Carbon Sequestration as Greenhouse Gas Mitigation Policy

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Forest ecosystem has potential to capture and retain large volumes of carbon over long periods as trees absorb carbon through photosynthesis process. A young forest, when growing rapidly, can sequester relatively large volumes of additional carbon roughly proportional to the forest.s growth in biomass. A mature forest acts as a reservoir, holding large volumes of carbon even if it is not experiencing net growth. Forest management can thus have an influence on carbon sequestration. Present estimates indicate that with appropriate policies the carbon pool in the terrestrial system could increase by up to 100 GtC by the year 2050 compared to the level of carbon that would be sequestered without such policies (IPCC, 2001). This is equivalent to about 10 to 20% of projected GHG emissions from fossil fuel consumption during the same period. Reducing deforestation, expanding forest cover, expanding forest biomass per unit area, and expanding the inventory of long-lived wood products are some of the activities that could help global community realizing the carbon sequestration potential of forest ecosystem.

Carbon sequestration as a climate change mitigation policy option had received significant attention over the past several years, and despite widespread opposition to its inclusion in the Kyoto process carbon sequestration continues to provide handsome competition to other mitigation options. This note provides a brief overview of economic, legal and institutional issues related to carbon sequestration.

1.0 Economics of Carbon Sequestration

Early works on economics of carbon sequestration focused on examining whether expansion of

forest sinks could play a major role in the effort to slow the accumulation of atmosphere CO These studies typically used a hypothetical government programs such as subsidies, or government purchases, to promote forestry management practices like afforestation of agricultural land, or conservation of forestland, and attempted to estimate cost of sequestration by assessing the costs of various inputs to production including land, labor and material.

While the general result of these studies suggested that significant opportunities for carbon sequestration exist all over the world, the specific cost estimates varied substantially across studies from 5 to 500 dollars per ton. Several reasons listed below could be attributed for this wide range of cost estimates.

Type of Model

There are three broad categories of models in literature including engineering, sectoral and econometric models. The engineering models generally use reported land prices to estimate the social cost of converting land from one use or practice to another. These models are generally limited in scope to the immediate on-site effects of a program or practice. On the other hand, sectoral models estimate the opportunity cost of land using supply and demand equations for each sector under consideration, say agriculture, forestry, or both (Adams et al., 1999). The costs are derived from estimates of changes in consumer and producer surplus as the amount of land dedicated to agriculture or forestry expands or contracts. The models incorporating both agriculture and forestry could include the effects of competing demands from the two sectors for land. Econometric studies use historic market responses to changes (generally in timber prices) that are analogous to a government carbon sequestration program to infer how landowners would respond to direct or indirect carbon prices (Kerr et al 2001; Newell and Stavins 2000). These models inherently capture the interplay between agriculture and forestlands.

As always the case, the bottom-up models tend to be simple and transparent but fail to include dynamics of market interactions. The economic sectoral and econometric models on the other hand do capture the market interactions, but could be data demanding. In general, econometric studies seem to provide higher estimates of carbon sequestration costs, while the bottom-up models provide lower estimates because they account for less of the overall counteracting results.

Type of Metric

Various studies in literature differ in terms of the metric used for cost-effectiveness calculations, i. e., dollars per ton. The main difference across studies is typically in their definition of the denominator, namely ton. Three approaches followed in the literature include, ‘flow summation’ approach - wherein tons are defined as the total flow of carbon throughout the life of the program; ’average storage’ approach - which defines the tons as the average amount by which storage of carbon in the study area increases; and ‘levelization/discounting’ approach - is a flow-based metric that discounts the weight of tons more heavily as they occur further in the future. One way of conceiving this is that the levelization/ discounting method assumes that the marginal value of sequestering a ton of carbon is constant over time, so that the present value can be discounted in the same way as any other economic benefit. Among these three approaches, the ‘flow summation’ approach is conceptually flawed as it leads to an argument that it does not matter *when* the carbon is sequestered, and as a result it also does not matter *whether* it is captured at all. The ‘average storage’ approach has limited applicability. The ‘levelization/ discounting’ approach on the other hand has a sound basis and can be applicable for a wide range of programs.

Besides the above discussed two categories studies differ in terms of type of costs they report - i. e., point estimates or cost curves based on total, average, or marginal costs. In general, there seems to be an emerging consensus that cost curves expressing marginal costs as a function of equivalent annualized sequestration levels are the most useful for comparing across analyses of mitigation options.

