Framing the Co-Benefits Discussion
from an economic perspective

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Easy and Difficult

- In a first best world, there are no co-benefits
- In a second best world of the sort that Ottmar calls us to consider….
  - ALL BETS ARE OFF

A Simple Economic Model

{As simple as possible to reflect interactions:
a competitive market for some good X}

- **X=F(K,L,E) is the production function for X; usual properties;**
- **X = positively valued good; B[X] is benefit schedule for X;**
- **K = capital; r is the price of K;**
- **L = labor; w is the price of L;**
- **E = energy; p is the price of E;**

A Simple Economic Model Continued

- **Energy consumption produces emissions, so:**
- **Z_1 = G(E) is greenhouse gas (carbon, e.g.);**
- **Z_2 = H(E,A) is other pollutant (soot, e.g.); $C_2[Z_2]$ is social cost of Z_2;**
- **A is capital that works to reduce soot emissions; its price is r, as well.**
- **$C_1[Z_1]$ is the social cost schedule for Z_1; and**
- **$C_2[Z_2]$ is the social cost schedule for Z_2.**

The Valuable Content of the Competitive Market Assumption:

The competitive market operates as if maximizes net social welfare derived from good X

- **Max {B[F(K,L,E)] – wL – rK – rA – pE – $C_1[Z_1]$ – $C_2[Z_2]$ + $\mu_1[Z_1$ – G(E)] + $\mu_2[Z_2$ – H(E,A)]}**

Denote the solution by

(K*, L*, E*, Z_1*, Z_2*, A*, μ_1*, μ_2*)

First Order Conditions for the Optimum:

- $B'[F(K^*,L^*,E^*)] \cdot F_K(K^*,L^*,E^*) = r$
- $B'[F(K^*,L^*,E^*)] \cdot F_L(K^*,L^*,E^*) = w$
- $B'[F(K^*,L^*,E^*)] \cdot F_E(K^*,L^*,E^*) = p + \mu_1^* \cdot G'(E^*) + \mu_2^* \cdot H_E(E^*,K_2^*)$
- $\mu_1^* = C_1'[Z_1^*]$
- $\mu_2^* = C_2'[Z_2^*]$
- $\mu_2^* \cdot H_A[E^*,A^*] = r$
- $Z_1^* = G(E^*)$
- $Z_2^* = H(E^*,A^*)$

Setting Taxes for Both Pollutants:

The competitive market still operates as if maximizes net benefits derived from good X if the taxes are right

- **Max $\{B[F(K,L,E)] - wL - rK - rA - pE - t_1Z_1 - t_2Z_2 + \mu_1[Z_1 - G(E)] + \mu_2[Z_2 - H(E,A)]\}$**

Characterize the new solution by

$(K', L', E', Z_1', Z_2', A', \mu_1', \mu_2')$

First Order Conditions for Tax Solution

- **$B'[F(K',L',E')]\cdot F_K(K',L',E') = r$**
- **$B'[F(K',L',E')]\cdot F_L(K',L',E') = w$**
- **$B'[F(K',L',E')]\cdot F_E(K',L',E') = p + \mu_1\cdot G'(E') + \mu_2'\cdot H_E(E',A')$**
- **$\mu_1' = t_1$**
- **$\mu_2' = t_2$**
- **$\mu_2'\cdot H_A[E',A'] = r$**
- **$Z_1' = G(E')$**
- **$Z_2' = H(E',A')$**

Interpreting the First Order Conditions for the Optimum:

- **Notice that (K^*,L^*,E^*) and the associated Z_1^* and Z_2^* can match (K',L',E') with $Z_1' = Z_1^*$, $Z_2' = Z_2^*$ and $A' = A^*$ as long as the taxes are set to satisfy two simple conditions:**

- **$t_1^* = C_1'[Z_1^*]$**

- **$t_2^* = C_2'[Z_2^*]$**

- **Note that this implies that there are no co-benefits, in a first best world, to be derived through Z_2 by regulating Z_1. Welfare *would fall* if $t_1 \neq C_1'[Z_1^*]$. Put another way, considering Z_2 while regulating Z_1 could imply co-*dis*benefits.**

What if the Taxes for Both Pollutants are Zero?

- $B'[F(K',L',E')] \cdot F_K(K',L',E') = r$
- $B'[F(K',L',E')] \cdot F_L(K',L',E') = w$
- $B'[F(K',L',E')] \cdot F_E(K',L',E') = p$
- $A' = 0$
- $Z_1' = G(E')$
- $Z_2' = H(E',0)$
- **The amount of energy used in this case is E^0, and emissions are Z_1^0 and Z_2^0.**

Taxing Carbon Only – Are There Ancillary Benefits?

