor Arnold Schwarzenegger in November 2008, the governors of California, Illinois, and Wisconsin signed agreements to work with the governors of six states and provinces within Brazil and Indonesia to develop methodologies for REDD credits that could be used for compliance purposes in future state, regional, national, and international markets. It remains to be seen what role regional markets and agreements would play in a future U.S. federal regime, though much discussion between the states and federal governments has focused on allowing states flexibility in the types of instruments they use to achieve reductions and not to negate valuable arrangements that have been made prior to a federal policy taking place.

11 See http://ec.europa.eu/environment/forests/pdf/sec_2008_2619.pdf.

12 The European Parliament's decision is available at http://www.europarl.europa.eu/news/expert/infopress_page/064-38799-280-10-–41-911-20081006IPR3879806-10-2008-2008-false/default_en.htm.

3.1.6. Potential from a national U.S. compliance market

A national-level U.S. carbon market offers the most significant potential volume of international forest carbon demand in the medium term. A market starting in 2012–2013 would have approximately three times the carbon volume of the current ETS based on the emissions targets set in recent legislative proposals in early 2009. The most relevant bill at the time of this writing is the Waxman-Markey American Clean Energy and Security Act of 2009 (ACESA), which was passed by the House Energy and Commerce Committee in late May 2009 and will be voted on by the full U.S. House of Representatives later in the summer. Waxman-Markey includes provisions enabling regulated entities to use international forest carbon credits to satisfy up to a fixed portion of their compliance obligations. Depending on the availability of domestic offsets, it sets an absolute tonnage limit of 1 billion to 1.5 billion/year for allowed compliance use of international credits (from any source, not just forests) derived from uncapped nations, though the president can recommend that this limit be raised or lowered. The Waxman-Markey bill also proposes a 20% discount on all credits derived from uncapped countries or sectors after the first five years. The proposed bill also includes set-aside provisions dedicating 5% of allowance revenues for international forest carbon activities from reduced deforestation. The Waxman-Markey proposal also includes a strategic carbon reserve that would be a revolving fund stocked in part by international forest carbon credits. Credits from this fund would be managed by the government and sold into the compliance market, dependent on certain price triggers, as a means to moderate increases in prices.

4. Clearing the Market

Often people allude to supply or demand in isolation when describing how large the market for international forest carbon, or any market for that matter, may be. But it is the process of supply and demand coming together—or clearing the market—that determines the price, quantity, and total value of market transactions.

We now return to a closer examination of the potential demand for international forest carbon as part of a compliance market for GHG allowances, as has been envisioned in the most important recent U.S. legislative proposals in both the House and Senate. If international forest carbon is financed through a fund, the total demand is simply determined by the available budget and the agreed-upon payment price. In contrast, in a GHG allowance market, the mandatory emissions reductions imposed by the total emissions cap (the targets) fundamentally drive the overall demand for all forms of abatement, including forest carbon. The stricter is the total cap, the fewer allowances are available in the system, and the greater the required demand for total abatement. In this market, depending on whether restrictions are imposed on trading, international forest carbon credits are part of the supply to meet this abatement demand. International forest carbon credits must compete for this demand against all other opportunities for reducing emissions in the covered sectors as well as for generating tradable offset credits in uncovered sectors. The greater the range of mitigation opportunities allowed in the market, the greater the potential for low-cost reductions, and the lower the share of demand that is likely to be met from any single abatement source, such as international forest carbon. In this environment, at each price point, the demand for international forest carbon credits is the total demand for abatement in the system minus the available supply of other, lower-cost (or legally required) abatement.

4.1. Estimated impact of U.S. compliance demand

Here we examine the impact of U.S. compliance demand for international forest carbon, starting first with a discussion of REDD exclusively, then looking at the other forest carbon activities besides avoided deforestation.

4.1.1. REDD only

Figure 4.1 illustrates the estimated compliance demand for REDD credits from reductions in deforestation emissions in developing countries under a cap-and-trade policy scenario based on the targets in Waxman-Markey Discussion Draft (American Clean Energy and Security Act of 2009), requiring U.S. emissions in 2020 and 2050 to be 17% and 73% below 2005 levels, respectively.13 The modeled scenario also includes an assumed global marketplace for GHG reductions extending from 2013 to 2050, as described by Piris-Cabezas and Keohane (2008). The estimated supply of international forest carbon credits from all sources (reduced deforestation, afforestation/reforestation, and changes in forest management) is from the Global Timber Model (GTM), described in Section 2, based on the latest estimates used by EPA for its preliminary analysis of the Waxman-Markey bill (EPA 2009).[14] For simplicity, we estimate the potential supply from reduced deforestation at 50% of the annual supply for all forest carbon mitigation predicted at each price level. This is the lower end of the range based on the most recent estimates from the GTM that, depending on the price, reduced deforestation represents 51%–70% of total forest carbon mitigation potential in developing countries, as shown in Table 2.5.[15] The scenario shown in Figure 4.1 depicts a com-

13 The "markup" draft had slightly different short-term targets than the initial discussion draft numbers used in this section, but the same implications hold whichever numbers you consider.

14 Although derived from the same model, these data are better suited for policy analysis than the Global Timber Model estimates reported in the Kindermann et al. (2008) review discussed in Section 2, as they are based on rising rather than constant carbon price scenarios. Rising prices are more consistent with the price trajectories predicted under an emissions trading system based on GHG cap that becomes tighter over time. This analysis also uses the latest EPA supply estimates for domestic offsets through agriculture and forestry mitigation in the U.S.

15 By examining the lower end of this range, we likely underestimate the potential contribution of reduced deforestation in the early years when prices are lower. This is thus a conservative assessment of the economic potential of REDD relative to the full international forest carbon scenario discussed in the next section.

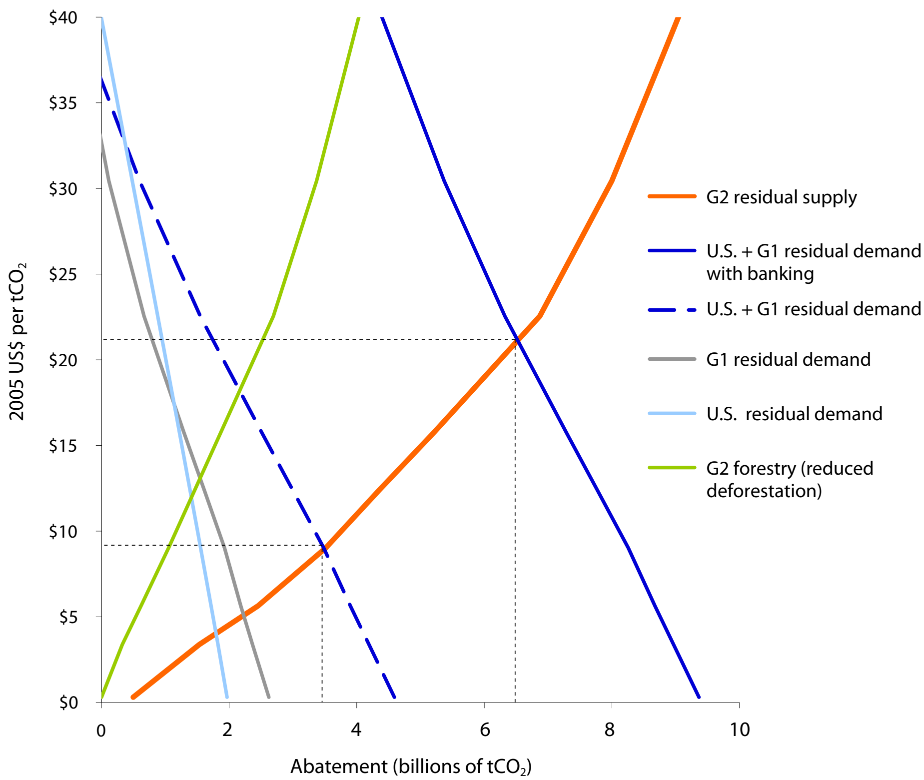
pletely free market for emissions reductions from all sources, so as to illustrate the scope of the potential contribution of tropical forest carbon to U.S. compliance. This is in contrast to the actual Waxman-Markey proposal and other legislative proposals that impose restrictions on the amount of reductions that can be credited and limits on the amount of compliance that can come from uncapped sectors both domestically and internationally.

The light blue line is a snapshot for 2020 of the net or residual demand for REDD and other international credits in the United States, calculated by taking the abatement required by this U.S. policy and subtracting out all the estimated available domestic sources of abatement, including forestry and agricultural offset activities, at each price point. The gray line is this same residual abatement calculated for the Group 1 or G1 countries (the European Union, Japan, Canada, Australia, and New Zealand) based on 2050 emissions targets of 60% below 1990 levels. The darker blue dashed line gives the total global demand for all international credits, including REDD, based on the 2020 targets in both the U.S. and the G1. This is the sum of the net demand from all the nations in the market that are modeled to have taken binding emissions caps as of 2020.

