INCORPORATING PRICE EFFECTS INTO LIFECYCLE ANALYSIS

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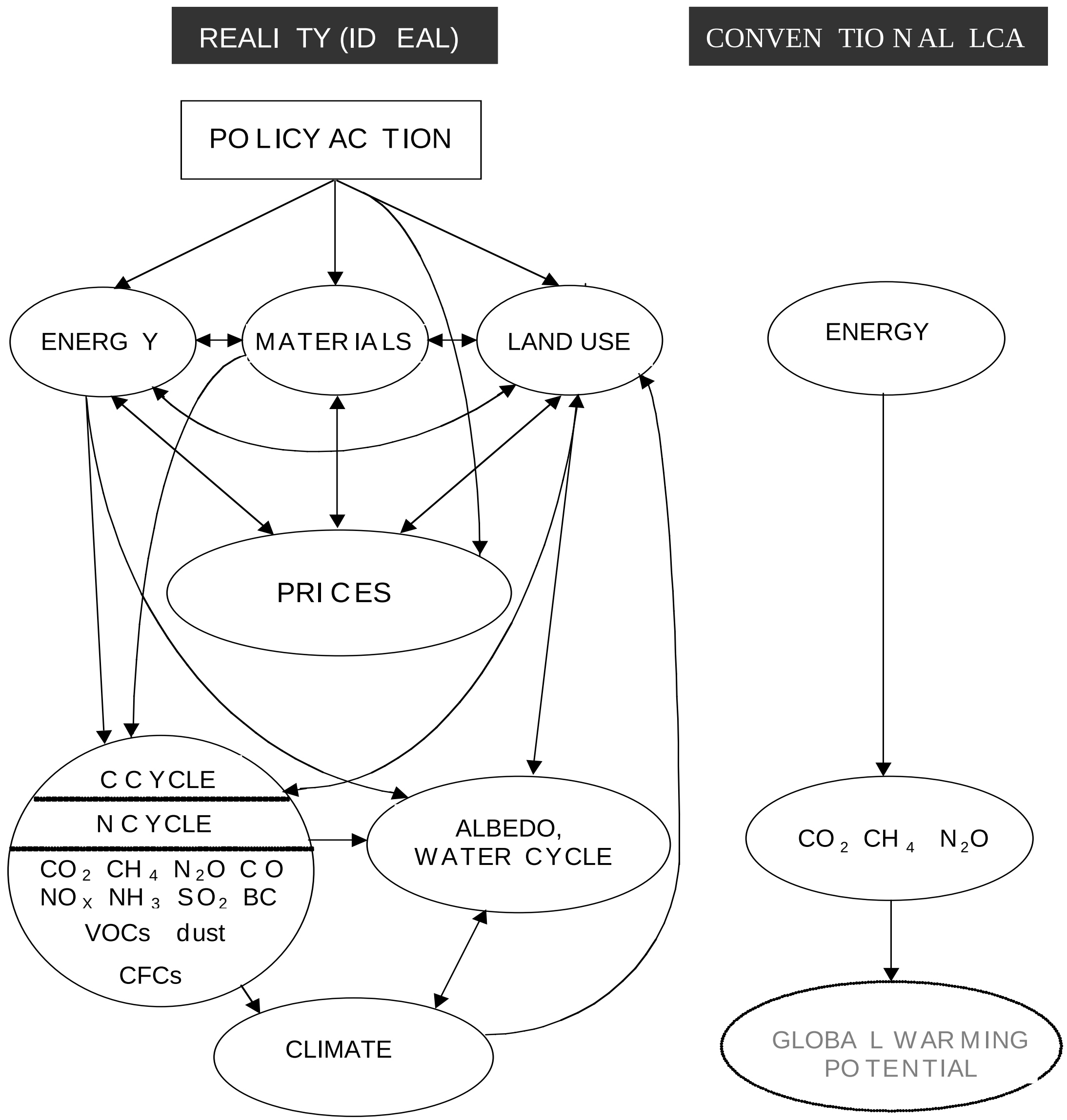
Incorporating price effects into LCA -- what is the issue?

- In the real world, any policy or assumed market action that affects the production or consumption of a fuel may affect the price of the fuel (say, gasoline), the price of the inputs to the production of the fuel (crude oil), and the price of coproducts (e.g., diesel fuel). These price effects will ripple throughout all linked sectors of the world economy and affect equilibrium levels of production and consumption, which finally will affect GHG emissions.

- Conventional LCA does not represent these price effects, and hence mis-estimates what actually happens to climate in the real world (with real economies).

