ENVIRONMENTAL POLICY UNDER RISK AVERSION: PRICES VS. QUANTITIES

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Overview

Mechanisms to regulate to regulate environmental externalities can be divided into price instruments, e.g., a tax, and quantity instruments, e.g., a cap-and-trade (C&T) system. Absent uncertainty in the cost and benefit of abatement, these instruments yield equivalent results (Kolstad, 2009). However, given uncertainty, the seminal work of Weitzman (1974) proved that the expected loss in social welfare vis-à-vis the optimal policy could diverge based on the choice of instrument. In particular, if the marginal cost of abatement has a steeper slope than that of the marginal benefit from abatement, then a price instrument would lead to a lower expected loss in social welfare vis-à-vis the first-best outcome and vice versa.

While the literature has extended the analysis to cover features such as multiple pollutants (Ambec and Coria, 2013) and market power by producers (Heuson, 2010), the impact of risk aversion has not yet been considered. Indeed, it is not evident how the Weitzman (1974) result would be affected if the regulator were inherently risk averse. Taking the perspective of a risk-averse regulator that anticipates the behaviour of a perfectly competitive industry that produces an externality, we tackle the following two research questions (RQs):

1. How is optimal price (P) or quantity (Q) regulation affected by the regulator's degree of risk aversion?
2. What is the impact of risk aversion on expected welfare and its variance under each regulatory instrument?

Methods

We use a bi-level mean-variance framework (Bessembinder and Lemmon, 2002) for analysis. At the lower level, a perfectly competitive industry reacts to uncertainty in inverse demand, or the marginal benefit (MB) of consumption, while its marginal cost (MC) is deterministic. Scenario-specific industry production maximises profit inclusive of the cost of any environmental control imposed by the regulator. However, industry does not directly internalise the social cost of damage from its production. Instead, a risk-averse regulator at the upper level selects the level of the environmental control, i.e., either a tax or a cap on externalities, in anticipation of industry's response. The regulator maximises an objective function that is a weighted average of the expected social welfare and its variance, where social welfare comprises the sum of consumer surplus, producer surplus, and the social cost of damage. The parameter $R \geq 0$ captures the regulator's risk aversion, where $R=0$ corresponds to risk neutrality.

Two single-level benchmark models provide context for our findings: central planning (CP) and unregulated industry (UI). CP corresponds to a first-best outcome in which the regulator directly controls industry output to internalise the full social cost of damage from the externality in any scenario. Meanwhile, UI refers to a situation in which industry maximises its profit per scenario absent environmental control.

Results

We subject the resulting closed-form expressions for the optimal production tax and cap to comparative statics with respect to risk aversion. In terms of RQ1, we first note that a cap fixes industry output but obviates its ability to respond to the MB's variations. Thus, greater risk aversion straightforwardly decreases the optimal cap as illustrated in Figure 1 in terms of the MB and MC. For some arbitrary cap, $r^Q > 0$, the shaded grey trapezoid is the expected social welfare. Since the vertical intercept of the MB can deviate from its expected value of A in a given scenario ω, the gross consumer surplus is affected in proportion to the size of the cap. Yet, the red and green triangles that are related to the price response of demand and the cost, respectively, are unaffected by the realised scenario. Thus, a *ceteris paribus* increase in the cap leads to more exposure to uncertainty in the realised welfare, thereby incentivising the regulator to lower the cap with risk aversion. By contrast, the imposition of a tax shifts the MC of production while still allowing the output to adjust to the uncertainty in the MB of consumption. Consequently, it has the seemingly counterintuitive result of decreasing the optimal tax, i.e., actually inducing an increase in expected production, with risk aversion. Figure 2 illustrates that an arbitrary choice of tax, $r^P > 0$, will lead to lower production than the unregulated level, $q^0(\omega)$. For a given ω, the difference between regulated and unregulated realised welfare is equal to the shaded grey trapezoid. More specifically, the deviation comprises two terms: (i) the area of a scenario-dependent rectangle related to the stochastic gross gain in avoided damage cost from a production tax and (ii) the red and green triangles that reflect the cost and the price responsiveness of demand, respectively, which are not affected by the random shock. Clearly, the expectation and variance of (i) both increase with the tax. Hence, increasing the tax could make the gains in welfare due to avoided damage costs more vulnerable to random demand shocks, thereby necessitating a lower production tax for *ceteris paribus* increases in risk aversion.