Unresolved Issues

There are a few issues that are not fully addressed in the literature and these include:

(a) Secondary benefits from carbon sequestration programs (like, conversion of marginal agricultural land to forest stands) are believed to be as high as cost of conversion itself, implying that carbon sequestration might be nearly costless. Only few studies in the literature included possible secondary benefits and the issue demands more attention.

(b) Carbon ‘leakages’ occur when the effects of a carbon sequestration program leads to a countervailing response beyond the boundary of the program. For example, if forestland is preserved from harvest and conversion in one location, the unchanged demand for agricultural land and forest products could lead to increased forest clearing and conversion in another region. Thus the effects of the preservation may be partially or entirely undone by the ‘leakage’. Accounting for ‘leakage’ would increase the cost of sequestration. Stavins (1999) is among the few studies, which address the ‘leakage’ issue. However, ‘leakage’ is not a problem concerned with carbon sequestration programs alone as similar concerns surround the other GHG mitigation options as well. One way to check leakage could be by ensuring payment to industrial and carbon forests for both their carbon and wood outputs.

(c) Impact on systems of public finance is not an issue that directly concerns the carbon sequestration cost studies, but is of critical importance for effective implementation. In general, those instruments that require revenue raising such as subsidies and contracts have a higher social cost than those that raise revenue, such as auctioned marketable allowances and emissions taxes. Since carbon sequestration programs are typically conceived through subsidies, the overall cost of sequestration would be more than what the studies in the literature have reported so far.

All the unresolved issues listed above have a bearing on how the carbon sequestration program is implemented and it is on this aspect the next section focuses.

2.0 Legal and Institutional Issues related to Carbon Sequestration

Key challenges inherent in the development of markets for carbon offset credits include:

. • Measurement and verification of carbon storage, which includes the duration of time over which carbon is stored, whether or not it is in addition to baseline storage, and the amount of .leakage. . i.e., carbon emitted elsewhere through displaced forest activities;
. • Adjusting for uncertainty and for risks that carbon will be released sooner than the contractual period, either intentionally or by accident or neglect, and assignment of liability when this occurs;
. • Development of compatible regulatory frameworks at local, national and international levels that include agreement on what activities are eligible for credits, and who will receive the credits;
. • Establishment of institutional arrangements that reduce transaction costs; and
. • Achievement of verifiable socio-economic as well as environmental benefits that strengthen community livelihoods and support sustainable development objectives.

Carbon sequestration is a reversible process and the concerned legal system should clearly describe who is responsible if the sequestered carbon is subsequently released and the basis for the credits thereby lost.

Liability and Issue of Permanence

To deal with lack of permanence of carbon credits a common approach has been either to acknowledge the same, assess the environmental and economic benefits of limited-term sequestration, and allot credits in proportion to the time period over which carbon is sequestered, or to provide reasonable assurance of indefinite sequestration. The first alternative has led to what has been called the tonyear approach, in which activities would accrue credits for each year that a ton of carbon is withheld from the atmosphere and some quantity of ton-years would be equated with a permanent ton. For the second alternative, three mechanisms have evolved for providing reasonable assurance of indefinite sequestration: a) provide partial credits according to the perceived risk that they will be maintained for a specified time, b) link temporary sequestration projects with obligations for later action to assure permanence of the emissions reduction, and c) tax sequestration credits to finance research and development into emissions-saving technologies (Chomitz, 2000).

In a ton-year system, credit would be awarded for the number of tons of carbon held out of the atmosphere for a given number of years and some equivalency factor would be defined to equate a specific number of 'ton-years' with permanent sequestration. Several approaches have been suggested for defining the equivalency factor, i.e. the number of ton-years that is to be equated with permanence (IPCC, 2000; Fearnside et al., 2000; Moura Costa and Wilson, 2000). Basically one would integrate over time the number of tons sequestered and convert this to tons of carbon emissions offset by dividing the equivalency factor, i.e. ton-years/f = permanent tons, where f is the equivalency factor. There is no unique way to determine a conversion rate between ton-years and permanent tons and that the choice among a number of justifiable possibilities is thus a policy decision. A new approach that avoids many of the above mentioned problems is so called 'rental' approach suggested by Sedjo (2001). Just as a space can be rented to provide for the temporary parking of a car, space could be rented for parking carbon.