- How can we incorporate these economic effects into LCA? (The best way to do this isn't obvious.)

Ideal versus conventional model



CONVENTIONAL LCA VS. REALITY

No policy analysis: conv. LCA assumes that one set of activities replaces another.

Energy systems are well represented (~90%), but material s life cycle, infrastructure, and land-use usually are not.

Conventional LCAs do not model price changes and their effects.

Some CH_4, N_2O omitted. CO, NO_X, SO_X, PM, O_3, etc., omitted. C cycle and N cycle are incomplete. Albedo, water cycle not modeled.

GWPs are simplistic and do not capture several important aspects of climate change

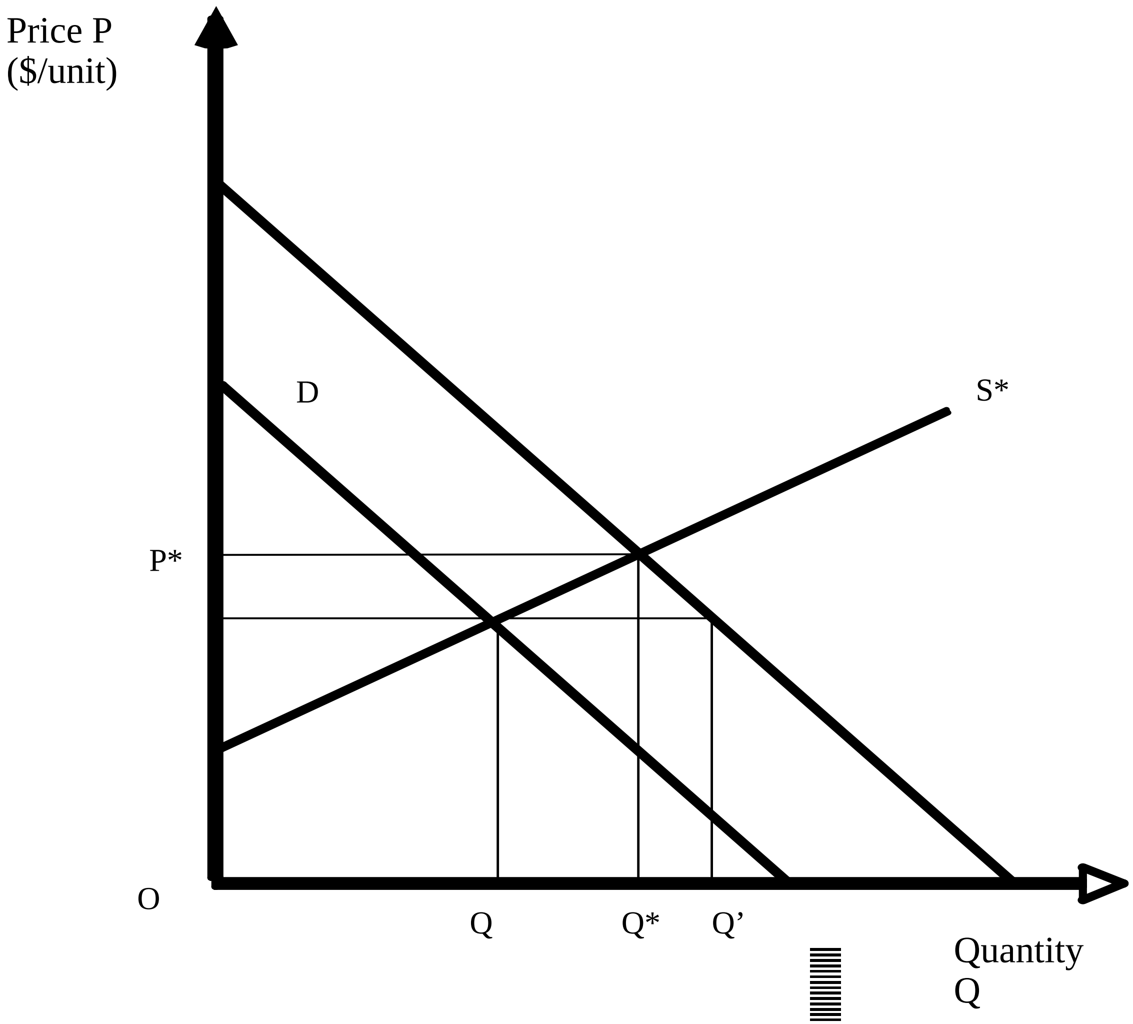
But first -- can we make a case that this really isn't an important issue? Can we argue that prices won't change?

