

Hotelling credits

Exploiting impatience to induce decreasing emissions

Austin Nichols

August 12, 2008

Introduction

Need to reduce GHG emissions efficiently to absurdly low levels over the next 20 to 100 years. Also: anticipated improvements in the technology of abatement or production lead to substantial projected declines in the marginal cost of emissions reductions. This leads to lower socially optimal emissions levels over time, holding social marginal benefit constant.

The type of cap-and-trade permit system usually advanced as a paragon of efficient market-based intervention typically specifies a fixed annual limit; this limit can be adjusted annually or on an ad-hoc basis, but the approach does not build on producers' intertemporal optimization, and may induce rent-seeking behavior where producers feign inferior technology to induce regulator laxity.

Instead of an annual limit, can specify a total amount of emissions allowed for all future time (under the current form of government). Hence credits effectively become an exhaustible resource with a constant marginal cost extraction technology and perfect competition, amenable to the classic Hotelling (1931) analysis. I therefore call these Hotelling credits (using the terms credits, permits, and allowances interchangeably).

Analysis

With firm i 's cost of production $C(q, E_i)$ declining in emissions level E_i and marginal cost of abatement $-C_E$ declining in E_i , define the firm's demand for credits (emissions permits) implicitly by $-C_E(E^*) = p$ when credits are trading at price p . Aggregate demand is the sum $D(p) = \sum E^* = \sum -C_E^{-1}(p)$ and the competitive equilibrium has $\dot{p} = \rho p$ where ρ is the cost of capital or the discount rate.

So price rises exponentially with time or $p = p_0 e^{\rho t}$, and emissions fall, with no change in technology. For example, supposing the marginal cost of abatement is $-C_E = f/E$ the path of emissions is exponentially declining as $E = E_0 e^{-\rho t}$. Quantities produced and profits also adjust over time.

Analysis

Same answer restated: With aggregate demand for emissions credits $D(p)$ the annual flow “utility” from emissions is the area under the (inverse) demand curve or “total consumer surplus” (but with firms so there is no issue of income effects and CS is really the right measure). In a competitive market, we can just maximize area under the demand curve i.e.

$$u(E) = \int_0^E D^{-1}(x) dx$$

and let S be the stock of emissions to date, or $E = \dot{S}$. Then the Hamiltonian is maximized when

$$\mu = u_E$$

$$\dot{\mu} = u_S + \rho p$$

but $u_E = D^{-1}(E) = p$ so the costate variable equals the price of an emissions credit ($\mu = p$). And $u_S = 0$ so $\dot{p} = \rho p$ and prices rise exponentially at the discount rate.

Analysis

This is also true by an arbitrage argument—a firm must be indifferent between holding a credit until the next period or using it at the optimum but the credit is a capital asset and must earn the same rate of return as any other asset.

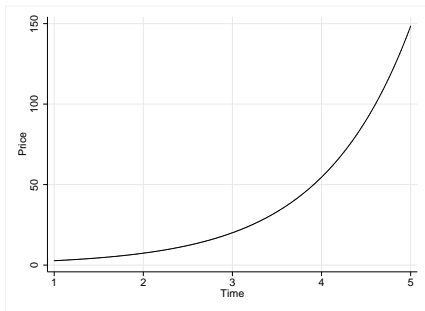
This is not the social planner's problem, for which we would need to specify the "utility" of stocks and flows of emissions at each point in time and determine the optimal path of emissions, then design a mechanism to induce firms (and households?) to comply. But for any target stock of total emissions over all time, this competitive equilibrium in the Hotelling credit market will induce firms to comply, in theory. If we want to reduce emissions to some low level, and not zero, in the limit, can exempt some classes of economic activity, e.g. household production such as breathing or burning firewood.

Analysis

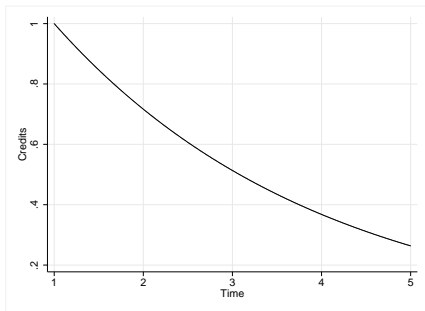
With improvements in technology over time, suppose the marginal cost of abatement falls at every level of abatement—so the socially optimal level of abatement rises. The privately optimal level of abatement increases if price remains constant, but if the number of annual credits to be used is fixed, the price will fall so that abatement is fixed instead.

