[*NATURAL RESOURCE EXTRACTION WITH REVERSIBLE STOCK POLLUTION*]

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Overview

This paper concerns the stock pollution problem associated with energy extraction, for example, the pollution of soil with heavy metals as a result of coal mining. The problem is particularly prevalent in China, where farmland is becoming unusable as a result of nearby mining. Unlike the existing literature that assumes that such pollution naturally decays, this paper considers that the pollution stock is reversible only through capital investment. By examining typical current regulations that require the mining firm to partially or totally reclaim the disturbed land after an operation shuts down, we find that the firm will delay the reclamation as long as possible because of the crucial role of discounting given positive interest rates. The firm also has no incentive to contain the pollution unless there is a finite period by which it must reclaim. If, on the other hand, the firm is also required to pay the pollution damages during operations, such as the opportunity cost of the farmland made unavailable due to pollution, it will have less incentive to delay the reclamation. It will also be incentivized to apply pollution control technologies. Numerical simulation shows that the application of efficient pollution taxes that match the opportunity cost of stock pollution during operations can result in a dramatically changed behavior by the firm, including, in some cases, the desire to reclaim the land as quickly as possible after operations cease.

The paper is arranged as follows. After the introduction, in Section 2, the model for mineral extraction with externalities caused by the stock pollution is developed to examine the current regulation. We then add the new rule, under which the mining firm's strategies and resultant pollution paths are analyzed. In Section 3, numerical simulation is illustrated for different practical cases. Conclusions are provided in Section 4.

Methods

Profit maximization via optimal control (two state variables, two control variables) and numerical simulation. Various models are developed and solved based on differing environmental rules and taxes. Analytic solutions provide some general insights.

Results

The first model, which only requires reclamation, explains why firms wish to delay reclamation at the end of mine life; the current environmental regulation that requires the mining firm to reclaim the disturbed land after an operation shuts down is contrary to their profit maximization, and so they delay as long as possible.

Second, a new environmental policy is designed to fix the inefficiency of the current regulation by adding a pollution tax for the environmental disturbance while in production. We show that under some parameterizations of the model immediate reclamation upon closure is in the firm's best interest because by doing so it avoids the ongoing fixed cost of the environmental damage. The firm is also incentivized to make use of pollution control technologies that reduce the accumulation of pollution over the life of the mine. Most mining regulations throughout the world do not require firms to pay ongoing damages for stock pollution, setting up a mismatched incentive system that can be corrected by the addition of this simple tax.

Numerical simulation shows that under the new set of pollution taxes, which we assume match the temporal social damage during operations, the firm's behavior can be dramatically changed. The addition of this quasi-fixed

operating cost can increase extraction rates, shorten the mine life, and lower the stock of pollution at all points of the extraction process. It can also (optimally) sterilize reserves. Given the difficulties of enforcing remediation, a second-best policy of requiring that the firm pay an elevated ongoing damage tax with the assumption of no subsequent reclamation produces a good approximation of the socially efficient pollution flow.

Perhaps of most interest, if ongoing damages are high an environmental regulation only requiring mandatory reclamation at the end of mine life can result in a negative social surplus from mining, even if the mine operator is compliant. This appears to be the complaint of many environmental groups and NGOs. A requirement that the firm pays the socially efficient damage tax while in production produces a positive social surplus from mining even if the firm avoids reclamation. The firm also continues to earn a profit and engage in the mining activity. This result comes from the presumed ability of the firm to alter its production profile and control some of its pollution via pollution control technologies. As such control technologies become more effective the motivation for a damage tax increases.

Conclusions

In many real situations, mining pollution does not naturally decay. Instead of modeling natural decay, which is the focus of most papers assessing the environmental impact of extractive activity, this paper models stock pollution which is reversible only with the application of capital. Using a natural resource extraction model with externalities of stock pollution in surrounding farmland, we find why current mine regulations requiring the application of capital to stock pollution at the end of mine life may fail to incentivize firms to control and remediate pollution. Taxing firms for contemporaneous environmental damages while in production provides a first-best outcome. Taxing firms for contemporaneous environmental damages at elevated rates can also provide a second-best outcome that takes into account the possibility of failed or delayed reclamation and that approximately matches the optimal pollution profile given no such failures.

References