Figure 4.1 also illustrates the importance of allowance banking. When the long-term targets are credible and anticipated, regulated entities have a potential incentive to over-comply with their current requirements and bank excess allowances or other types of credits for use in later periods when allowance prices could be higher, as is likely the case with a tightening cap (Dinan and Orszag 2008; Murray, Newell, and Pizer 2009). This flexibility over the timing of abatement thus potentially creates an added source of abatement demand in the present, driven by the anticipated needs to undertake more expensive emissions cuts in the future.

All recent U.S. legislative proposals set forth emission targets extending through the middle of this century and become progressively stricter over time. In Figure 4.1, when there is no banking, the estimated equilibrium market price is around \$9/tCO_2 as given by the intersection of the dashed blue line and orange line, representing the estimated supply of REDD credits (the green line) plus all other net abatement supply from the Group 2 or G2 countries (developing countries and the former Soviet Union). In this scenario, demand for abatement in future periods is expected to be higher as the caps in the U.S. and G1 are assumed to be stricter and since the G2 countries are also assumed to begin reducing emissions after 2020. This expectation of higher demand for abatement in future periods creates an incentive to bank credits, augmenting the current demand for REDD and other abatement opportunities outside of the U.S. and G1. When banking is included, the total residual from both the U.S. and G1 demand shifts out to the solid blue line, which now intersects the orange supply curve at \$21/tCO_2. The residual demand for abatement in the U.S. and G1 are roughly equal in 2020, without including banking. However, the bulk of the estimated demand to bank excess abatement stems from the U.S. This is because U.S. emissions are projected to rise more rapidly than the G1's under a BAU scenario, creating a larger requirement to reduce emissions in the future, especially since the modeled U.S. targets to 2050 are tighter than the G1's.

Figure 4.1. Estimated supply and net compliance demand for REDD in 2020 under Waxman-Markey Discussion Draft (American Clean Energy and Security Act of 2009).



Source: Adapted from Piris-Cabezas and Keohane (2008) based on marginal cost curves for domestic and international offsets from EPA's analysis of Waxman-Markey. International forest carbon supply estimates are from the Global Timber Model described in Sohngen and Mendelsohn (2007) based on rising price scenarios used by EPA. The Group 1 (G1) countries include the European Union, Japan, Canada, Australia, and New Zealand. The Group 2 (G2) countries include the emerging economies, the developing countries, and the economies in transition not included in the EU.

Assuming that all global REDD potential can be realized according to recent cost estimates from the GTM, which was discussed in Section 2, the potential purchases by the U.S. to comply with targets in line with the Waxman-Markey Discussion Draft are estimated at 1.9 billion tCO_2/year (valued at $32 billion) starting in 2013. These estimates account for the competition for REDD credits with other countries in a global marketplace for GHG reduction credits, as described above.[16] The estimated U.S. purchases of REDD credits are estimated to rise to 2.2 billion tons (valued at $52 billion) by 2020. Most of the REDD opportunities are tapped early on, with over half of the total purchases of REDD estimated to occur in the first decade. Yearly purchases of international forest carbon average 1.9 billion tons over the first decade of the program (2013–2023) and 1.0 billion tons over the entire program (2013–2050). Overall, under this scenario, international forest carbon represents 16% of cumulative U.S. abatement through 2050.

REDD is estimated to produce significant cost savings, reducing the carbon price by 22%. In 2013, the price is estimated at $17/$tCO_2$ and $22/$tCO_2$, with REDD and without any forest carbon from developing countries, respectively, rising at 5% per year thereafter (see Table 4.1 and Figure 4.2). Under the case without any forest carbon from developing countries, forestry mitigation within the U.S. and G1 is still considered available for domestic compliance use in each region. In addition, this scenario allows forest carbon credits—chiefly afforestation/reforestation and changes in forest management—from the G2

16 This analysis is based on the Environmental Defense Fund (EDF) spreadsheet tool described in Piris-Cabezas and Keohane (2008).

countries that comprise the former Soviet Union to separately enter the U.S. compliance market even in the absence of a forest carbon mitigation program for the other G2 countries.[17]

With REDD, over half (53%) of cumulative U.S. abatement over 2013–2050 must still be met through energy sector reductions within the U.S. An additional 8% is met through domestic agricultural and forestry offset activities in the U.S., while the remaining 24% is met through other reductions in G2 countries, chiefly in the energy sector. Without REDD, domestic energy sector reductions provide about 63% of cumulative U.S. abatement, while domestic offsets account for 9% and forestry credits from the former Soviet Union account for 0.5%.

Table 4.1. Estimated impact of forest carbon tons in the U.S. compliance market under targets in Waxman-Markey Discussion Draft (American Clean Energy and Security Act of 2009).

Scenario	Average annual U.S. purchases (billions of tCO_2/year), 2013–2023	Average annual U.S. purchases of forestry credits from G2 countries (billions of tCO_2/year), 2013–2050	Forestry credits from G2 countries as share of total U.S. abatement, 2013–2050	Carbon price in 2013 (2005 US$/$tCO_2$)
No forest carbon from developing countries	0.11	0.05	0.5%	21.8
REDD (100% supply of reduced deforestation)	1.93	1.01	16.0%	16.9
REDD (50% supply of reduced deforestation)	1.04	0.51	8.1%	20.7
All forest carbon mitigation (100% global supply of reduced deforestation, afforestation/|reforestation, and changes in forest management)	3.03	1.76	27.8%	12.4

Note: All scenarios allow U.S. imports of all forest carbon mitigation from the G2 countries comprising the former Soviet Union as well as domestic compliance use of all forest carbon mitigation activities within the G1 countries (other industrialized countries except the former Soviet Union). Source: Based on model from Piris-Cabezas and Keohane (2008) using marginal cost curves for domestic and international offsets from EPA's preliminary analysis of Waxman-Markey (EPA 2009). International forest carbon supply estimates are from the Global Timber Model described in Sohngen and Mendelsohn (2007) based on rising price scenarios used by EPA.

These estimates indicate the total economic potential for REDD in a U.S. compliance market but this overstates the amounts of actual U.S. purchases as it does not account for the proposed limits on the allowed use of domestic and international offset credits.[18] In addition, the estimated REDD potential is based on the opportunity costs of land and does not incorporate the additional categories of costs, described in Section 2, such as transactions costs, program administration costs, and the costs of building institutional capacities. Finally, the estimates are based on a hypothetical scenario in which all tropical forest countries are willing and able, as of 2013, to effectively implement the full suite of actions needed to reduce deforestation under a carbon market system. Of course, countries actually vary widely in both their declared interest in participating in a REDD system as well as in their current capabilities to monitor and reduce deforestation. The incentives created by robust compliance markets for GHG reductions, as well as other pools of REDD funding, that will likely be powerful drivers for the development of these capacities. Nevertheless, developing the institutions and designing and implementing the strategies to reduce

17 Forest carbon credits from the former Soviet Union would likely not be eligible for U.S. market use under the international forest carbon provisions of the Waxman-Markey "markup" draft, which are limited to "developing" countries as defined by the OECD. However, forestry credits from the former Soviet Union could potentially enter the U.S. market under other categories of international offset credits. If these forestry credits were to be classified under the developing country provisions, this would slightly increase the estimated impacts of allowing forestry credits from developing countries into the U.S. compliance market.

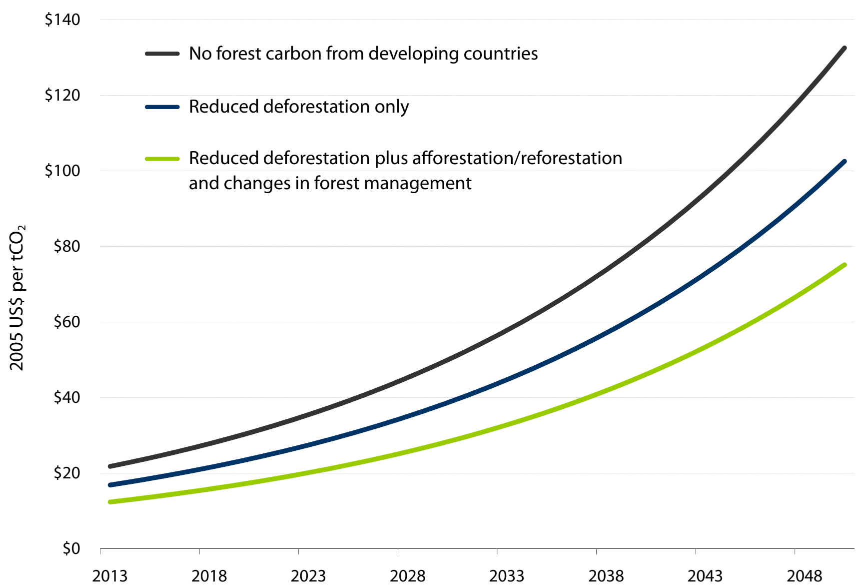
18 For example, under the Waxman-Markey "markup" proposal, depending on the availability of domestic offset credits, a maximum of 1.0-1.5 billion REDD tons and other international offset credits could be used for compliance each year over the first five years and then 1.25-1.88 could be used each year, subject to a 4:5 trading ratio. This discount provision means that 1.25 billion offset tons would only satisfy 1 billion ton's worth of compliance obligation. EPA's preliminary analysis of the Waxman-Markey bill indicates that, accounting for the discount, the limit on international offsets would still be binding in every year from 2013 to 2050 (EPA 2009). This analysis does not break out the quantity of tropical forest carbon tons from other international credits.

deforestation can be expected to take time so that the full economic potential for reducing deforestation worldwide will not be realized immediately.