- **If $t_1^* = C_1'[Z_1^*]$ and $t_2=0$, then**
- **$B'[F(K',L',E')]\cdot F_E(K',L',E') = p + t_1^*\cdot G'(E')$**
- **The amount of energy used in this case is E^1, and emissions are Z_1^1 and Z_2^1.**
- **There is a welfare loss equal to $B(X^0) - B(X^1)$ and welfare gains equal to $C_1(Z_1^0) - C_1(Z_1^1)$ and $C_2(Z_2^0) - C_2(Z_2^1)$. The latter is the ancillary benefit.**
- **The ancillary benefit is positive by virtue of $t_2=0$**

Taxing Carbon to take Ancillary Benefits in Account?

- **Now let the ancillary benefit affect policy, by $t_1 = C_1'[Z_1^*] + C_2'[Z_2]$.**
- **Then $B'[F(K',L',E')] \cdot F_E(K',L',E') = p + t_1 \cdot G'(E')$**
- **The amount of energy used in this case is E^2, and emissions are Z_1^2 and Z_2^2.**
- **In this case, we try to regulate two externalities with a single tax. The apparent ancillary benefit is equal to $C_2(Z_2^0) - C_2(Z_2^2)$. However, there are also ancillary costs equal to $B(X^0) - B(X^2)$, and additional primary benefits equal to $C_1(Z_1^0) - C_1(Z_1^2)$.**
- **Because the tax is greater than optimal, the ancillary costs are necessarily larger than the additional primary benefits. That is, the apparent ancillary benefit is overstated. When compared to the policy with two taxes, there is an obvious welfare loss.**

Other Circumstances – A Second Best Quantity Limit on Soot that is Too Low

- **Now assume that the producers of X operate in a competitive market, that they face a tax for emissions of Z_1 denoted t_1, and that they face a quantity control $Z_{2bar} > Z_2^*$ for whatever reason. They would then operate collectively as if they were solving:**

- **Max** $\{B[F(K,L,E)] - wL - rK - rA - pE - t_1Z_1$
  $+ \lambda[Z_{2bar} - H(E,A)] + \mu_1[Z_1 - G(E)]\}$

- **The seven first order conditions for solutions (K”, L”, E”, Z_1”, Z_2”, μ_1”, λ”, A”) are:**

Other Circumstances – A Second Best Quantity Limit on Soot that is Too Low

- $B'[F(K'',L'',E'')] \cdot F_K(K'',L'',E'') = r$
- $B'[F(K'',L'',E'')] \cdot F_L(K'',L'',E'') = w$
- $B'[F(K'',L'',E'')] \cdot F_E(K'',L'',E'') = p + \mu_1 \cdot G'(E'') + \lambda'' \cdot H_E(E'', A'')$
- $\mu_1'' = t_1$
- $Z_{2bar} = G_2(E'')$ and $Z_1'' = G_1(E'')$
- $\lambda'' \cdot H_A[E'',A''] = r$

Other Circumstances – A Second Best Quantity Limit on Soot that is Too Low

- **Of course, $Z_{2bar} = Z_2''$ accommodates the eighth variable.**

- **Notice that $\lambda'' < C_2'[Z_2^*]$ since $Z_{2bar} > Z_2^*$ and the shadow price of the sub-optimally high constraint on Z_2 adjusts accordingly.**

- **It follows that setting the tax on carbon at the first-best optimum {i.e., taxing carbon at $t_1'' = t_1^* = C_1'[Z_1^*]$} would no longer achieve the first-best solution.**

- **In particular, the critical energy and emissions patterns in that configuration would mean that $E'' > E^*$, $Z_2'' > Z_2^*$, and $Z_1'' > Z_1^*$ (because $E'' > E^*$).**

- **One might think that the "correct" level of energy (i.e., E" = E*) could be achieved by setting**

$$t_1'' = t_1^* + \{t_2^* \cdot G_2'[E^*]\} - \{\lambda'' \cdot G_2'[E'']\} > t_1^*.$$

- **This would fix the form of the first order condition for energy and could even assure that the inputs of production were employed in the proper proportions under some conditions.**

- **It would not, however, guarantee that (K*,L*,E*) would be employed in the long run because distorted pricing of Z_1 and Z_1 would influence the cost structures of firms and thus equilibrium in the product market.**

The Second Best World is Complicated

But one final insight is fundamental. In cases where adjusting the tax on carbon improves welfare (perhaps by an overestimated amount), then co-benefits are appropriate though perhaps fleeting. If subsequent policy changes were to bring soot emissions closer to their optimum levels, then those co-benefits would decline; i.e., the value of climate policy would have to be adjusted downward.