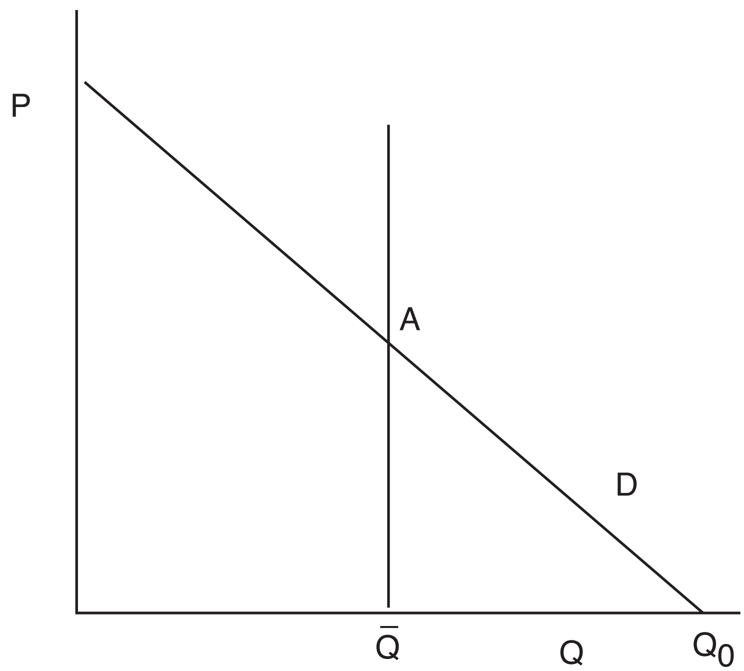
Addendum to Lecture 14

Kyoto Climate Change

The United States needs to reduce CO_2 emissions



D = demand for CO_2

Q_0 = initial level

$\overline{Q}_t$ = target level

$Q_0 - Q_1$ = reduction required

The area $A\overline{Q}Q_0$ = social cost of CO_2 reduction.

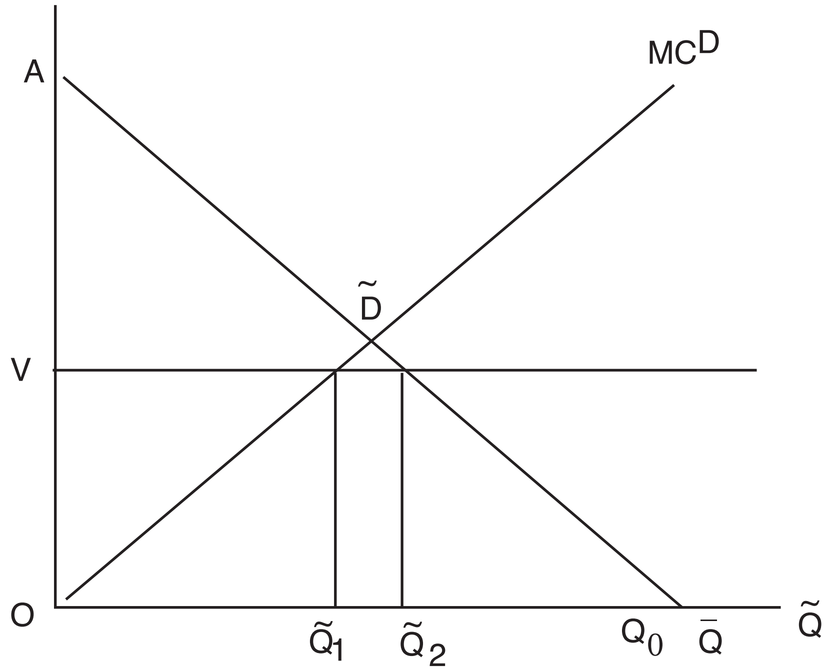
Mechanisms to reduce cost:

1. Purchase CO_2 permits from other countries (Russia), price V.
2. Provide carbon reduction in less-developed countries through the clean developed mechanisms (CDMs),

MC^D = marginal cost of CO_2 provision of *CDM*.

Using the target levels as benchmarks, let $\tilde{Q}$ denote consumption of CO_2 beyond $\overline{Q}$.

$\tilde{D}$ = demand for $\tilde{Q}$



$MC^D\left(Q^A\right)$ = marginal cost of quantities available through C*DM* **.**

<u>Equilibrium results:</u>

$\tilde{Q}_1$ = amount obtained through *CDM*

$\tilde{Q}_2 - \tilde{Q}_1$ = amount purchased on CO_2 market

$\tilde{Q}_2$ = extra emissions available beyond $\overline{Q}$.