4.1.1.1. Modeling supply-side constraints

To explore the implications of practical limitations on the supply of REDD, we consider a scenario in which the estimated supply of REDD credits from the GTM (e.g., the green line in Figure 4.1) is simply assumed to be half as large at each price point in each and every year. Under this new scenario, REDD still plays a significant role in a U.S. compliance market. The annual quantities of REDD tons purchased by the U.S. begin at a just over 1.0 billion tons in 2013 (valued at $21 billion), and rise to 1.2 billion by 2020 (valued at $35 billion). Over the 2013–2050 period of the bill, average yearly U.S. purchases of international forest carbon credits fall a little less than half, from 1.01 billion tCO_2/year to 0.51 billion tCO_2/year if the supply is assumed to be half as large. Even with 50% of the original supply estimates, international forestry provides about 8% of total U.S. abatement over 2013–2050, while the U.S. energy sector provides 61% and domestic offsets account for an estimated 9%. The reduction in supply also means that the cost reductions are lower, with the carbon price estimated at $21 in 2013, a 14% reduction.[19]

Figure 4.2. Impact of reduced deforestation and all forest carbon scenarios on projected GHG allowance prices under targets in Waxman-Markey Discussion Draft (American Clean Energy and Security Act of 2009).



Source: Adapted from Piris-Cabezas and Keohane (2008) using marginal cost curves for domestic and international offsets from EPA's preliminary analysis of Waxman-Markey (EPA 2009). International forest carbon supply estimates are from the Global Timber Model described in Sohngen and Mendelsohn (2007) based on rising price scenarios used by EPA.

4.1.2. Other (non-REDD) international forest carbon

The opportunities for complying with U.S. targets increase if the suite of creditable international forest carbon activities includes afforestation, reforestation, and changes in forest management.

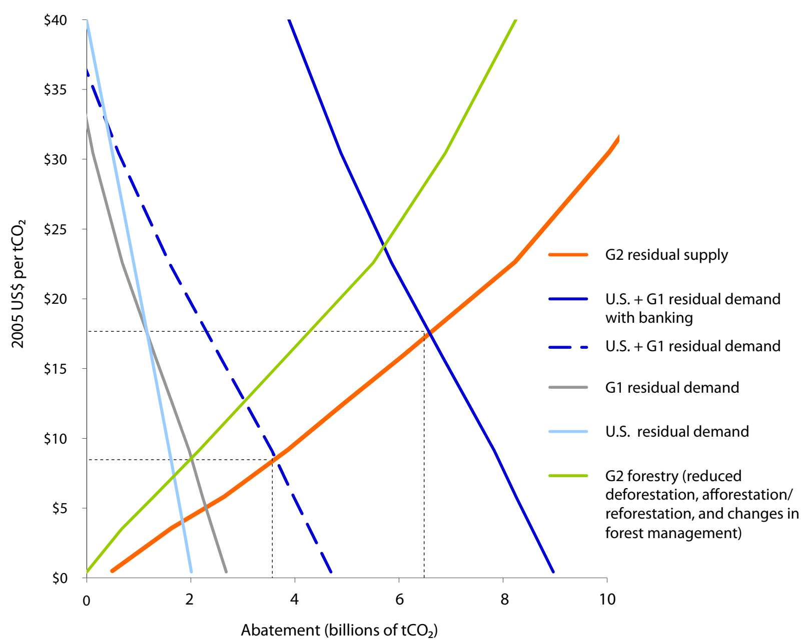
Based on the scenario described above, Figure 4.3 shows the estimated supply and demand for all sources of international forest carbon from the G2 (developing countries and the former Soviet Union) in 2020. Compared to Figure 4.1, which only included deforestation reductions, the green line is now shifted to the right, indicating greater supply of forest carbon emissions available at each price point. Without considering banking, the price is estimated at $8 in 2020, as given by the intersection of all excess demand

19 The 14% reduction is relative to a baseline price of $24—the estimated price without international forest carbon from developing countries, but international forestry mitigation opportunities from all other countries are limited to 50% of the original potential.

for credits from capped nations (the dashed blue line) and the total excess supply of credits, including forest carbon, from the rest of the world (the orange line). Taking into account the demand to bank credits for future periods more than doubles the estimated excess demand for credits in 2020 (the solid blue line), raising the price from about $8 to $17. Broadening the suite of international forest carbon options thus lowers the estimated price in 2020 to $17 from $34 without any international forest carbon and from $24 with deforestation reductions alone, taking banking into account. When a broader suite of forest sector activities is credited, international forest carbon tons purchased by the U.S. start at around 2.9 billion tons/year in 2013 (valued at $36 billion), rising to 3.3 billion (valued at $58 billion) in 2020. As summarized in Table 4.1, from 2013 to 2023, total U.S. purchases of international forest carbon tons are estimated to average 1.0 versus 1.8 billion tCO_2/year respectively, under a deforestation-only versus all-forestry (deforestation, afforestation/reforestation, and changes in forest management) program. Over the 2013–2050 period, total forestry purchases are about three-quarters larger when all forest sector opportunities are included, averaging around 1.8 billion tons per year versus 1.0 billion when deforestation reductions alone are credited. The potential cost savings are also greater when the more comprehensive set of forestry options is included, reducing the price by 43% (from around $22 to $12 in 2013) compared to the case with no forest carbon from developing countries.

As this discussion suggests, the potential purchases of international forest carbon by the U.S. is quite large, but depends critically on supply-side factors such as how much of the estimated potential supply can be realized in practice. It also depends on the global demand for international forest carbon, determined by the overall emissions targets adopted by the U.S. and other capped countries, as well as the eligibility of different forest carbon activities, imposed limitations on trading of international forest carbon and other sources of abatement in the U.S. and other countries, and the possibility of banking excess emissions reductions for use in future periods.

Figure 4.3. Estimated supply and net compliance demand for all developing country forest carbon in 2020 under targets in Waxman-Markey Discussion Draft.



Source: Adapted from Piris-Cabezas and Keohane (2008) based on marginal cost curves for domestic and international offsets from EPA's analysis of Waxman-Markey. International forest carbon supply estimates are from the GTM described in Sohngen and Mendelsohn (2007) based on rising price scenarios used by EPA. G1countries include the EU, Japan, Canada, Australia, and New Zealand; G2 countries include the emerging economies, the developing countries, and the economies in transition not included in the EU.

4.1.3. The role of banking on the timing of abatement

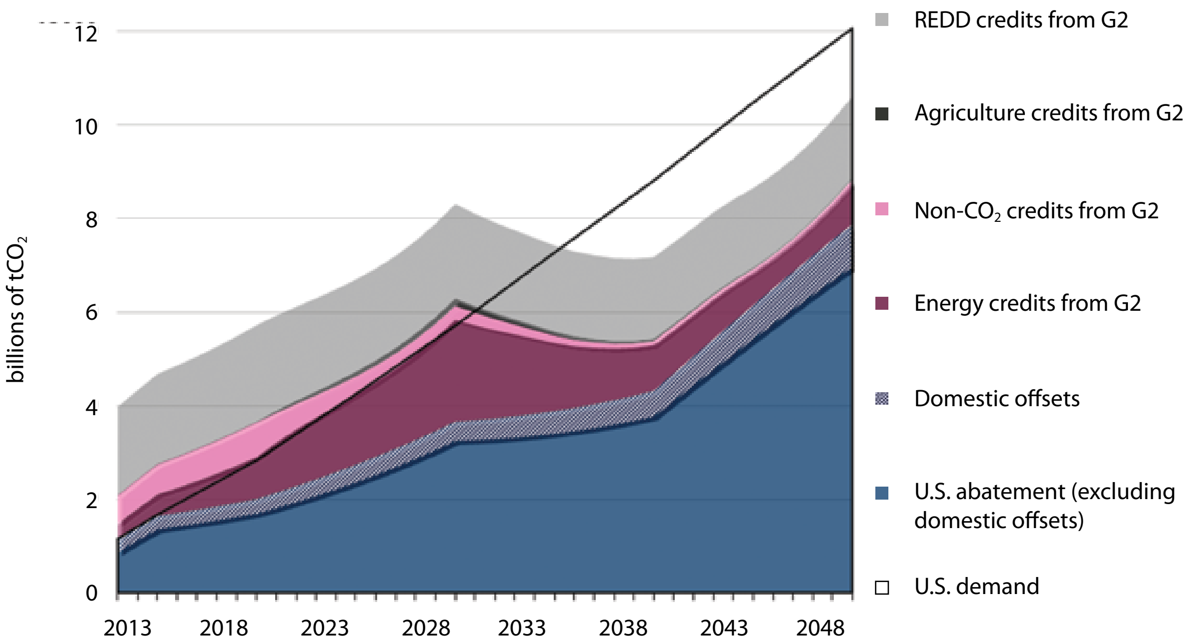
As described above, the possibility of banking raises demand for emissions reductions activities from sources in the near term. This is because current compliance demand is supplemented by demand to meet anticipated compliance needs in future periods when the price might be expected to be higher due to a progressively tightening cap. Figure 4.4 shows how emissions reductions from different sources in the U.S. are predicted to evolve between 2013 and 2050 under a Waxman-Markey-type policy under the extreme scenario in which the maximum estimated potential of credits is available from all forest carbon activities worldwide. The rising black line indicates the required level of emissions reductions under the tightening cap on total emissions. Total abatement exceeds the required emissions until around 2035, with international forest carbon (the gray wedges) supplying much of the reductions that enable this over-compliance. These excess reductions create a bank of credits that are used to satisfy obligations in the later periods.