An argument can be made that the liability should be borne by the tree owner (seller of sequestration services) to ensure that incentives to continue the existence of the planted forest are maintained and thus ensure that the carbon remains sequestered. However, with a long-term certificate, buyers of certificates that were no longer valid would need to try to recover losses from the tree owners. Recovering compensation could be difficult and costly and involve intercountry litigation. An alternative as mentioned above would be for certificates to be valid for relatively short time periods, say, one year with the renewal option. In short-term renewable credits it is easier to deal with compensation issue (in case of either accidental or intentional destruction of the forest), particularly if payment is made after the carbon has been sequestered for the required time period, i.e., at the end of the sequestration year rather than at the beginning. The annual flow of income to the tree owners would generate the incentive to maintain the trees and their carbon for another year. Under this system, the tree owner would be free to eliminate the tree (for logging or land conversion) and release the carbon, but the cost to the owner would be the loss of the annual income that would have been received for sequestering the carbon. Liability compensation, however, need not be a problem for tree owners if the carbon payment is based on the carbon that has already been sequestered for the previous period.

Institutional Issues - Some Existing Examples

The Kyoto Protocol of 1997 requires Annex I (industrialized) countries to reduce their emissions to 5 percent below 1990 levels by 2008-2012. These obligations can, in part, be met through three mechanisms: joint implementation (JI), clean development mechanism (CDM), and international emissions trading (IET). Under JI and CDM, emissions reductions can be done through Land Use, Land Use Change and Forestry projects. CDM projects are restricted to afforestation and reforestation activities, while JI projects may also include forest management activities. Thus, the Kyoto Protocol provided the basis for generation of credits from sequestration programs but actual implementation is still pending as the 'rules of the game' are still uncertain. Insights on institutional arrangements can be drawn from available evidence from various experimental carbon sequestration programs.

A number of independent initiatives are springing up at national and international levels that use various approaches. Although this diversity can lead to innovation and provide lessons, it may also reflect conflicting interests that need to be reconciled. Ultimately, a global carbon market requires the support of an institutional infrastructure that can increase investor confidence and reduce transaction costs in international trading. This infrastructure may include national offices, regulatory agencies, and establishment of trust funds, trading platforms such as exchanges, brokers, certifiers and insurers. For example, establishing a national carbon registry can help to prevent double selling of carbon credits and also provide transparency for prices that are critical to fair negotiations. Preventing leakage requires an institutional capacity to enforce laws. This capacity also creates greater incentive to invest in sustainable forestry practices such as Reduced Impact Logging that result in higher carbon retention. However, much of the economic benefit from this is in higher future yields - provided that access to forests can be controlled over the full rotation period.

Effective markets for carbon sequestration ultimately require benefits for forest communities, for without communities' cooperation on enforcement, these markets may be ineffective or expensive. Communities' participation can lead to higher transaction costs, such projects will not always provide the lowest-cost opportunity for offsetting carbon emissions, but this participation is consistent with the Kyoto Protocol.s requirement that CDM projects promote sustainable development. The following table outlines a few on-going programs on carbon sequestration.

Program/ Organization	Remarks
PROFAFOR	Case study of pilot CDM project in Ecudator involving small-scale farmers established 23000 hectare of pine, eucalyptus and indigenous species in a deforested region with a combined aim of controlling erosion and prevention of landslides.
FONAFIFO	National forestry fund in Costa Rica to provide payments to protected areas and private forest owners by contracting them for 20 years periods of reforestation, sustainable forest management and forest prevention activities. Certified Tradable Carbon Offsets (CTO's) generated from the program are sold to international investors and donors through a Joint Implementation Office. Transactions costs are reduced through intermediatory organizations which helps farmers with small plots to submit group applications.
State Forests New south Wales, Australia	Sells certified and Guaranteed Carbon Offsets also offers buyers from plantation timber sales.
Climate Care Warranties, UK	Allows consumers to purchase carbon offsets with particular consumer goods – cars, airline tickets etc.
Australian Afforestation Pvt. Ltd.	Joint business establishment of Toyota Motor Corporation, Mitsui Co. Ltd., and Nippon Paper Industries Co. Ltd., to plant and manage 5000 hectares of eucalyptus forests. Toyota with major investment keeps the carbon credits and sells the wood to Nippon Paper.

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