How much would Carbon Cost a Buyer?

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Abstract

As society endeavors to reduce greenhouse gas emissions (GHGE) it becomes important to find low cost emission offsets. Agriculture and forestry have received a considerable attention for supplying emissions offsets with increasing focus on what it might cost to do so. This paper examines the critical issue of estimating offset cost as it relates to carbon sequestration in agriculture and forestry. The paper discusses an approach for estimating sequestration cost in context of implementation of a GHGE reduction plan. A formula is developed to estimate net marginal delivered cost of a claimable offset. The formula can be used as a basis for determining the potential of carbon sequestration in mitigating GHGE.

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1 Introduction

As society endeavors to reduce greenhouse gas (GHG) emissions it becomes important to find low cost emission offsets (EO). Agriculture and forestry can potentially provide a number of options for creating EOs (McCarl and Schneider, 2000, 2001). These options include the oft-discussed carbon sequestration from afforestation or agricultural tillage changes as well as a number of other options (IPCC, 2001). The widely contemplated implementation of the strategy for emission reduction involves forms of cap and trade systems involving tradable emission permits (see the discussion in the Kyoto Protocol, United Nations Framework Convention on Climate Change). The attractiveness of an option to an offset buyer depends upon it's relative cost in comparison with options from a variety of other sources.

Nearly 80% of GHG emissions today come from electricity generation and forms of petroleum based fuel consumption (EPA, 2003). The incidence of emission cutbacks is likely to fall on such energy sector industries. In turn, firms in the energy industries are likely to seek to buy emission permits from across the economy, not just from agriculture and forestry. As such agricultural and forestry carbon costs need to be compared with such diverse activities as carbon removed from the atmosphere by flu gas capture operations; carbon avoided by electricity generation when there is fuel switching to biofuels, natural gas, or nuclear power as opposed to coal or petroleum-based generation; along with many other options (see the discussion of options in IPCC, 2001).

To estimate the competitive potential of carbon sequestration through agriculture and forestry sectors, an estimate of cost is needed. Also, many of the possible agricultural emission offsetting practices have environmental quality and income distribution implications. Due to these co-benefits of sequestration, the estimate of sequestration cost might be useful for determining the level of incentives that might be needed to encourage farmers to adopt such practices. In this paper, a conceptual economic approach will be taken to developing a formula that estimates net marginal delivered cost of a claimable GHG emission offset.

1.1 Policy and Formula Components

The cost components relevant in a claimable offset delivered cost estimate depend in part upon the implementation of programs to promote greenhouse gas offsets. A general framework needs to cover the possibilities for an implementation of

- a private market involving tradable emission permits as it is the case in sulfur dioxide market operating in the United States today (see Stavins (1998,2002,a,b) for discussion) and as envisioned in the Kyoto Protocol,
- a governmental based implementation, where at least some part of the costs would be borne in governmental circles.

Conceptually, in either case the cost of delivering a ton of greenhouse gas offsets via a given practice is composed of the total change in all costs and revenues involved with practice adoption along with all costs incurred in sale to buyers less possible credits for government cost offsets and co-benefits divided by the incremental quantity of greenhouse gas offset that is judged to be created. We now examine the cost and the quantity of greenhouse gas offset components.

2 Total net cost of offset production

The total cost including any income enhancements, cost offsets and co-benefits (thus being a total *net* cost) consists of several major terms estimates of each of which are needed for current and future years. The items are as follows

2.1 Producer level development cost (PDC).

When a producer chooses to undertake a carbon sequestering activity this will involve a change in operations. The producer will bear costs and earn revenues from this operation change. In general, the net producer cost is the difference in practice induced net revenue and variable cost streams plus the difference in any long-term fixed cost requirements as discussed in Antle and Mooney (2002). This includes, for example, lost or gained revenues from changes in yields relative to existing practices minus any changes in variable cost items minus any change in the amortized cost of fixed cost items. Estimates are needed for each recommended practice or land use alternative and the existing practice of the

- yield per acre by principal commodities along with an estimate of the relevant price
- input usage per acre (fertilizer, seed, hired labor, tractor fuel etc.) and relevant prices
- new equipment needs and the existing equipment that must be disposed of (i.e. one might have to get a planter that works in a no till environment plus a smaller

tractor and dispose off old planter, moldboard plow and large tractor or even recapitalize from a cropping to a pasture based system).