This analysis provides insights on the effect of international forest carbon mitigation on the timing of actions to reduce greenhouse gas emissions. Given the strong incentives for banking, REDD and other forest carbon activities serve to shift the time profile of emissions reductions in time to take advantage of the lower-cost options available in the near term. In addition to protection against expected higher future prices, the reservoir of banked credits could provide firms with a buffer against unexpected price spikes and volatility in the future. The contribution of international forest carbon to greater emissions cuts in the early years could also be important as a short-term hedge that helps keep global options open for limiting warming and also provides some insurance against the need for steeper cuts in emissions in the future given uncertain knowledge over climate sensitivity.

By providing a source of lower-cost reductions that makes it more attractive to over-comply in the near term, international forest carbon thus also helps to meet emissions reductions targets faster as well as at lower cost. According to the model in Piris-Cabezas and Keohane (2008) and the cost curves from the GTM described above, the U.S. is predicted to achieve 29%–33% of its cumulative reductions for the 2013–2050 period by 2025, with REDD and all forest carbon opportunities, respectively, compared to 27% without REDD.[20] Speeding the reductions provides additional atmospheric benefits by reducing the time that greenhouse gases persist in the atmosphere.

20 As noted before, this analysis likely understates somewhat the potential early-year mitigation opportunities that are attributable to deforestation reductions rather than other international forest sector opportunities.

Figure 4.4. Estimated U.S. abatement by source activity under targets in Waxman-Markey Discussion Draft. Scenario with full estimated supply of reduced deforestation (REDD) potential.



Source: Adapted from Piris-Cabezas and Keohane (2008) based on marginal cost curves for domestic and international offsets from EPA's analysis of Waxman-Markey. International forest carbons supply estimates are from the Global Timber Model described in Sohngen and Mendelsohn (2007) based on rising price scenarios used by EPA. This scenario only includes the reduced deforestation (REDD) mitigation potential in developing countries. All other sources of forest carbon mitigation are included for the G2 countries of the former Soviet Union. The Group 2 (G2) countries include the emerging economies, the developing countries, and the economies in transition not included in the EU.

In summary, international forest carbon efforts could offer an attractive "bridge strategy" of reducing near-term emissions while buying time to adapt to a low-carbon future. Early emissions reductions also have particular value as a global insurance policy for maintaining climatic options in light of scientific uncertainty (Fisher et al. 2007). As tropical forests are disappearing, moreover, REDD is also a cost-effective opportunity for reducing emissions that is available for a limited time only. The time-limited and irreversible nature of REDD—once deforestation occurs on a particular area, it cannot be avoided again until the forest, if ever, regrows—adds further value to protecting tropical forests now rather than foreclosing future options for lowering global emissions. As a result, contracts for REDD that temporarily achieve reductions in deforestation emissions for a limited period while giving governments and/or companies the option to pay more to make these emissions reductions permanent at some future date could provide important risk-hedging benefits (Golub and Greenberg 2009). On the one hand, such options could increase flexibility for achieving greater emissions cuts in the future at a reasonable economic cost, if later scientific advancements deem such reductions to be necessary. On the other hand, if purchased by regulated companies, such real options that preserve the possibility of reducing emissions through international forest carbon could help hedge firm-level risks associated with development of new energy technologies such as carbon capture and storage (Golub et al. 2008).

4.1.4. The effect of limits on the use of international forest carbon credits

The available supply of international forest carbon credits and other sources will depend on the costs of achieving these reductions as well as the extent to which the policy framework imposes restrictions on the use of different types of emissions reduction opportunities. Such restrictions will mean that the full economic potential may not be available for use in complying with the policy, requiring a reliance on other, higher-cost options.

A limit imposed on the use of a particular emissions reduction option, such as international forest carbon, will, if set sufficiently low, constrain the quantity purchased to an amount below what would clear the market without any restriction. This means that there are some buyers and sellers left on the sidelines who would have preferred to purchase and sell additional reductions. Under this situation, the price that will clear this restricted market may be either lower or higher than under a free market situation, depending on the way the limits are structured (e.g., Dixon et al. 2008). If the quantitative limit is a restriction on the demand for credits (e.g., the amount of credits that U.S. companies can buy), as has been proposed in the U.S. legislative proposals to date, the same potential supply will be chasing a smaller pool of buyers. Competition among the suppliers to sell into this smaller market will tend to drive down the price below what would have satisfied all buyers and sellers in an unrestricted marketplace. In such a case, international forest carbon tons might trade on a parallel market at a lower price than they would in the overall carbon market. For example, tons from the CDM have historically traded at a discount to allowances on the EU ETS, which has a quota on the use of these credits.[21] Alternatively, restrictions on the supply of credits that developing countries can sell will mean that there is now a smaller supply to satisfy the same demand. Greater competition among the buyers for this limited supply would tend to raise the price above what it would have been under a market with no restriction on the use of the credits.

4.1.5. Market structure

The degree of competition in the marketplace will also determine the international forest carbon price. If the international forest carbon marketplace is not perfectly competitive with large numbers of buyers and sellers, then the market price will depend on the relative bargaining power of the parties. This might be the case if international forest carbon sales and purchases are channeled at the level of national governments. In this case, the market might be characterized by a small number of large buyers and sellers (e.g., the U.S. and Brazil, respectively) who would likely determine the price through a process of negotiation. While national governments are likely to be important players in a future market for forest carbon the market could also evolve to include subnational entities, including private companies, as both direct buyers and as sellers of forest carbon credits. For example, nested approaches have been proposed through which a national government as well as private companies, indigenous groups, state governments, and other subnational entities could directly transact carbon credits with international buyers under a national-level accounting framework for forest emission reductions (Angelsen et al. 2008; Pedroni et al. 2007). The availability and price of international forest carbon tons for the U.S. market will also depend on the way carbon markets in other countries are structured as well as the extent to which the U.S. market is linked to them. Whether and to what extent other countries and regions such as the EU allow international forest carbon for compliance will affect the degree to which these markets will compete with the U.S. for these tons. Even if these markets do not allow international forest carbon for compliance, they may still indirectly affect demand for international forest carbon if they are linked to the U.S. market. Based on the market clearing analysis described above, allowances in the U.S. are expected to be cheaper than allowances in the EU if these carbon markets are not perfectly linked, and this would be more so if the U.S. allowed international forest carbon and the EU did not. To the extent that European companies can use U.S. allowances to comply with obligations under their domestic climate programs, however, their demand for U.S. allowances would bid up their price. This price increase would in turn indirectly increase the demand for international forest carbon by U.S. companies as an alternative means of compliance.

21 The gap between prices for a Certified Emission Reduction (CER), which represents a CDM offset credit, and "regular" EU allowances (EUAs) in the EU ETS has narrowed considerably from late 2008 to 2009, due possibly to several factors including the global economic recession reducing allowance demand and the emergence of "swap" markets that arbitrage trades between these highly fungible instruments.

4.2. Potential for cost savings and greater climate benefits

By introducing lower-cost opportunities to reduce emissions, inclusion of forest carbon in a global regime could help achieve a higher level of climate protection for the same cost as a regime without forest carbon. At the global scale, including international forest carbon as an emissions reduction option, with some limitations on trading prior to 2020, lowers the total costs of a policy to stabilize GHG concentrations at 550 ppm CO_2e by up to 23% if banking is permitted (and up to 25% without banking when the policy costs are higher).[22] The estimated cost savings from including avoided deforestation can enable a more stringent climate target of at least 530 ppm CO_2e stabilization without an increase in the overall cost, compared to a policy in which deforestation is excluded from the carbon market (Bosetti et al. 2009). A range of other analyses from the Stanford University Energy Modeling Forum 21 and related efforts also suggest that the collective group of international forest and other land-based mitigation options may provide important cost savings to reach climate stabilization goals over the next century. Estimated net savings of $2 trillion through global forestry mitigation could finance as much as a 10% stricter target or about 0.25°C less of warming over the century, depending on the modeled scenario (see Table 4.2).

Table 4.2. Estimated potential of REDD to lower costs and buy additional emissions reductions: a comparison of models.