With permanent “Hotelling credits” the price path alters with smoothly changing marginal costs, but typically prices continue to rise and emissions continue to fall even as costs decline. The case with bankable annual credits is intermediate.

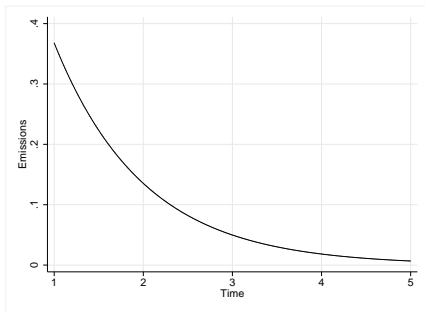
Price path



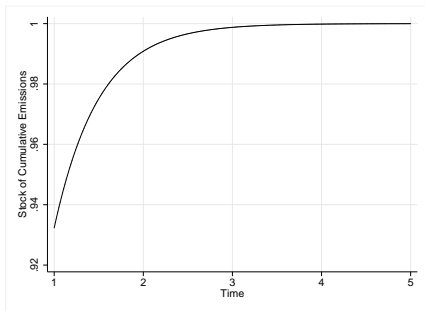
Credits outstanding for future use



Emissions path



Cumulative Emissions with no Technological Change



Extensions

Gaudet and Kahr (1991) analyze the problem of optimal extraction of a nonrenewable resource when productivity follows a stochastic process.

The optimal extraction rule obtained is similar to the Intertemporal Capital Asset Pricing Model (CAPM) where the relative riskiness of the resource asset play a crucial role: the expected excess return to holding the resource in the ground is proportional to the covariance between the return to holding the resource and the rate of change of per capita consumption.

This offers a possible approach to modeling the evolution of Hotelling credit prices under stochastic technology shocks.

Mixed credits

A more politically feasible model, and plausible extension, is the case where gilt-edged credits usable in any year are limited to a fixed quantity for all time, but annual credits are issued in any given year, usable in that year only.

Likely to be similar to a model of bankable credits (Fell et al. 2008) with a declining annual supply (esp. with a finite time horizon imposed on the entire policy) but with the right ratio of Hotelling credits to annual credits an optimal price path and credit use (emissions) path may be easier to achieve.

A better approach probably is not to allow annual credits but to allow new issues of permanent credits with some revenue from auctions going to holders of existing credits to compensate them for capital losses.

Commitment versus Flexibility

There is a tradeoff implied here about the value of commitment and the value of future flexibility—the Hotelling credits only work if the government can credibly commit to holding fixed the number of total credits issued.

Committing may be easier than it sounds, if a scheme for issuing new credits while compensating holders of existing credits for their capital losses is announced with the creation of the credit system that makes the cost of issuing new credits prohibitively expensive (with many stakeholders who would oppose changing the ground rules of credit issuance due to foregone compensation).

But as more is learned about the socially optimal emissions level, the government may want to change the total dramatically. Lowering the total cap is easier—the government can buy up credits and retire them. Raising the total cap is harder, if the commitment is credible, since the government has chosen a credible commitment mechanism precisely to make raising the total cap very hard.

Endogenous investment

What we'd really like to model is, how investments that reduce the marginal cost of abatement might be induced by the rising price path of credits. This turns out to be hard, but is the interesting case for policy and an economics paper.

Even given the right specification of the likely return on such investments and a plausible family of cost functions that technology can march across, the modeling is hard, but those inputs are hard to come by—I welcome suggestions! The behavioral responses are also embedded in an immensely complex game of regulator and regulated and interplay among the regulated, with much institutional detail and preëxisting regulation/legislation.

References

- Fell, Harrison, Ian A. MacKenzie, and William A. Pizer. 2008. "Prices versus Quantities versus Bankable Quantities." Resources for the Future draft Discussion paper.
- Gaudet, Gerard and Ali Khadr. 1991. "The evolution of natural resource prices under stochastic investment opportunities : An Intertemporal Asset-Pricing Approach." *International Economic Review* 32(2): 441–455.
- Hotelling, Harold. 1931. "The economics of exhaustible resources." *Journal of Political Economy* 39(2): 137–175.