These estimates are needed for the items as they evolve over time as some practices, particularly those involving forestry, will involve changes in the dynamic pattern of yields and costs.

2.2 Producer adoption inducement costs (PAIC)

For a long time agriculturalists have been perplexed by the fact that practices such as adoption of less intensive tillage systems or afforestation appear to be economically and agronomically attractive but are not being adopted to the extent they "should be". However analyses and discussions with farmers (Klemme, 1985; Sunding and Zilberman, 2002; Fox et al., 1991; Kurkalova, Kling, and Zhao, 2003; Bennett, 1998) have generally revealed that there are potential disincentives in terms of learning time, change in income regimes, increased risk, and investment costs among other items. These items generally need to be offset by incentive payments above and beyond the PDC as discussed above. Similarly, one may need an additional incentive to transfer from annual cropping to a forest based system due to the change from an annual income stream to one from infrequent and periodic harvest. Thus, in general the PDC cost estimate is just a lower bound and a higher inducement may need to be paid to stimulate the adoption of offset generating practices. For example, in a study in Iowa, Kurkalova, Kling, and Zhao (2003) find a premium of $2.40 per acre per year for corn and $3.50 per acre per year for soybeans is needed to induce conservation tillage adoption beyond the economic advantage it has over conventional tillage.

2.3 Market transactions costs (MTC).

The cost changes and incentives needed to get a farmer to produce an offset generating project are only part of the costs incurred when selling to a buyer like a power plant needing GHG offsets. In particular, the offsets still need to be conveyed to the buyer. Transaction costs have been identified as one of the greatest hurdles for tradable permit systems (Hahn and Hester 1989) and their magnitude will have important consequences not only for the size and efficiency of markets, but for their overall structure. Atkinson and Tietenberg (1991) review cases where the transactions costs caused market participation to be substantially lower than was expected. McCann and Easter (1999,2000) argue inclusion of transactions costs is an important aspect of the problem that is frequently omitted. Stavins (1995a, 1995b) shows this biases the comparative desirability.

Agricultural programs have traditionally exhibited substantial transactions costs. Alston and Hurd (1990) estimate that the transactions costs of administering the farm program ranged from 25 to 50 cents for each dollar distributed. McCann and Easter (2000) in the case of soil conservation find transactions costs of the magnitude of 38% of total costs or over 50% of direct payments.

In terms of transactions costs a number of components arise as discussed below.

2.3.1 Assembly Costs

Entities like companies owning power plants often emit large quantities of greenhouse gases and in a cap and trade world would need large quantities of offsets compared to what a farmer can produce. It is clearly not economically efficient for a purchaser in quest of 10,000 tons of annual GHG offset permits to deal with a single farmer in a distant location who is potentially doing a tillage change, grassland conversion, biofuel enterprise or forest establishment on 400 acres of land which could generate a ¼ to 3 tonnes of carbon per acre. This implies a role for intermediaries (brokers or aggregators) in the market who would aggregate emission offsets generated by producers into a large enough group to stimulate power plant interests and in turn sell permits. Cost arises in such a process. In particular, suppose we try to see how many farmers would be involved using average carbon gain from a tillage change from West and Post (2002) of approximately a quarter of a ton of carbon per acre. Under such a carbon quantity then a 10,000 tonne annual lot of offsets would require 100 farmers each controlling 400 acres or 10,000 farmers in developing countries each controlling 4 acres.

Assembly costs include not only initial assembly but in the longer run any costs incurred in keeping the group together and dispersing payments. This element of transactions cost is potentially very expensive and also may depend on implementation regime. For example governments might aggregate groups of farmers and in turn sell offset permits.