Model and type	Results
WITCH coupled with GTM (integrated assessment analysis; Tavoni, Sohngen, and Bosetti 2007)	Including emissions reductions from deforestation, afforestation, and reforestation (A/R) and changes in forest management enables an atmospheric target of 550 parts per million (ppm) CO_2e for the same total cost as a 600-ppm target without forestry mitigation. Global forestry mitigation saves about $2 trillion on net; this buys the climate an estimated additional 0.25°C less warming by the end of the century at no added cost (compared with energy-sector-only reductions).
WITCH coupled with GTM, DIMA, and Woods Hole Research Center estimates (integrated assessment analysis; Bosetti et al. 2009)	Including avoided deforestation as an emissions reduction option, with some limitations on international trading prior to 2020, lowers the global costs of a 550-ppm-CO_2e climate stabilization policy by up to 23% and 25%, depending on the possibility of banking. These cost savings enable a more stringent target of at least 530 ppm stabilization for the same cost as a policy excluding deforestation.
GLOCAF coupled with GCOMAP and IIASA cluster model (integrated assessment analysis; Eliasch 2008)	The costs of reducing global emissions to 50% of 1990 levels by 2050 (475-ppm-CO_2e stabilization) may be lowered by 25%–50% in 2030 and 20%–40% in 2050 when deforestation reductions and A/R are included. The cost savings of almost $2 trillion could finance a 10% lower global emissions target.
MESSAGE (integrated assessment analysis; e.g., Riahi et al. 2006)	Includes a broad set of land-based options: avoided deforestation, A/R, agricultural mitigation, and biofuels for both liquid fuels and energy with carbon capture and sequestration. The biofuel options compete heavily with forests; forestry and biofuel options contribute 1%–2% and 6%–24%, respectively, over the next 50 years, and 4%–8% and 14%–29% over the next century when stabilizing at about 650 ppm CO_2e. Substantial conversion of primary forests to managed plantation forests is predicted.
GRAPE (integrated assessment analysis; Kurosawa 2006)	Includes avoided deforestation, A/R, agricultural mitigation, and biofuels for liquid fuels (but not for energy). It estimates a large role for forestry activities: 55% and 15% of the abatement over the next 50 and 100 years, respectively.
GTEM ("general equilibrium" model; Jakeman and Fisher 2006)	Includes avoided deforestation, A/R, and agricultural mitigation; excludes biofuels. For 650-ppm-CO_2e concentrations target, estimated contribution of forestry is 11% of total abatement over the next 50 years, with all land-based mitigation options saving $1.6–$7.6 trillion depending on the inclusion of non-CO_2 mitigation options.

Source: Rose et al. (2007), Fisher et al. (2007), Bosetti et al. (2009).

4.3. Concerns about "market flooding"

Although consistent with this view of how markets can work to reduce overall costs of compliance, a perceived risk by some is that international forest carbon may flood the carbon market, dampening the price signal to develop and deploy clean energy technologies in other sectors. These concerns have been largely voiced with regards to the scale of potential forest carbon credits relative to the size of the European Union's Emissions Trading System (ETS). For example, the European Commission cited a potential

22 Trading is limited to 10% of each country's total emissions up to 2020 to reflect the effect of carbon restrictions proposed in recent legislative proposals such as the Lieberman-Warner bill (S. 2191).

imbalance between the supply and demand for REDD credits among the reasons for its recommendation to exclude REDD from the EU ETS (EC 2008).

The effect of international forest carbon on carbon prices and technology incentives depends on several factors which affect the demand and supply of credits, as described in the previous sections. These factors include:

- How much mitigation from forest carbon activity can actually be achieved and credited in practice (supply), which depends on the total costs of international forest carbon mitigation; the practical institutional and governance constraints in many tropical countries and forest frontier areas; the set of countries which choose and are able to participate; and the particular crediting conditions.

- The demand for international forest carbon, based on the overall emissions reduction target and the availability and costs of other mitigation alternatives. Under stricter targets, there will be greater demand for international forest carbon and more expensive reductions from other sectors.

- The options for banking excess near-term actions to reduce emissions against future obligations, thus potentially raising current demand for international forest carbon.

- Rules on the fungibility of international forest carbon credits. Restricting the use of forest carbon and other mitigation options would tend to raise the carbon price (and the total costs) above the level expected if their use is unrestricted.

4.3.1. "Flooding" evidence

Tavoni, Sohngen, and Bosetti (2007) estimate that global implementation of a total forest carbon package (REDD plus afforestation/reforestation and changes in the management of timber plantations) would delay deployment of some technologies and reduce investment in energy intensity research and development by about 10%, for a fixed stabilization target of 550 ppm CO_2 (about 650 CO_2e). Based on announced targets from Annex 1 nations and a static analysis of a single-period market in 2020, Anger and Sathaye (2006) and a recent update by Dixon et al. (2008) find a 30% cost savings from introducing REDD. They estimate the carbon price is reduced by 45% in the case of unlimited REDD trading and by 20% when tropical forest credits are restricted to 20% of Annex 1 mitigation. The modeled scenario also allows unlimited credits for developing country mitigation from projects under the CDM, which reduces the carbon price by almost 60% compared to a market without CDM trading (Dixon et al. 2008). Other studies find more muted impacts, depending on the policy scenario and whether a multi-period market is examined. In another static scenario with no restriction on the use of CDM or other international offset credits, the Eliasch (2008) study for the UK Office of Climate Change estimates that adding REDD as well as afforestation/reforestation credits from developing countries would lower the European Union's carbon price in 2020 by 4% to 41%, depending on whether the EU commits to 20% or 30% reductions below 1990 levels by 2020. These estimates are reduced greatly depending on the assumed "supplementarity" limits on the share of emission-reduction requirements that can be satisfied through REDD and other international credits

As discussed in the previous sections, sufficiently ambitious and credible long-term targets anticipated by market participants also provide incentives for saving up credits for use under tighter future targets. The schedule for how the targets evolve over time also drives expectations of future allowance prices. This has the potential to affect abatement demand in current periods when allowance banking is permitted, as in all the prominent proposals for U.S. cap-and-trade legislation. Taking banking into account and assuming a fixed emissions reductions path consistent with a stabilization target of about 550 ppm CO_2e, Piris-Cabezas and Keohane (2008) estimate a global REDD program would lower the global carbon price by 13% from \$23 in 2012, while using all forestry mitigation options would reduce the price by 31%. Based on the same carbon market model but using the most recent curves from the Global Timber Model described above, a global REDD program is estimated to reduce the price by about 30% from $24 in 2013, while using all global forestry options lowers the price by about 48%. As shown in Figure 4.2, this results in forest carbon credits lowering the carbon price along its entire growth path from 2013 to 2050.

Using similar policy assumptions but a more integrated modeling framework that takes into account impacts on the climate as well as technological innovation in the energy sector, Bosetti et al. (2008) also find that banking has important implications for the carbon price trajectory and the associated impact of REDD. Taking into account banking, they estimate that credits for deforestation reductions in Brazil would lower the global carbon price by about 8% and reduce overall policy costs by 11%. Credits for deforestation reductions worldwide are estimated to lower the price about 18%–23% and the long-term policy costs by 21%–23%. The contribution of Brazil-only is notable as it is disproportionate to the modeled quantities of REDD abatement. While Brazilian REDD reduces costs by roughly half as much as the global potential, total deforestation emissions reductions in the Brazil case are only about one-third of the predicted REDD abatement in the global models by 2050. Although these estimates do not consider possible emissions leakage outside of Brazil (see next section), these results suggest that a relatively modest amounts of REDD can generate significant cost savings by reducing the need to rely on higher-cost abatement from other sectors.

Compared to the study by Tavoni, Sohngen, and Bosetti (2007), which examined a less stringent target and included all forest sector opportunities, Bosetti et al. (2009) find more modest and varying effects of REDD on technology R&D and energy sector innovation. Global REDD is estimated to reduce investments in solar and wind power by 6%–7% and investments in nuclear by 3%–6%. Global REDD is also estimated to decrease R&D on energy intensity reductions by 8%–9%. At the same time, REDD allows greater flexibility in terms of reducing fossil fuel consumption, which leads to slightly greater demand for oil versus the no-REDD case, changing the relative competitiveness of different technologies. As a result, REDD is estimated to slightly increase investments in integrated combined cycle (IGCC) and carbon capture and storage (CCS) technologies.

4.3.2. "Flooding" in perspective

The evidence presented herein shows that the inclusion of REDD and other forms of international forest carbon mitigation serving as offsets in a compliance market can indeed have a substantial downward impact on the allowance price and thereby "crowd out" or delay other mitigation actions on the margin. But this need not undermine the goals of climate policy, as some suggest, for the following reasons:

1. Reducing the allowance price is in many ways the core purpose of offsets: to reduce the cost of achieving a given level of compliance. This makes any aggressive action to cut emissions more economically (and politically) acceptable, increasing the probability of passage.

2. Even with the comparative cost advantages of international forest carbon, the majority of long-term abatement in a U.S. policy such as the Waxman-Markey proposal would still come from other sources in the energy and industrial sectors. Forest carbon can help meet the targets cost-effectively, but the scale of the overall effort still leaves most of the work to other sources.

3. As indicated above, forest carbon mitigation is an effective transitional strategy that strongly contributes to the accumulation of an allowance bank against future compliance obligations. What this means is that REDD and other such activities can help accelerate abatement, as banking requires over-compliance in the early years of the program, bringing reductions sooner than they would have otherwise occurred.

