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Prices vs. quantities in a dynamic problem: Externalities from resource extraction

R.J. Briggs *

Department of Energy and Mineral Engineering, The Pennsylvania State University, 123 Hosler Building, University Park, PA 16802-5000, United States

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ABSTRACT

This paper shows how a stationary tax policy can optimally address a flow externality associated with resource extraction when the policymaker faces asymmetric information. In the model I consider, the policymaker must set policy in each period before the realization of a price shock. Resource owners then learn the value of the shock, and the owners choose extraction quantities. The optimal policy is a stationary tax rule that responds to a positive shock to the current price by reducing next period's tax rate. Intuitively, a reduction in next period's tax rate makes extraction next period less expensive and thus dampens the resource owner's current response to a price increase. This policy is robust to some, but not necessarily all, boundary solutions.

1. Introduction

Non-renewable resource extraction often generates significant externalities. The 2010 Deepwater Horizon oil spill in the Gulf of Mexico provides a recent, salient example. Produced water from gas

* Tel.: +1 814 863 1640; fax: +1 814 865 3248.
E-mail address: rjb46@psu.edu.

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extraction via hydraulic fracturing is another. Chemicals like arsenic and cyanide used to leach metals from ore often pollute groundwater, and smelting or separation processes may pollute air with oxides of nitrogen, mercury, or acidic gases. Indeed, the metals mining industry accounted for 1.8% of US National Income in 2008 while simultaneously contributing 30% of all the toxic material disposed or released during the same period—more than any other industry (US BEA, 2010; US EPA, 2010). As non-renewable resources on this planet become more difficult to recover and extraction processes intensify, the external costs associated with extraction are likely to continue to increase. A patchwork of standards, liability law, and reclamation bonds mitigate most of the worst outcomes in the U.S., but the inflexibility of regulations, the option of bankruptcy, and the overall size of damages when accidents occur make these policies less than optimal.

Incentive-based instruments – taxes or permits – may improve welfare if added to the list of policies used to control pollution from non-renewable resource extraction. The purpose of this paper is to investigate how these policies differ when used to control pollution from this type of source. Although Weitzman (1974) derives the well-known result that taxes and permits have different impacts on welfare when private agents have asymmetric information in a static setting, resource extraction presents a fundamentally dynamic decision problem. In this paper, I analyze how the dynamic structure of the resource extraction problem affects the trade-offs between taxes and permits.

Several papers in the economics literature extend the original "prices vs. quantities" work of Weitzman (1974) to dynamic social problems. For the most part, however, private agents face static economic problems in these papers. Newell and Pizer (2003) and Hoel and Karp (2002), for example, use dynamic models to examine how the welfare implications of price and quantity policies change when the externality comes from a stock instead of a flow. Agents in these models make sequences of static decisions while policymakers maximize welfare over the infinite horizon.

Weitzman (2002) investigates the optimal regulation of a competitive fishery where the stock of fish evolves subject to uncertainty. This also amounts to a dynamic social problem over a sequence of static, private decisions. Private agents in this model do not link current and future fishing decisions because of the open access problem: since individual agents do not have property rights to the remaining fish, agents simply harvest fish up to the point where price equals marginal cost in each period.

More recently, Coria (2009) explores how taxes and permits affect the diffusion of abatement technology adoption under imperfect competition. In this paper, regulators set an environmental tax or permit quantity for a market populated by symmetric firms engaged in Cournot competition. In each period, firms observe policy and dynamically choose an abatement technology adoption plan in response, giving consideration to the impacts of technology adoption on future costs and benefits. While private agents do take account of the future in their current decisions in this setting, the difference between taxes and permits arises from strategic considerations rather than asymmetric information.

The contribution of this paper relative to the prior literature is thus a comparison of price and quantity policies when both the private and social problems are dynamic and private agents have asymmetric information, with an emphasis on the role of dynamics rather than the role of strategic interactions. I analyze a stripped-down resource optimization problem where private agents are assumed to have well-defined property rights over a fixed and known stock of a non-renewable resource and information on an additive shock that is unavailable to policymakers in the short-run. I assume homogeneity and perfect competition amongst resource owners to keep the model focused on the essential dynamics of this problem and their interaction with tax and permit policies.

Policymakers in the model choose an environmental tax rate or permit allocation in each period to maximize firm profits less damages from an externality, subject to the constraints that individual resource owners maximize profits given this policy and given their asymmetric information. Since Newell and Pizer (2003) and Hoel and Karp (2002) find that price instruments tend to compare favorably to quantity instruments in the case of a stock externality, I analyze policy to control a flow externality.[1] This choice has the added advantage of keeping the focus of the paper squarely on the

[1] For a concrete example of this type of externality, consider the volatile organic compounds and nitrogen oxides from gas field drilling, maintenance, and recovery that currently contribute to ground-level ozone formation in the Upper Green River Basin in Wyoming (Johnson, 2011).