2.3.2 Measurement and monitoring

The conveyance of quantities of greenhouse gas offsets from parties will require measurement and monitoring to establish offsets are in fact being produced and continue to be produced. In general, this requires the development of a low cost measurement and monitoring approach that involves a sampling based scheme integrating field level measurement, computer simulation, and remote sensing on some dynamic and geographically appropriate basis. Post et al. (1998) review the literature on monitoring and verification showing that the cost of these activities depends critically upon the accuracy desired. Kaiser (2000) reports "...a pilot project in Saskatchewan has convinced some experts that a statistical approach can bring down the costs of measuring carbon uptake concluding that carbon absorbed by changes in land use could be measured for a relatively low 10 to 15 cents per hectare". Lal et al. (1998) presents a similar estimate. Mooney et al. (2003) estimate cost for a single field sample at $16.37. Substantial efforts are being devoted to simulating carbon quantities (Parton et al. (1994), Paustian et al. (1996, 2004), Izaurralde et al. (2001)) and observing carbon increments through remote sensing (Wilcox, Frazier, and Ball, 1996).

2.3.3 Certification

Certain bodies may develop offset quantity estimates arising by practice. For example, a government rating could be established that indicates the number of offset credits from a tillage change under a set of circumstances. Costs of obtaining such a certification as borne by private parties and by the government would be relevant cost components.

2.3.4 Enforcement

Some estimate is needed of costs that will be encountered for the enforcement of permit contractual obligations. In the sulfur dioxide case, the authorizing legislation introduced penalties, which were much greater than marginal cost of generating emission offsets. Stavins (1998) argues that magnitude of penalties has been an important determinant of the high degree of compliance and the emission management program success.

2.3.5 Additional adoption cost incentive estimates

Cost may well be encountered involving education and training of producers on how to alter their practices so that they produce emission offsets most efficiently. These costs need to be estimated in a way so that one does not double count the producer adoption incentive terms as discussed above.

2.3.6 Procedures for and cost of risk/liability for adverse outcomes

Certain classes of offsets are volatile and subject to uncertainty including possible destruction by extreme weather events, fires, floods etc. Brokers and or contracts may include procedures to insure against certain types of failures. These may involve within contract enforcement mechanisms, insurance, or some sort of planned safety margin where more offsets are produced then are sold enabling the group to make up for unanticipated shortfalls. Again, cost estimates are needed for such procedures.

2.4 Government cost offset (GCO)

Government may have an active role in the assembly, measurement, producer education or market conveyance as well as in providing direct subsidies to some sequestration related actions. As such, government activity may offset some proportion of the transactions or producer development costs. In doing this, there may be certain government inefficiencies that are introduced. For example, it is common to hear arguments that government services are more expensive than private services. The relevance of the governmental cost offset, and the costs arising from government inefficiencies depend on whether one is computing the private or social cost of greenhouse gas offsets and will be discussed below.

2.5 Negative the net Co-benefits (CB)

Many of the possible agricultural greenhouse gas emission offsetting practices also have environmental quality and income distribution implications. For example, adoption of reduced tillage and can lead to reductions in soil erosion and chemical runoff improving water quality. Similarly conversion of cropland to grasslands can increase carbon sequestration and can simultaneously lower total production, in turn, raising agricultural prices and enhancing producer incomes. Such effects are beneficial and can help offset the costs of producing practices from a social perspective. Their relevance in the private market is questionable as it is unlikely that a permit scheme would be developed that gives private credit for co-benefits. As discussed below these may justify a governmental role in offsetting costs.

It is also worthwhile mentioning that the co-benefits are likely to be partially offset by co-costs that may arise due to the environmental implications of expanded emissions made possible in the energy sector by the offsets gained from sequestration (see the discussion in Elbakidze and McCarl).

3 Quantity of offset that can be credited

The quantity of GHG offsets that can be claimed for a project is the incremental quantity of GHGE avoided plus the sequestration stimulated adjustments for any discounts that are imposed by the market place or governing agencies. Let us discuss these terms separately.

3.1 Incremental quantity of carbon and other GHGS

The quantity of emission offsets that can be claimed before application of any discounts is the difference from the time path of increments in sequestered carbon stock plus the changes in GHE emissions computed before and after project possibly discounted to a present value basis following Richards (1997). When the calculation spans across multiple greenhouse gases then the IPCC 100 year global warming potentials (IPCC, 2001) need to be employed to express the total calculation in terms of tonnes of carbon equivalent.