4. As indicated by several studies referenced throughout, reducing the cost of achieving a given GHG target allows policymakers to consider setting more stringent targets than they might otherwise impose, thereby increasing the overall environmental benefits achieved. If the goal of policy is to regulate up to the point at which the marginal cost of further regulation equals the marginal benefit of further action, then reducing the marginal cost of action means that even more climate benefits can be pursued.

4.4. Considering "common but differentiated responsibilities"

Because deforestation comprises the bulk of GHG emissions for many tropical countries, including REDD in an international forest carbon market has the potential to help reduce net emissions in tropical countries as they take on part of their "common but differentiated responsibilities" to fight climate change, consistent with the UNFCCC's Berlin Mandate. How the costs of achieving forest sector reductions are shared between developing and industrialized countries will depend on the policy design, particularly on how the reference level used to measure and compensate reductions is established and evolves over time. For example, if deforestation is expected to increase over the coming decades, as various modeling projections have suggested (e.g., Fisher et al. 2007), then only crediting reductions in deforestation emissions below historic levels, as is widely discussed in the UNFCCC deliberations and recent U.S. legislative proposals, would entail developing countries undertaking domestic reductions before they are eligible to receive international compensation. In other words, if emissions are projected to rise *above* historic levels under BAU scenarios, and if countries receive future compensation for going *below* historic levels, then they have to do some of the work without compensation to get emissions down *to* historic levels. In this case, if the forest sector represents the great share of a country's emissions, rather than simply offsetting emissions of industrialized countries, international forest carbon trading is similar to emissions trading between capped countries that only trade in additional reductions below their negotiated national emissions targets; with trading, the overall cap still remains the same, but the emissions burden is shifted via compensation to capture economic efficiencies.

International forest carbon could induce broader participation in the global carbon market to achieve greater overall reductions. For example, based on the deforestation targets announced by the Brazilian government at the UN climate meetings in Poznan and the U.S. targets proposed by President Obama, a hypothetical bilateral agreement between the United States and Brazil in which 80% of Brazil's deforestation reductions could be used for U.S. abatement exclusively until 2020 would reduce the U.S. allowance price by an estimated 4%. In addition to the 20% of deforestation emissions reductions which Brazil would not trade, the associated cost savings could finance about a 1% increase in the stringency of the cumulative U.S. emissions cap (e.g., a 1% reduction in allowable emissions over 2013–2050) while keeping the costs of compliance in the U.S. the same as in the case without forest carbon credits. Alternatively, if the 2050 targets are maintained, this could allow the U.S. to reduce its emissions by 4%–10% below 1990 levels by 2020, at no additional cost to U.S. companies, compared to simply returning to 1990 levels by 2020, as proposed by President Obama, in the case that international forest carbon is not a compliance option.[23] More modest reductions could achieve greater climatic benefits while still lowering compliance costs relative to the no-international-forest-carbon-allowed case. These potential atmospheric gains are estimated assuming that Brazil receives the full market price for its deforestation reductions, generating significantly greater resources than the $21 billion target for the Amazon fund proposed under Brazil's national climate plan (Piris-Cabezas and Lubowski 2009). This scenario illustrates the potential power of carbon markets, though Brazil to date has expressly sought compensation for forest emissions reductions in the form of direct contributions to its Amazon Fund only and has officially indicated aversion to trading forest carbon in a GHG allowance market.

23 The 4% estimate is based on maintaining the same costs to the U.S. economy as a whole. The 10% estimate is based on the maximum cost savings to U.S. companies, without considering the potential economic benefit of revenues raised by the government through allowance auctions.

5. Leakage Potential

It is broadly recognized that the effectiveness of an opt-in policy to reduce forest carbon emissions could be undermined by emissions leakage from sources that remain outside the policy. This section defines leakage, its economic underpinnings, and policy options to address it.

5.1. What is leakage?

Leakage is the phenomenon by which efforts targeted to reduce emissions in one place simply shift emissions to another location or sector where they remain uncontrolled or uncounted. Leakage occurs "whenever the spatial scale of the intervention is inferior to the full scale of the targeted problem" (Wunder 2008). The potential for leakage arises when rules, regulations, and incentives for action affect only part of the potential participants or emissions sources (Murray 2009). An international forest carbon program is likely to be limited in coverage. Most policy proposals are targeted exclusively at crediting nations that have not signed up to binding GHG reduction targets. Any policy to emerge in the near term is likely to be voluntary; countries are not obligated to join. If a country does not opt into the program, it cannot receive compensation for reducing deforestation or increasing forest carbon stocks, but it will also not be penalized for any forest losses that occur. However, as described below, the actions taken by other countries to reduce deforestation or expand forest area may cause shortages in commodity markets that will be met in part by an increase in supply (and emissions) from countries that do not opt into an international forest carbon program. This is referred to as international leakage. Subnational leakage can occur when a country adopts a program at the national level but implements it at a voluntary level within the country. For example, a country may opt to take on an international forest carbon policy but choose to implement it by paying volunteer landowners for undertaking REDD projects. Since not all landowners are obligated to undertake a project, leakage can occur within the country and undermine the targeted efforts.

5.2. Why does leakage occur?

Leakage is largely the result of economic processes. Parties engage in emitting activities when they are producing goods and services. In the case of deforestation, emissions usually occur because people are clearing land for agricultural production, mining, or other developed uses. Forest degradation often occurs while logging forests for timber or fuelwood. When these actions are stopped or significantly curtailed in the name of climate policy incentives, the underlying question is, How will the demand be met for the goods and services that would otherwise be produced on that land? It is not unreasonable to expect that in some cases, the demand will be met by simply shifting the emitting activity elsewhere. If it is shifted to a place than remains outside the purview of the policy, then the emissions will go unaccounted for and undermine the emission reductions that are accomplished within the policy.

5.2.1. Market-driven leakage

Wunder (2008) identifies several different channels for leakage to occur:

- markets for land, labor, capital, and outputs
- technical change
- income effects from program payments
- ecological conditions

In the case of REDD and other land-based emitting activities, the land and output markets are probably the most significant leakage venues. Society places demands on the goods and services produced by land, but the amount of land available to produce them is fixed. Land-use economics studies have clearly shown that policy-targeted changes on land use in one place can cause a reallocation of land use—e.g., a shift between forest and agricultural land—on the rest of the landscape unless specifically and effectively prohibited by the policy (e.g., Wear and Murray 2004; Alig et al. 1998). Agricultural and forest commodities are likely to be traded in markets that operate at local, regional, national, or global scales. Therefore, market forces may translate changes in the supply of commodities in one part of the landscape into changes in the demand for and supply of commodities in other, potentially distant locations. Markets tend to expand the spatial impact of seemingly local actions. Even without well-integrated markets, parties can shift activities and emissions locally in response to restrictions in one place and the need to meet basic needs (e.g., subsistence agriculture). This too, is a matter of allocating scarce land resources.

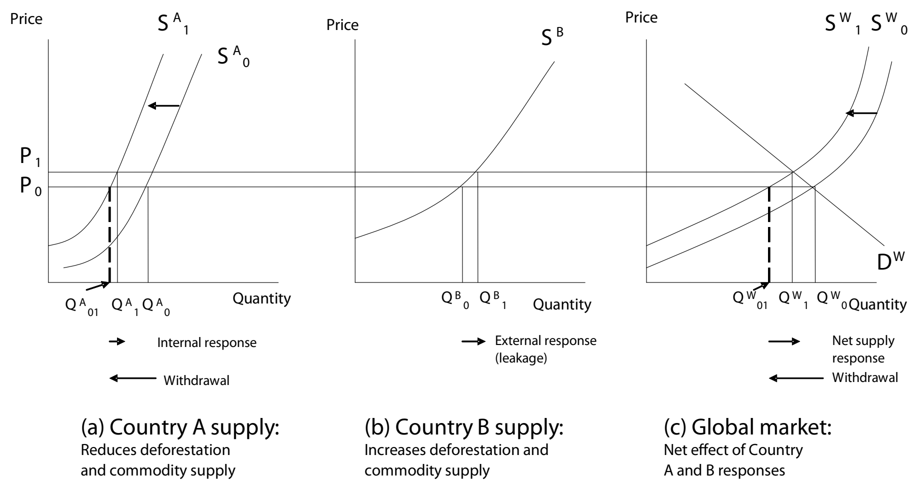
Leakage from tropical deforestation depends on the factors underlying deforestation in the first place and the extent to which those factors are mobile. Agricultural expansion is the most significant determinant of deforestation across the tropics (Chomitz 2006). Reducing this activity in one country might shift expansion to another country, particularly if land-clearing was for the purposes of cash crop production for global commodity markets. But if subsistence agriculture or local market production is the driver of a country's deforestation, reducing deforestation there may not cause much international leakage unless it heightens reliance on cash crops produced abroad.