- *Argument:* Politics, regulation, culture, or technology actually constrain inputs and outputs such that price changes do not occur or else have no effect. *Response:* This is possible in particular cases, but as a general rule it does not appear to apply to most of the important major commodities in the world (e.g., energy commodities such as oil and coal or raw materials such as inputs to steel production).

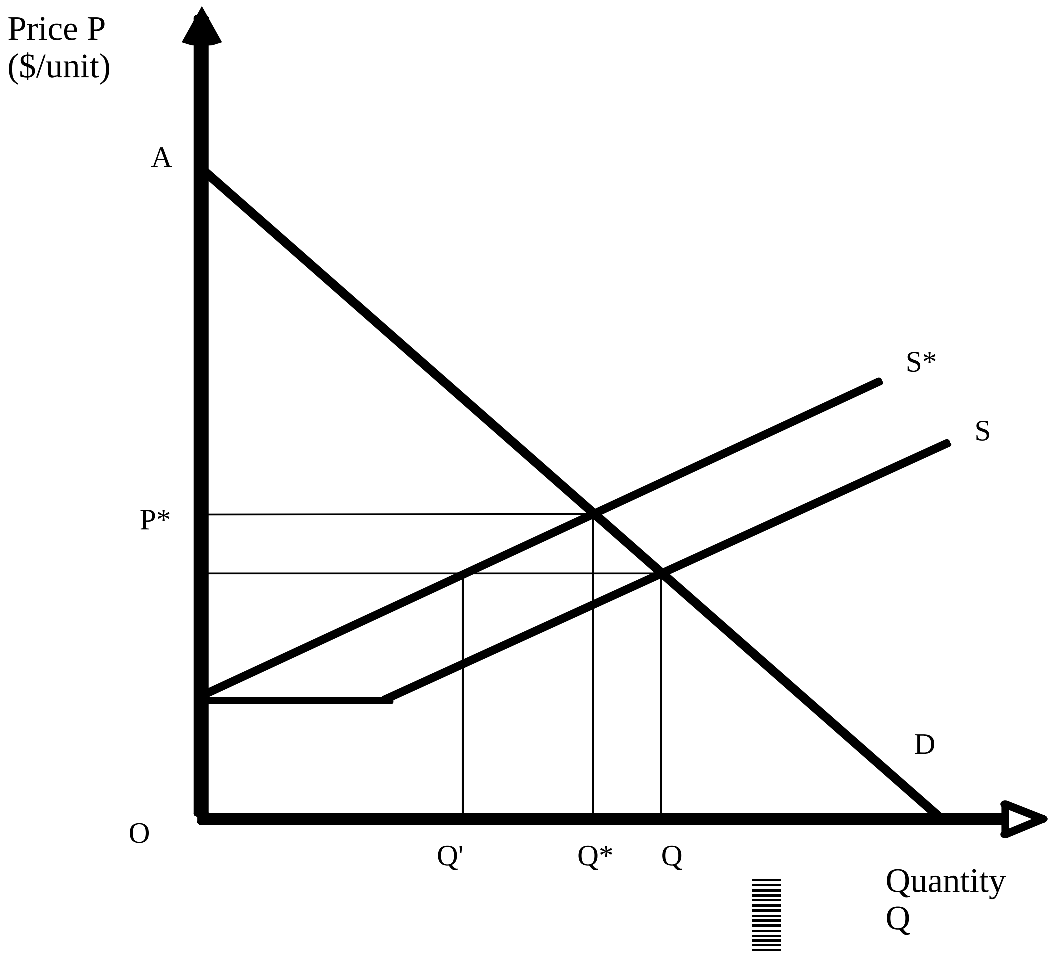
- *Argument:* Prices do not change in response to "small" changes in supply or demand; and in most instances in our problem the change in supply or demand will not be large enough to affect prices. *Response:* In the absence of constraints (already discussed above), such thresholds in theory do not exist, because in theory, supply and demand functions are continuous. (Put another way, supply curves can't be step functions.)

- *Argument:* Apart from the foregoing, the relevant elasticities are otherwise zero (e.g., supply curves are completely "flat"), with the result that prices don't change. *Response:* Empirically, I believe that this is almost never the case; e.g., long-run rising marginal costs generally are rising because of increasing economic scarcity of factors of production.