3.2 GHGE discounts

The GHGE offsets from a particular activity may be subject to discounts due to concerns commonly called *additionality*, *leakage, uncertainty,* and *permanence*. For example, in the rules for Kyoto Protocol Clean Development Mechanism (United Nations, Framework Convention on Climate Change), while submitting an offset project to claim offset credit one is required to verify that the offsets are additional (*additionality*) and that they will not lead to more emissions elsewhere (*leakage*). In addition, a purchaser may apply additional discounts reflective of the *permanence* and *uncertainty* characteristics of sequestration that alter the quantity saleable or the price paid. Each is discussed below.

3.2.1 Additionality (ADD)

Under the negotiations surrounding the Kyoto Protocol a concern was that projects should only receive credit for items that would not have been done in the absence of GHGE offset incentives. The concern was that if a lot of land would have left farming to become grasslands under business as usual in the target region then a project involving such a transformation should receive a discount for the amount of land that would have converted anyhow. The other additionality related concern is the good actor and associated moral hazard concern. Both are discussed below.

Article 12, paragraph 5 of the Kyoto Protocol states “Emission reductions resulting from each project activity shall be certified by operational entities … on the basis of: … (c) Reductions in emissions that are additional to any that would occur in the absence of the certified project activity.” In addition, in response to a call for agency developed accounting rules, in the February 2002 U.S. Administration climate change mitigation plan, the Secretaries of Agriculture, Energy, and Commerce, along with the EPA Administrator identified the need for development of “fair, objective, and practical methods for reporting baselines, reporting boundaries, calculating real results, and awarding transferable credits for actions that lead to real reductions” as key needed actions (Abraham et al. 2002).

Collectively, these statements imply that an implementing agency will potentially reduce the volume of salable carbon by the reductions that would have occurred under business as usual. This implies, in the sequestration case, the need to project a future baseline describing future land use and land management in with and without project cases and the possible reduction of the claimable amount of GHG offsets by the amount that would have occurred without the project, which we will call here an *additionality*

(ADD) discount.

One may also wish to adjust the discount to compensate "good actors" who have previously chosen actions (say adopted conservation tillage) that remove carbon from the atmosphere even though they did this under business as usual. This might also help avoid a moral hazard issue where producers discontinue practices so they might enroll in a program. Under such cases the carbon increments may be small as the system has reached equilibrium and negative discount may be needed to maintain practices.

3.2.2 Leakage (LEAK)

The effectiveness of sequestration in mitigating GHGE can be undermined if what is called leakage in the Kyoto context or slippage in the agricultural context occurs. Namely, actions to enhance carbon storage may alter current or anticipated production levels, in turn creating alterations in market conditions (e.g. price effects) that can induce an increase in emitting activities elsewhere (Barrett, 1994). Agriculture is widely regarded as one of the most highly competitive economic sectors within the economy. Agricultural markets are truly global with commodities moving freely throughout much of the world. As such leakage is certainly a concern. Localized projects will stimulate additional economic activity domestically or internationally. Such markets portend substantial leakage possibilities. For example, Wu (2000) estimates CRP program implementation stimulated leakage in the 20 percent range, while Wear and Murray (2001) show leakage estimates in the 85 percent range for a forest preservation case. Leakage discounts are likely to be needed either in terms of standardly applicable rates or in terms of requirements of leakage rates estimation exercises within project appraisals.

The formula and approach in Murray, McCarl, and Lee (2004) should provide a starting point for handling this issue.

3.2.3 Permanence (PERM)

Once an ACS practice is put into place, soil carbon begins to accumulate until it reaches a new equilibrium whereupon the sequestration ceases (West and Post (2002) find a 10-15 year period for tillage changes, and 30+ years for rotation changes while Skog and Nicholson (2000) show afforestation cases of 80 years). Regardless of the time frame, the point is that after an initial period one should expect a decreasing carbon increment over time from a sequestration practice and that the majority of the carbon gains probably occur in the first couple of decades. Furthermore, once stored the embodied sequestered carbon is volatile. When the practice is discontinued, say reverting from reduced tillage practice back to conventional moldboard plowing, most of the carbon is released back to the air very quickly and the system reverts back to the pre practice equilibrium. This implies that if a program goal is to permanently retain the GHGE offset then the program must be designed to both encourage a change in land management and retain that change for as long as the carbon is wish to be maintained. This may entail maintenance payments beyond the time when effective saturation has been achieved. However, many soil scientists argue that farmers, once they have learned how to operate the ACS practices, find that the practice benefits are self-evident and will not revert to traditional practices. This argument will undoubtedly hold for some cases but may not hold for all cases. A discount may be appropriate to reduce the carbon down to account for the fact that it may be released in the future. The approach in McCarl, Murray, and Schneider (2003) should provide a starting point for handling this issue.

