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Prices vs. quantities with endogenous cost structure and optimal policy

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ABSTRACT

Authorities often lack information for efficient regulation of the commons. This paper derives a criterion comparing prices versus tradable quantities in terms of expected welfare, given uncertainty, optimal policy and endogenous cost structure. I show that one cannot determine which regulatory instrument that induces the highest expected welfare based on the relative curvatures of the cost and benefit functions alone. Furthermore, optimal policy involves different production (or price) targets across the regulatory instruments, and does not equalize marginal costs and expected marginal benefits under prices. The reason is that firms choose a cost structure which induces too large variance in consumption of the public good under prices, and the regulator has to compensate for this when determining optimal policy. Because no such negative externality arises under quantities, the relative performance of prices is deteriorated. A numerical illustration suggests significant impact. Finally, either regulatory instrument may induce the highest technology investment levels.

1. Introduction

Authorities often lack the information they need for efficient regulation of the commons. Protection or regulation of access to public goods like clean air, water, biodiversity, fisheries and recreational areas are all important examples.

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In his seminal paper on price- vs. quantity-based regulatory instruments, Weitzman (1974) addressed the question about how to regulate public goods under uncertainty. Price-based regulatory instruments fix the price of licenses, but leave the issued quantity uncertain. In contrast, quantity-based instruments fix the quantity of licenses issued, but leave the price uncertain. This trade-off raises an essential question for policy design: which type of regulation best help mitigate the cost of uncertainty so as to maximize social benefits of the public good? Weitzman (1974) found that price-based instruments are advantageous when the marginal benefit schedule is relatively flat as compared to the marginal cost schedule, and vice versa. This has since been the consensus among most economists (e.g., Kolstad, 2000; Hoel and Karp, 2001; Pizer, 2002; Nordhaus, 2007).

It is also widely recognized that firms' cost structures are endogenous in the longer run, and that regulatory instruments have the ability to induce investment and technological progress. Indeed, a large body of literature argues that long run effects on R&D and firms' implementation of technology may be at least as important as short-run cost effects for evaluating public policy.[1] Particularly relevant for the present paper, this literature finds that different policy instruments tend to induce disparate investment levels (e.g., Montero, 2002; Requate and Unold, 2003; Zhao, 2003) and technology choices (Krysiak, 2008; Storrøsten, 2013).[2]

There are several reasons why firms may invest in new equipment; e.g., equipment breakdown or poor performance, R&D and new available technologies, and new information on market conditions or the de facto strictness of regulation. Of course, such factors may induce investment also after regulation is introduced. Furthermore, it is often the case that the equipment necessary to produce some public good is not installed (or even developed) before the public policy is announced. A good example is pollution abatement equipment, which tends to be installed after regulation has been announced.[3]

Firms that invest in production equipment usually face a menu of possible technologies. For example, emissions of greenhouse gases may be reduced by, e.g., a switch from coal to gas, renewable energy, or carbon capture and storage. It is reasonable to expect the choice of technology to affect the firm's cost structure. But if so, the slope of the marginal production cost schedule, which is a central exogenous parameter in Weitzman (1974), is endogenous and may depend on the regulatory instrument.[4] This is relevant even in the short run if the firms' investment decisions take place after regulation is announced.

The central question addressed by this paper: what is the best regulatory instrument under uncertainty when the firms' cost structures are endogenous? I derive an analytical criterion for ex-ante evaluation of the relative performances of prices versus tradable quantities under optimal policy with endogenous technology choice. Following Weitzman (1974), the comparative results are based on expected welfare across the two regulatory instruments, and derived under the assumptions of quadratic cost and benefit functions. I assume reciprocal technology investment costs. The (non-comparative) results about social optimal policy under the two instruments are also first derived under these assumptions, but later generalized to less restrictive functional forms.[5]

I show that one cannot determine which regulatory instrument that induces the highest expected welfare based on the relative curvatures of the cost and benefit functions alone; i.e. the well-known criterion derived in Weitzman (1974) does not apply when the firms cost structures are endogenous. For example, the relative performance of tradable quantities decreases in the cost of investment and increases in the intercept parameter of the marginal benefit function. Furthermore, optimal policy

[1] See Kneese and Schultze (1975) and Orr (1976) for early presentations of this view. Jaffe and Stavins (1995) offer an empirical approach. See Jaffe et al. (2002), Löschel (2002), and Requate (2005) for surveys of the literature.

[2] So far, there has been little empirical analysis on the effects of different policy instruments on environmental R&D, mainly because of little available data (Jaffe et al., 2002). Still, there are some empirics on the effects of alternative policy instruments on the innovation of energy-efficiency technologies. These studies generally suggest that there is a significant relationship between environmental regulation and R&D, see, e.g., Lanjouw and Mody (1996), Newell et al. (1999), and Popp (2002).

[3] See Fowlie (2010) for an empirical analysis of technology implementation induced by the US NO_x Budget Program.

[4] How the choice of technology is affected by the regulatory instrument is arguably an important consideration in evaluation of public policy in itself (Krysiak, 2008). Furthermore, firms' technology choice will affect the demand for technology and, thereby, the direction of R&D effort (Griliches, 1957; Ruttan, 2001).

[5] The generalization is done in Section 2.5.