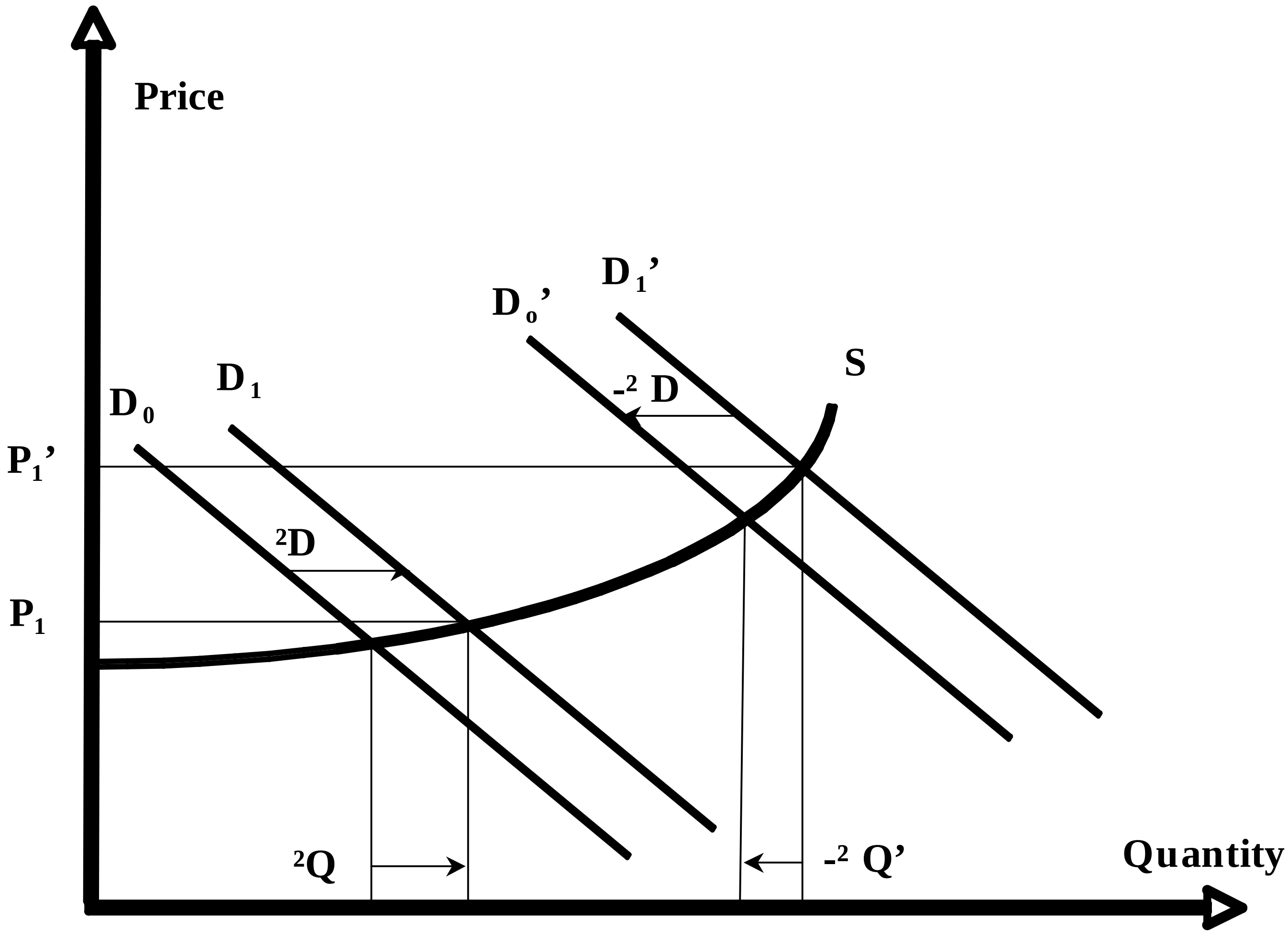
How changes in demand affect prices



How changes in supply can affect prices (co-product case)



Another example: land supply curves



D_0 = demand curve just prior to start of biofuels program; D_1 = demand curve just after start of biofuels program; D_1' = demand curve just prior to end of biofuels program; D_0' = demand curve just after end of biofuels program; S = supply curve; ^{2} D = expansion of demand due to start of biofuels progam; $-^2$D = contraction of demand due to end of biofuels prog am; ^{2} Q = increase in quantity of land cultivated due to expansion of demand for biofuels; $-^2$ Q' = decrease in quantity of land cultivated due to contraction of demand for biofuels; P_1 = price just after start of biofuels program; P_1' = price just prior to end of biofuels program.