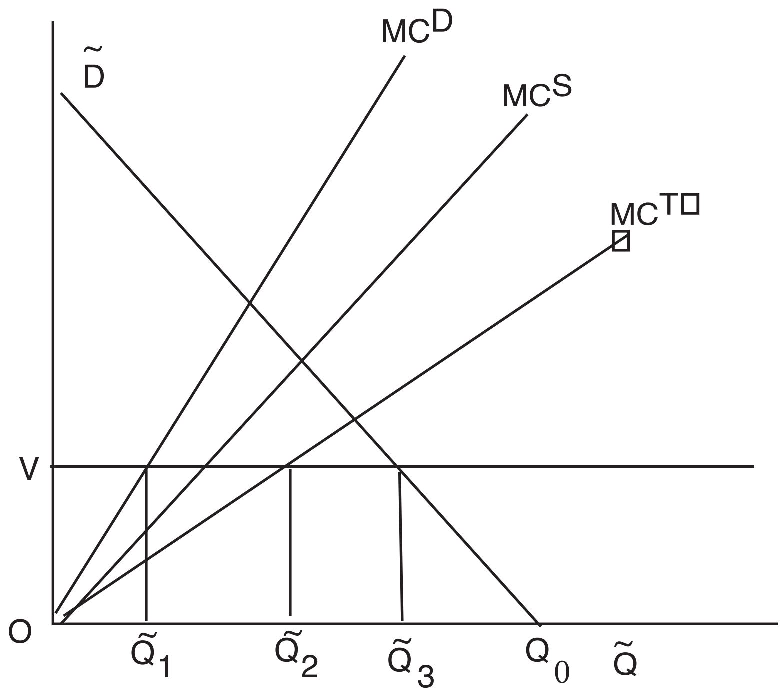
Soil carbon sequestration can be added to the analysis. Let

$$MC^S(\tilde{Q}) = \text{marginal cost of sequestration}$$

and

$$MC^D(\tilde{Q}) = \text{marginal cost of } CDM.$$

We can combine the two to form MC^T by horizontal addition. The result is



$$\tilde{Q}_1 = \text{quantity provided by } CDM$$
$$\tilde{Q}_2 - \tilde{Q}_1 = \text{quantity provided by sequestration}$$
$$\tilde{Q}_3 - \tilde{Q}_2 = \text{quantity provided by buying } CO_2 \text{ permits}$$
$$\tilde{Q}_3 = \text{extra } CO_2 \text{ beyond } \overline{Q}.$$

The Unstable Nature of Soil Carbon

After many years of traditional tillage, an acre of land has exhausted much of its carbon context and can absorb up to (approximately) $\overline{S}$ tons of carbon.

Let S_t be the amount of carbon sequestered in time t, $S_0 = 0$. The amount of carbon sequestered in year t is $X_t = \alpha(\bar{S} - S_t)$.

Assume $\bar{S} = 7$ and $\alpha = .1$.

At year 1, if no tillage is used,

$$X_1 = .7 \text{ tons.}$$

Let ΔY be loss of yield because of low tillage, P be price of output, and V be price of carbon. A farmer will apply no tillage if

$$\underbrace{\alpha V\left(\bar{S} - S_t\right)}_{\text{gain from carbon}} - \underbrace{P\Delta Y}_{\text{loss of revenue}} > 0 \quad .$$

(The model is more complex. Low tillage builds soil and increases yield in the long run, but we shall simplify.)

The attractiveness of sequestration declines over time. However, if a farmer switches to traditional tillage, β of S_t is released. If farmers are paid V dollars only for buildup of carbon, a farmer will use no tillage as long as

$$\alpha V\left(\bar{S} - S_t\right) > P\Delta Y .$$

There is a critical carbon level in the soil $S^C = \bar{S} - \frac{P\Delta Y}{\alpha V}$, and a farmer will adopt no tillage if $S_t < S^C$.

To maintain carbon in the ground once it is introduced, we need to institute a penalty on tillage activities that will release carbon. Thus, the farmer receives V for sequestered carbon and pays a certain price for released carbon. If the price of the released carbon is also V, a myopic farmer (or a renter) will continue to adopt low tillage when

$$\underbrace{\alpha V\left(\bar{S} - S_t\right)}_{\text{gain from sequestration}} + \underbrace{V\beta S_t}_{\text{penalty for emission}} > \underbrace{P\Delta Y}_{\substack{\text{loss of profit} \\ \text{due to sales}}} .$$

This formula suggests that when a farmer gains and loses based on the emission or sequestration of carbon, the range of adoption increases to include individuals with high carbon storage. The formula suggests that when

$$S_t > \frac{P\Delta Y - \alpha V\bar{S}}{(\beta - \alpha)V},$$

the farmer will adopt low tillage.

If $P\Delta Y$ is very small, the denominator is negative, and the farmer will always adopt. Higher carbon pay and lower output price will enhance adoption.