Other significant drivers of deforestation and degradation include logging for timber resources and fuelwood (Kohlin and Parks 2001; Bashaasha et al. 2001), road-building, and human settlement (Cropper et al. 2001), each of which has different spatial and market feedback implications for leakage. Reducing logging in one location often just shifts it either to another location within the country (Wear and Murray 2004) or to other countries (Gan and McCarl 2007), and thus leakage potential can be high if no counteracting provisions are put in place (Sohngen and Brown 2004; Murray et al. 2004).

5.2.2. Conditions affecting leakage magnitude

Despite its importance as a climate policy issue, there has been relatively little empirical study of leakage from forest carbon policies. In part this is due to the fact that there has been little to no opportunity to examine and estimate the leakage consequences of real, on-the-ground policies. Thus any estimates of leakage are drawn from either other policies that are similar in nature (e.g., protected areas policy) or prospective modeling exercises that predict the future leakage effects of policies when they will be implemented. Toward the latter end, some analytical work by Murray et al. (2004) develops a formula for leakage that is a function of underlying parameters in the directly affected commodity market: elasticity of demand and supply and share of the market affected by the carbon policy–induced product withdrawals as well as the relative carbon density of the lands affected by the policy. The formula does not directly capture some of the other market feedbacks identified by Wunder (2008), but it does provide some analytical and numerical insights into factors that can enhance or diminish leakage. Figure 5.1 Provides a simplified example of how leakage can work within the context of a global market for a commodity like timber or agricultural products.

Figure 5.1. Market phenomena causing leakage.



Source: Adapted from Murray 2009.

Here we consider a two-country example. Country A and B are developing countries, not subject to any binding international GHG reduction commitments but home to large forest carbon stocks under pressure from deforestation and thus potential participants in a REDD program. Country A undertakes a REDD program; Country B does not. REDD leads to a contraction of Country A's commodity supply (S^A_0 to S^A_1 in panel a), but not Country B's (panel b). Country A's action causes a contraction in the global supply of the commodity (S^W_0 to S^W_1 in panel c). Since the global demand (D^W) is fixed, the supply contraction causes the global commodity price to rise from P_0 to P_1. This rise in price causes an increase in the supply from Country B (from Q^B_0 to Q^B_1); the corresponding increase in emissions in Country B is considered leakage, since Country B is outside of the GHG cap and REDD system altogether.

This work reveals that leakage is amplified under the following conditions:

- relatively inelastic demand in the commodity market directly affected by the intervention
- carbon losses per unit of output are greater in the areas not covered by the policy than on the areas targeted by the policy
- producers covered by the policy have a small share of the world market

Inelastic demand implies that the market will be inclined to seek supplies from any sources that will supply it rather than simply cut consumption or switch to other commodities in response to the price rise. This exacerbates the market forces that lead to leakage. Murray et al. (2004) provide an example with timber as the commodity driving deforestation. Their analysis shows that leakage can diminish if the timber potentially supplied from Country B is a poor demand substitute for the timber preserved in Country A. In this case, the market is less likely to move toward Country B supplies when Country A product is removed from the market.

When the policy causes supply shifts to countries that incur relatively high emissions per unit of product produced, this too enhances leakage. Alternatively, if carbon-rich forests protected in one place shift timber harvesting to locations managed sustainably with little net loss of carbon over time, then this can greatly diminish leakage. Moreover, if reducing deforestation leads to an increase in the price for timber, this creates a positive incentive for afforestation and reforestation, i.e., good leakage.

Finally, when the forest carbon actions of the covered countries have a collectively small impact in the global market, the supply contraction is easily replaced by increased supply elsewhere, thereby creating leakage. This is often a misunderstood point. Some argue that leakage is inconsequential when only a small part of the market is affected because small market disruptions have virtually no effect on market prices. With no market price change, the argument goes, how can leakage occur? The critical point here is that the reason that no market price effects occur is that the rest of the market can easily fill the supply gap produced by reduction of Country A's supply, when that supply is a small share of the world market. In other words, it is the realization of leakage that fills the supply gap and reduces pressure on the market price. On the other side of the spectrum, leakage dissipates the larger the share of the world market that is covered by avoided deforestation policies. The policy implication, discussed further below, is that including all or at least most of the world's deforesters or potential deforesters in a REDD policy can greatly diminish leakage and improve policy effectiveness.

5.3. Empirical evidence

The analytical approach of Murray et al. (2004) provides a back-of-the-envelope formulaic approach to calculating leakage, but it is an incomplete empirical measure because it is focused on a single market rather than a comprehensive integrated assessment of multiple markets.[24] Unfortunately, relatively few integrated modeling studies to date have estimated leakage from avoided deforestation. Those that have are summarized in Table 5.1. The studies are divided between those that track the displacement of forest products as a result of restrictions in one location—the type of market behavior referenced above—and those that track the emissions displacement associated with this product movement. The latter are the real measure of interest because they deal with emissions, but the former studies provide a glimpse of the empirical magnitudes of the economic forces underlying leakage.

Table 5.1 reveals a very wide range of estimates that depend on the policy taken, the location, and the modeling approach used. Leakage is expressed in percentage terms reflecting the ratio of displaced emissions elsewhere to the direct emission reductions of the program. So if a program leads to a direct reduction of 100 million tons of emissions, but shifts 50 million tons to non-participating forests, leakage would be 50%. Note that in each case the policies are assumed to be operated in isolation, i.e., payments are made for a specific activity and location, and the rest of the market is assumed to be unaffected. As discussed above, operating a policy in isolation will tend to exacerbate leakage, so these values would tend to overestimate leakage in policy with more comprehensive coverage. That said, the upper end of this range (~90%) suggests that leakage effects should not be ignored even if this overstates the impacts by a factor of five.

24 Note that Murray et al. (2004) also take an integrated modeling approach to the problem as highlighted in Table 1.

Table 5.1. Published leakage estimates from avoided deforestation or forest preservation set-aside (stop logging) policies.

Region	Policy Action	Modeling Approach	Estimated leakage magnitude (%)	Source
Product volume displacement estimates				
Temperate, Pacific Northwest U.S.	stop logging public lands	ex post partial equilibrium econometric model of U.S. timber market	within region: 43 national: 58 continental: 84	Wear and Murray 2004
Global	reduce forest output at national and regional levels	ex ante global computable general equilibrium model	45–92	Gan and McCarl 2007
Carbon emissions displacement estimates				
Temperate/U.S. regional	avoided deforestation and logging set-asides on private lands (regional policies in isolation)	ex ante integrated model of U.S. forest and agricultural sectors	avoided deforestation Northeast: 41–43 Pacific NW: 8–9 other regions: 0–92 logging set-aside Pacific NW: 16 South: 64	Murray et al. 2004
Tropics/Bolivia	logging set-asides in national park	ex ante partial equilibrium model of Bolivian timber market	2–38	Sohngen and Brown 2004

From Murray 2009 (adapted from Sathaye and Andrasko 2007).

5.4. Policies to address leakage

Given the potential losses from leakage, there are several different policy options for dealing with it (Murray 2009; Wunder 2008). Although leakage is caused by economic factors, it is essentially an accounting problem—economics causes the activities and emissions to shift, but it is only when it shifts into territories where it is unaccounted for that it becomes leakage. Therefore addressing leakage often involves making the accounting more comprehensive, either through better emissions monitoring or expanding policy coverage. Options include:

- ***Improving monitoring.*** At the project scale, some leakage can be handled simply by expanding the monitoring system to capture emissions outside the project boundary. Certain project accounting standards now call for this (e.g., Voluntary Carbon Standard) by tracking localized leakage belts surrounding the project area. But in principle, leakage can go far beyond the local area through market-driven shifting, so monitoring at the regional or national level may be advisable to true up project-based systems for any resulting leakage.

- ***Expanding the scale and scope of policy coverage within country.*** Moving activity beyond the project level to the national level and requiring national level accounting of forest carbon activity/emissions will directly address the problem with subnational leakage, as any emissions transferred within the country will be captured in the national accounting and not be erroneously assigned as a credit. Moreover, expanding activity coverage from REDD to other changes in carbon stock (e.g., afforestation, reforestation, forest management, and possibly even agricultural management) also reduces the scope for emissions leaking from covered to uncovered activities (Murray et al. 2005). Many of the policy proposals in front of the UNFCCC at this time call for a national approach, and the international forest carbon provisions in the U.S. Senate cap-and-trade proposal by Boxer, Lieberman, and Warner (S. 3036) called for a national approach as well.

- ***Expanding the scope of policy coverage internationally.*** The more countries that are engaged in an international forest carbon program, the less the opportunity there is for leakage. Because forest carbon is seen as a voluntary option for countries, the perceived benefits of opting into the program must outweigh the perceived costs. The benefits (payments) will be tied to bring net emissions below some baseline level. Thus the higher the baseline, the greater the opportunity for reductions. Policy must be designed flexibly enough so that countries with high reduction potential get baselines that allow them to realize these gains, while warding off the potential for overly generous baselines to produce a lot of forest carbon "hot air" (illusory gains).

- ***Discounting credits to account for leakage.*** Policy coverage is unlikely to ever be complete, so some leakage will likely remain in the system. One option is to estimate the residual leakage that remains after the policy's scope has been defined and participation has been determined. This can be done either with predictive models or with actual data after the fact once the policy is under way. The estimated leakage can then be used to determine how many credits should be set aside in a leakage buffer rather than be used for compliance. Such a buffer can serve as a form of systematic insurance against leakage.

