The Green Paradox, A Hotelling *Cul de Sac*

Robert D. Cairns [1]*, and James L. Smith* [2]

Executive summary

1. Motivations underlying the research

Although a carbon tax would seem to be a potential remedy to the problem caused by greenhouse gas emissions, concerns have been raised regarding the manner in which such a tax might be implemented. If the social cost of each unit of emissions is believed to rise as atmospheric concentration increases, then the prescriptive Pigovian tax on each unit of emissions should increase over time as well. However, might producers who anticipate the increase therefore accelerate extraction of the resource to avoid higher rates in the future, and thereby inadvertently speed up global warming? This potentially adverse consequence of the Pigovian tax is known as the "Green Paradox," and it has even motivated suggestions that, to counter the adverse impact of producers' anticipated response to a rising tax rate, a decreasing tax might be employed. Analytical support for the Green Paradox is based on the Hotelling model of resource extraction. That model describes an intertemporal equilibrium, with endogenous price and output, in which it is assumed that at each instant in time individual producers can freely determine quantity produced, from zero to an unbounded level. We argue that such models and empirical examinations based on them yield unsound results that should not be used for policy evaluation.

Petroleum reserves are discrete and distinct. A firm develops a reserve through an irreversible investment that is significant compared to the value of the undeveloped reserve. In conjunction with the reserve's geology, that investment predetermines the production path. The simple arbitrage of shifting current outputs at will, as assumed in the Hotelling model, is inconsistent with real-world constraints on investment and output. We investigate alternative models of resource extraction that incorporate the type of geological and economic constraints individual producers actually face, to determine whether considerations based on the Green Paradox are relevant to real-world policy makers.

2. A short account of the research performed

We employ an optimization model of resource exploitation that incorporates the discrete nature of oil deposits, the irreversible nature of investments, and geological constraints that impact production. The model portrays the ability of a producer of an individual deposit to vary the intensity of initial investment (number of wells and well spacing), the rate at which initial production subsequently declines, the timing and scope of enhanced oil recovery operations, as

---

1 Professor, Department of Economics, McGill University, Montreal, Canada.

2 Corresponding author. Professor Emeritus, Department of Finance, Southern Methodist University, Dallas, USA. jsmith@mail.cox.smu.edu

Executive summary of the article: Cairns, Robert and James L. Smith, 2019. Journal Economics of Energy & Environmental Policy (EEEP), Vol. 8.2.

well as the date of ultimate abandonment. The model determines the producer's optimal investment, subsequent production, and resulting profit when facing any particular set of prices, costs, and taxes. That profit is the incentive for exploration, which is integrated into the analysis.

We conduct simulations of the model under various forms of a carbon tax (rising, falling, level) and find that, subject to the constraints of the model, any form of tax tends to reduce the rate of current production relative to the no-tax benchmark. The predictions of the Green Paradox are not borne out. The simulations also demonstrate that, as with any unit tax on a resource producer, a carbon tax causes a deadweight loss—for reasons that are overlooked in the Hotelling framework. Based on plausible assumptions about the social cost of carbon emissions, most of the "decreasing tax" regimes we examine fail a cost-benefit text.

Typical results are shown in the table below. Whether the tax rate is rising, falling, or constant through time, imposition of the tax reduces the initial rate of production. In addition, the volume of oil ultimately recovered from the deposit is also reduced, meaning that any of the tax regimes would produce a lower cumulative volume of emissions when compared to the "no tax" case.

Carbon Tax Scenario	Initial Royalty Rate	Royalty Growth Rate (per annum)
no tax	0%	0%
falling	49%	-3%
constant	24%	0%

Note: These simulations assume the price of oil is constant at $100/bbl. See the text for other price, cost, and tax scenarios. Each tax regime is calibrated to capture 50% of the potential economic rent from the given deposit; the scenarios are thus comparable in terms of "tax effort."

3. Main conclusions and policy implications of the work

Our main conclusion is that the technology of extraction envisioned by the Hotelling model is oversimplified, so much as to give misleading implications regarding the plausibility and policy-relevance of the Green Paradox. Based on an alternative model of resource development that incorporates geologic constraints on production and the irreversibility of investment, we find no support for the hypothesis that a Pigovian carbon tax, rising over time, would accelerate resource extraction or increase the current rate of emissions. Rather, in almost every case (whether the tax rate is rising, falling, or flat), the current rate of production and the ultimate volume of resource eventually extracted from the resource base are reduced. In no case does the tax shift production from the future to the present.

The contribution of our paper is to indicate that the smooth, convex, aggregated structure of the Hotelling model makes it a *cul de sac* for industry and policy analysis. The problem of

characterizing the impact of taxes on the rate and path of extraction is complicated and nuanced. Any model, including ours, gives an incomplete picture; the question is whether it aids understanding. Careful attention to technological detail, well beyond the simple representation in our model, should accompany policy respecting this industry.

Executive summary of the article: Cairns, Robert and James L. Smith, 2019. Journal Economics of Energy & Environmental Policy (EEEP), Vol. 8.2.