At least four modeling ways to address this issue

- Modify CGE model. Start with a general equilibrium model, ideally one with good representation of the sectors of the economy relevant to the analysis we are conducting.
  - Add the technology, process, and I-O linkage details necessary to adequately characterize the "lifecycles" of interest.
  - Add emission factors and other climate-relevant factors (e.g., albedo) as outputs of production and consumption activities, wherever the occur.
  - Add a climate model or simplified representation of climate effects to determine the climate impacts of changes in emissions and other climate-relevant factors.

- Modify LCA model. Start with an existing "conventional" LCA model.
  - Add supply and demand functions for the important processes or activities in the lifecycle (where importance ultimately is defined with respect to climate impacts).
  - Estimate how shifts in supply or demand functions due to new fuel policies or market outcomes affect prices of important climate-relevant commodities.
  - Estimate how price changes affect production and consumption of important climate relevant commodities.
  - Estimate how changes in production and consumption (due to price changes) affect emissions.

Four ways, continued

- “Link” existing economic, LCA, climate models. Not as straightforward as it might sound, because the linkages between processes, prices, and emissions should be fairly extensive. (It probably would be relatively straightforward, though, to run an economic model first to capture a few of the big effects.)

- Build a new economic-equilibrium/LCA model from scratch. Probably harder than the other three ways, but then, you’ll get exactly what you want.

Comparing conventional LCA with economically realistic LCA

Issue	Conventional LCA	Economically realistic LCA
The aim of the analysis	Evaluate impacts of replacing one limited set of activities with another (e.g., replace petroleum production and use processes with biofuel production and use processes).	Evaluate worldwide impacts of a realistic policy or market-action scenario compared with a no-policy or no-action scenario.
Scope and method of analysis	Fixed I-O representation (energy-in/product and emissions-out) of the set of linked processes and activities that define the lifecycle.	Input/output representation of processes and activities in the lifecycle but with dynamic price linkages between all the climate-relevant sectors of the economy.

Some details on the LCA-first method

- The essence of the proposed expansion is to add to an LCA model an independent calculation that produces an estimate of the change in lifecycle emissions worldwide due to changes consumption a commodity (due to changes in prices due to shifts in demand), per unit of the commodity used in an AFL.

- The first task is figuring out where to attach these price-related emission factors. (Ideally, to any activity or process in the lifecycle that directly or indirectly impacts climate significantly.)

More details

Each price-related emission factor could have up to 8 components:

- the direct effect on the commodity of interest in price-affected commodity uses;
- the effect on products derived from the commodity of interest (call these “derivative” products);
- the effect on commodities from which the commodity of interest is derived (call these “generative” commodities);
- same as the previous, except that the effect is on other products derived from the commodities from which the commodity of interest is derived (call these “parallel” products)
- the effect on *substitutes* for the commodity of interest;
- the effect on *substitutes* for products derived from the commodity of interest;
- the effect on *substitutes* for the commodities from which the commodity of interest is derived;
- same as the previous, except that the effect is *substitutes* for the other products derived from the commodities from which the commodity of interest is derived.

A price-related emission factor could be calculated thusly:

a) define the incremental “unit” of the commodity input of interest (e.g., a BTU of natural gas);
b) estimate the supply and demand curves for the commodity of interest in the largest pertinent market area (e.g., North America), in terms of the incremental unit defined in a) (e.g., a slope expressed in $/BTU/BTU);
c) estimate a functional relationship between shifts in the demand curve and changes in price for the commodity in the same market;
d) use the relationship from c) and the estimates from b) to estimate the change in the price of the commodity;
e) estimate the price elasticity of demand, the baseline price, and the baseline consumption of the commodity for each of the direct price-affected commodity uses (PACUs) for the commodity within the pertinent market;
f) with the change in price from d) and the quantities from e), estimate the change in quantity consumed (*along* the PACU demand curve) for the commodity in each PACU;
g) identify the appropriate lifecycle emission factors for the use of the commodity in each PACU;
h) multiply the change in quantity consumed for the commodity from f) by the lifecycle emission factor from g) to obtain the change in emissions, for each PACU;
i) sum the emissions changes from h) over all PACUs.

Some major issues

- Which activities/processes/sectors do we construct supply or demand functions for?

- In how much detail do we represent the price effect of an initial change in an activity (e.g., natural gas use by ethanol plants) on other sectors of the economy? Can we just identify all major uses of (for example) natural gas and the major substitutes for natural gas in each use, or do we need to also account for further linkages?

- Assuming that the model can represent the effect of policies that affect prices directly, by taxes or subsidies, do we represent the effects on government revenue and expenditures and on household net income and consumption?