- ***Ignoring leakage discounts once a threshold participation level is achieved.*** An alternative would be to establish a minimal participation requirement (Murray and Olander 2008), wherein leakage discounts are no longer applied if global participation rises above some level (e.g., participating countries account for more than X percent of total forest related emissions or emissions potential). This approach would not burden the international forest carbon transactions with discounts for leakage once coverage is large enough. In some sense this is similar to the rules that made the Kyoto Protocol binding (without any kind of leakage adjustment) once a certain share of the world's emissions were covered through national ratification. The system, imperfect as it might be, could be viewed as a step toward a better, more comprehensive long-term strategy.

6. Key Take-Home Messages

A better understanding of the economics of international forest carbon mitigation can help the international community and U.S. Congress better decide how to include these options in the climate policy portfolio. Several studies have been conducted in the last few years that directly address the economic potential of forest carbon, how its inclusion might affect the compliance market for carbon, and how policy design issues like scope of coverage might affect outcomes. These studies have produced a wide range of cost estimates for REDD and other forest carbon mitigation activities, which can confuse the discussion. Some point to the lower-cost estimates as evidence that international forest carbon is a very inexpensive option which, given its other environmental co-benefits, should play a major role in climate mitigation strategy. Others, however, are concerned that these low-cost options will flood the market and divert mitigation from other key emitting sectors such as energy. These claims need to be put in proper context, which we attempt to do here. Taken together, the economic results provide helpful insights to inform the policy development process moving forward. Key findings and policy implications are highlighted below.

Economic models suggest that over the next 20 years, carbon prices of US$10–$30 per metric ton of CO_2 (tCO_2) could generate reductions of 1–4 billion tCO_2/year globally through avoided deforestation. The models suggest that this amount could be as much as doubled if other options such as afforestation and forest management were credited.

Economic models can produce cost curves to indicate potential quantities of forest carbon reductions at different cost-per-ton levels. Forest carbon emission reductions, like other forms of mitigation, produce rising cost curves. Initial reductions can be quite inexpensive, perhaps as low as \$2–\$5/tCO_2 to reduce deforestation by the first 10% below baseline levels. Additional reductions, though, become progressively more expensive. If the program is focused on deforestation only, a central estimate of global reduction potential is 1.8–2.9 billion tCO_2 for carbon prices of \$10–\$30/tCO_2. Reductions in deforestation emissions, combined with increases in forest carbon stocks through afforestation and forest management in tropical regions, could amount to a significant boost in mitigation potential from the global forest sector. At the \$10–\$30/tCO_2 range referenced here, forest sector mitigation can offset 12%–20% of current global CO_2 emissions, a number that can make a substantial contribution to near-term reduction targets.

If compensation is based on future projected emissions potential, then the best purely economic opportunities from supply can be found in Africa.

Economic modeling suggests that future emissions from Africa are expected to rise more than in other regions. Moreover, opportunity costs of keeping land in forest are expected to be lower in Africa than elsewhere in the tropics. Taken together, this creates better potential forest carbon supply conditions for Africa. Economic modeling results suggest that at a price point of \$10/tCO_2, about half the global REDD potential comes from Africa. Africa's global potential share declines as the price rises, bringing in higher opportunity-cost reductions from South and Central America and Southeast Asia. However, governance reform, capacity building, and infrastructure needs may be greatest in Africa, suggesting that investment in these factors will be necessary to realize this potential.

If the United States includes international forest carbon reductions for compliance purposes, the supply of those reductions will depend on similar policy decisions by the rest of the international community as well as on the linkages between the U.S. market and other carbon markets.

Currently, the UNFCCC is negotiating the role that international forest carbon, through the REDD mechanism, will play in a post-Kyoto (post-2012) compliance regime. Options range from full use for compliance to no use, and variations in between. If the post-Kyoto framework allows for full use in compliance, this means that the United States will need to compete for these reductions on the open market, possibly raising costs of these credits in the U.S. market. However, if all countries are on board in the compliance market, this may provide the certainty and funding to ensure that the supplies will materialize in the first place, thereby bringing down costs for all buyers. This will depend not only on U.S. decisions on the applicability of forest carbon for compliance purposes, but also whether the rest of the world (via the UNFCCC) adopts international forest carbon (REDD) into its post-Kyoto compliance framework. Furthermore, even if other countries do not allow forest carbon for compliance purchases, their demand for reductions could still indirectly affect allowance prices in the U.S., depending on the linkages between the different markets.

Economic modeling shows that forest carbon as part of a global compliance market could lower the global allowance price more than 40%, depending on the scope of the program.

The success of international forest carbon as a compliance strategy will depend on its costs relative to mitigation in other sectors and locations. The greater the cost differential, the more of an impact including forest carbon will have on the carbon price. Evidence from economic modeling suggests that forest carbon can substantially lower the aggregate costs of hitting a global target, reducing allowance prices by about 22% if deforestation only is included, and by about 43% if all international forest carbon is included.

The U.S. can play a significant role in global compliance demand for international forest carbon.

Estimated potential purchases by the U.S. for compliance purposes to meet targets in line with the proposed Waxman-Markey legislation are 1.9 billion tCO_2/year (valued at $32 billion) for deforestation only starting in 2013, rising to 2.2 billion tCO_2/year (valued at $52 billion) by 2020. The opportunities increase if the suite of creditable international forest carbon activities includes afforestation, reforestation, and changes in forest management. Our analysis estimates total U.S. forest carbon purchases from developing countries at 2.9 billion tCO_2 ($36 billion) in 2013 rising to 3.3 billion tCO_2 ($58 billion) by 2020. These estimates consider competition for forest carbon credits between the U.S. and other countries.

Allowance price reduction benefits need not cause flooding or substantial diversion of effort from other sectors. Inclusion of forest carbon in a global regime could help achieve a higher level of climate protection for the same cost as a regime without forest carbon.

As indicated above, the inclusion of international forest carbon can bring down the allowance price considerably as it substitutes for higher-cost mitigation alternatives on the margin. However, more than 70% of global abatement must still come from other sectors in order to achieve the global targets called for by various international and domestic policies, so the lion's share of the effort still falls elsewhere. Moreover, including international forest carbon for compliance allows policymakers to consider more aggressive targets than they might otherwise. At the global scale, including avoided deforestation as an emissions reduction option, with some limitations on trading prior to 2020, lowers the total costs of achieving a GHG stabilization target of 550 parts per million (ppm) CO_2 equivalent by up to 25%, with modest estimated impacts on incentives for investment and innovation in renewables, carbon capture and storage, and other energy technologies. The estimated cost savings from including avoided deforestation can enable a more stringent stabilization target of least 530 ppm CO_2e without an increase in the overall cost compared to a policy where deforestation is excluded from the carbon market. Estimated net savings of $2 trillion through global forestry mitigation could finance as much as a 10% stricter target or about 0.25°C less of warming over the century, depending on the modeled scenario.

When banking of allowances is allowed, the inclusion of international forest carbon can accelerate abatement.

According to modeling worked referenced herein, the United States could achieve 29%–33% of its targeted cumulative reductions for the 2012–2050 period by 2025, compared to 27% without international forest carbon from developing countries. Speeding the reductions provides additional climatic benefits by reducing the time that greenhouse gases persist in the atmosphere.

International forest carbon could be used to induce broader participation in the global carbon market to achieve greater overall reductions.

For example, a bilateral agreement between the United States and Brazil allowing 80% of Brazil's deforestation reductions to be used for U.S. abatement exclusively until 2020 could reduce the allowance price by 4%. In addition to the 20% of deforestation emissions reductions that Brazil would not trade, the associated cost savings could allow the U.S. to reduce its emissions by 4%–10% below 1990 levels by 2020, compared to simply returning to 1990 levels by 2020 as proposed by President Obama, while keeping the costs of compliance to U.S. companies the same as in the case without forest carbon credits.

Broader participation is critical to prevent emissions leakage to countries that do not participate in a forest carbon program.

The effectiveness of an opt-in policy to reduce forest carbon emissions could be undermined by emissions leakage from sources that remain outside the purview of the policy. Avoiding deforestation in one place can simply shift it—and its emissions—to other places if proper incentives and accounting are not in place to prevent it. Economic analyses show that leakage can be substantial when policy incentives are isolated. This suggests that policymakers should make every effort to engage all major sources of forest carbon in an agreement in order to minimize leakage across countries. National accounting systems can help control for leakage within a country by ensuring that any leakage that does occur is captured within the national accounts. Absent national accounting, discounting or other credit adjustments will likely be necessary to adjust crediting to deduct for leakage problems.

Forests as a mitigation tool are complemented by their role in adaptation, suggesting that forests can pay a double dividend in combating climate change.

Tropical forests in particular provide natural insurance against many threats—drought, flooding, and vector-borne diseases, to name just a few. These risks could be exacerbated by climate change; thus, keeping forests intact or expanding forest areas can contribute positively to future adaptation efforts.

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