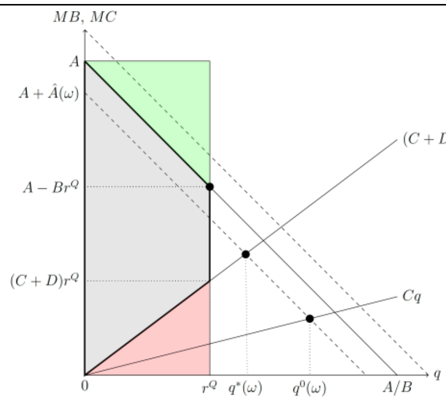

Figure 1. Marginal benefits and marginal costs under the Q instrument

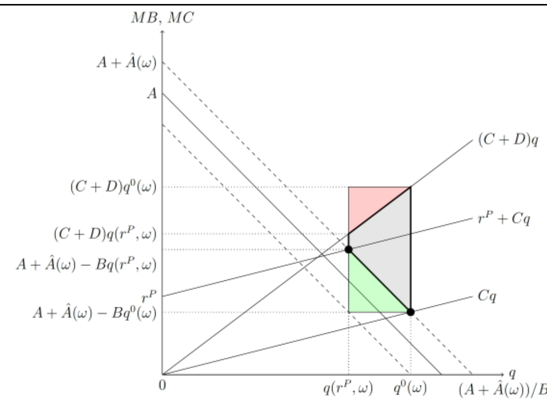

Figure 2. Marginal benefits and marginal costs under the P instrument

Figure 3 indicates how expected production varies with respect to *R*, which also verifies that greater risk aversion reduces the optimal production tax. In terms of RQ2, since the expected production under CP and UI is not affected by risk aversion, the expected welfare likewise remains constant with respect to *R* (Figure 4). However, in the two bi-level settings, expected welfare decreases monotonically in risk aversion due to the regulator's greater emphasis on reducing variance. In particular, for any positive tax, $r^P > 0$, the expected welfare under the P instrument exceeds that under the Q instrument, which can even degrade to below the level of UI. Yet, the variance of welfare is lower under the Q instrument vis-à-vis the P instrument, although the latter enables a tradeoff between the two metrics.

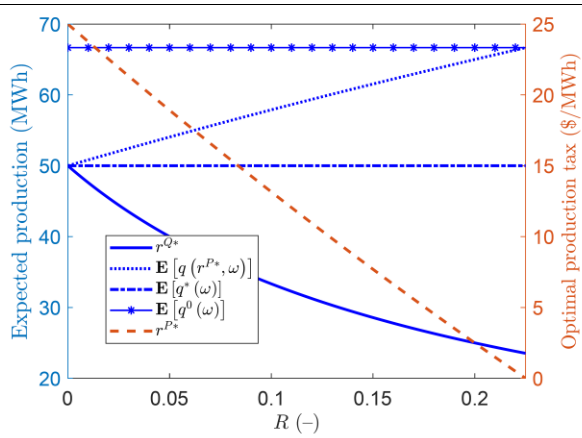

Figure 3. Optimal production tax and expected production with respect to risk aversion

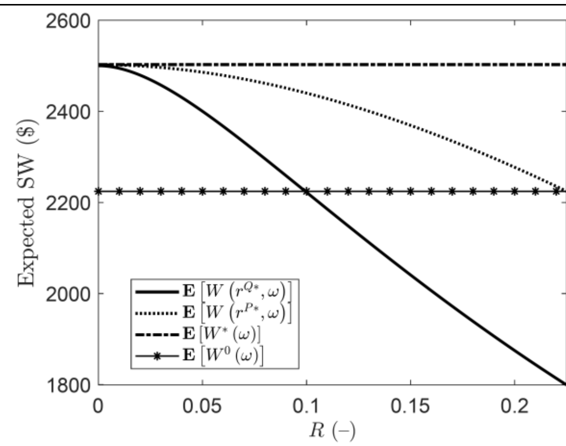

Figure 4. Expected social welfare with respect to risk aversion

Conclusions

We extend Weitzman (1974) to address a risk-averse regulator's choice of environmental control. Our mean-variance framework facilitates comparative statics, which we exploit to find a counterintuitive result, viz., that greater risk aversion may actually lead to a lower production tax (RQ1). The flexibility of the tax as a P instrument also drives the numerical results about the impact of risk aversion on welfare metrics (RQ2). Future work in this area could formalise the latter findings analytically and allow for either hybrid instruments or imperfect competition.

References

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