3.2.4 Uncertainty (UNCER)

Agriculture is characterized by uncertain commodity yields. This will certainly carry through to volume of GHGE offsets from sequestration. As such the issue arises as to how the uncertainty in offsets from ACS practices might be treated in the marketplace and what level of offset could be "confidently" counted on to occur. Approaches have been suggested where say one should be paid for delivering the offset level that defines a particular confidence interval not the average amount. For example, Canada (1998) has outlined a proposal in which the amount of carbon sequestered by a mitigation measure would be reported along with the uncertainty in this measurement and that credits could be claimed only to the extent that there was 95% certainty in the amount sequestered. Such a discount can be large. For example, the Chicago Climate Exchange uses an uncertainty discount in the neighborhood of 15% (Walsh, 2003).

In addition, one should note if offsets are aggregated through brokers across space for a multiyear period and perhaps across different offsetting actions that the uncertainty is likely to be mitigated by diversification.

3.3 Per ton cost computation

Now that we have been through the various terms in the cost calculation, we can express the cost per ton of a GHG offset in a formula. However from an economic standpoint, it is apparent that the cost per ton calculation will differ when expressing the private cost to a purchaser like a power plant and the social cost.

In particular, the private cost will be the sum of the incremental private producer development costs (PDC), the private additional incentives costs (PAIC), and the market transactions costs (MTC) less the cost borne by the government (GC). In turn, this sum would be divided by the incremental quantity of the offsets produced times any applicable discounts. The discount factors may vary between the private and social calculations.

$$\text{Private cost per ton} = \frac{(PDC + PAIC + MTC - GC)}{QGHGO * DISC}$$

where DISC = (1-ADD)*(1-LEAK)*(1-UNCER)*(1-PERM)

The social cost contains most of the same components but differs in that the government cost share is not directly included since it is just a transfer from the government to private parties. However, we do include a term for government inefficiency that accounts for any costs incurred when the government offsets private costs that would be above and beyond those that would be borne in the private market. Finally, we subtract off the value of the co-benefits and then divide the total sum by the discounted quantity of GHGE offset where the discount factors are conceptually the same as in the private market but may be quantitatively different numbers.

$$\text{Social cost per ton} = \frac{(PDC + PAIC + MTC + \varphi * GC - CB)}{QGHGO * (1 - DISC)}$$

4 Who gets the money

The formula above gives the price to a buyer of a claimable ton of GHG offset. However this does not give the amount of money going to the seller. In this case, the farmer would receive PDC+PAIC minus the share of the government payments (GC) accruing to the producer. The MTC less the share of those costs borne by the government would go to middlemen in the market place. The effective price paid by the buyer includes all of these costs divided by the claimable amount of offsets as expressed in the formula.

5 Concluding comments

The often cited farm level cost of carbon is not the price that will be looked at by potential buyers. Rather, one must include other terms involving additional incentives for adoption and market transactions costs. Also one must consider possible discounts that the market place or buyer may impose. Furthermore, consideration of such items will be of great importance if the magnitude of the discounts and cost terms vary across opportunities as they can change relative rankings of prospects.

Finally, we should note that co-benefits should be considered carefully as it is important to not consider co-benefits on the agricultural side alone. One should not ignore the fact, say, that conversion of a power plant from coal to natural gas has substantial benefits in terms of changes in particulate matter loadings and other air quality concerns. Thus, for co-benefits to be valid within an intersectoral cost comparison, considered explicitly or implicitly, the accounting needs to be evenhanded so that we have the co-benefit that are relevant in all sectors of the economy.

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