The Effect of Allowing Pollution Offsets With Imperfect Enforcement

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Abstract: Public policies for pollution control, including climate change policies, sometimes allow polluters in one sector subject to an emissions cap to offset excessive emissions in that sector with pollution abatement in another sector. The government may often find it more costly to verify offset claims than to verify compliance with emissions caps. Concerns about such difficulties in enforcement may lead regulators to restrict the use of offsets. In this paper, we demonstrate that allowing offsets may increase pollution abatement and reduce illegal pollution, even if the government has a fixed enforcement budget. We explore the circumstances that may make allowing pollution offsets an attractive option when enforcement is costly.

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When the government imposes a limit on emissions from firms in a particular sector of the economy, regulators may allow those firms to exceed their limits as long as they purchase enough pollution abatement in another sector to offset their own excess emissions. Allowing offsets can reduce the cost of emissions control, extend incentives for technological change to a broader range of economic activities, and develop capacity for pollution reduction in other countries. EU climate policy, current regional and proposed national US climate policies, and the US Clean Air Act all allow offsets (Broekhoff and Zyla, 2008). Offsets remain controversial, however, especially in climate policy (Wara and Victor, 2008). The difficulty of enforcing offsets is sometimes seen as a reason for restricting their availability.

Offsets may prove difficult to enforce for several reasons. First, pollution in the capped sector is often from point sources, whereas offsets may include more diffuse sources that are not easily monitored through traditional compliance inspections. For example, changes in agricultural or forestry practices to store carbon in soils might be allowed to generate offsets in a climate policy that caps emissions from power plants. Second, regulations may require providers of offsets to demonstrate "additionality," that is, that activities that create offsets in fact reduce pollution in that sector relative to business as usual (Montero, 1999; Bushnell, 2011). The public enforcement agency may find it costly or difficult to verify these claims of additionality. Finally, many policies allow offsets generated abroad, which may complicate verification and raise the costs of enforcement. For example, many offsets used in the EU Emission Trading System (ETS) derive from hydroelectric and wind projects in China (Capoor and Ambrosi, 2009), where corruption may pose a larger problem than in the European capped sector.

In this paper, we study the role of offsets in a model of pollution control policy with imperfect enforcement. The previous literature has not considered questions of desirable market breadth with heterogeneous enforcement costs or of whether to allow firms in a capped sector to claim offsets from an uncapped sector with imperfect enforcement.[1] In our model, an enforcement agency with a fixed budget must use scarce resources to detect violations by auditing compliance claims in both a capped sector and an offset sector. Verifying compliance is more costly in the offset sector. Making offsets available may affect both the amount of pollution and the rate of compliance.

We find that allowing offsets from a sector in which violations are more difficult to detect can still improve compliance because it reduces the cost of compliance for firms in the capped sector. In addition, our model reveals a benefit of allowing offsets, rather than simply imposing a cap on the second sector. Because polluters require monitoring in an offset sector only when they opt to claim offsets, compliance in this sector may cost less to verify than it would if the sector were subject to an emissions cap.

1 The Model

A simple model of imperfectly enforced pollution limits will suffice to illustrate how the use of offsets may yield higher levels of pollution abatement and lower levels of illegal pollution even if it is more difficult to verify offset claims in a second sector than to enforce pollution limits in the first sector.

Suppose the government has a budget B for enforcement of its limits on emissions on a pollutant emitted by firms in two different sectors, sector 1 and sector 2, where $B > 0$. We assume that the government seeks to maximize total pollution abatement in these two sectors, subject to its enforcement budget constraint. Suppose also that the government imposes a fine f per unit of illegal pollution, where $f > 0$. A per-unit fine is common in emission trading systems (Stranlund et al., 2002; Sigman, 2011). We assume that B and f

[1] Stranlund and Dhanda (1999), Malik (1990), Silva and Zhu (2008), and others present formal models of enforcement of emission trading systems without offsets. Stranlund et al. (2002), Johnstone (2005), Kruger and Engenhofer (2006), and Sigman (2011) analyze past experience with enforcement in these markets. Ohndorf (2010) considers enforcement with heterogeneity across projects in the offset sector alone.

are both fixed exogenously at levels low enough to prevent the government from ensuring perfect compliance with its pollution limits; otherwise, the government could increase either B or f by enough to deter all violations.

Suppose the government announces a limit on the quantity of pollution emissions per unit of time in sector 1 and issues permits for this quantity to firms in sector 1, which can then trade these permits. Regulated firms in sector 1 claim compliance with pollution limits by announcing their levels of emissions, and enforcement takes the form of random audits by the government to verify the claimed levels of emissions. If the government conducts an audit, then it will detect a violation with certainty. Without loss of generality, we let the cost to the government of auditing all firms in sector 1 equal unity, where $B < 1$, so that the government cannot afford to audit each firm with certainty. Suppose the cost of auditing is proportional to the number of audits, so that the cost of auditing each firm in sector 1 with probability p_1 simply equals p_1.

If the government allows offsets, then a firm in sector 1 may legalize emissions that would otherwise be illegal by paying a firm in sector 2 to abate its emissions by an equivalent amount. If firms make offset claims, then the government also conducts random audits of these offset claims to verify these claims of abatement in sector 2. An audit of an offset claim is more costly to the government, however, than an audit of a claimed level of emissions in sector 1. In particular, suppose the cost of auditing each offset claim with probability p_2 equals Axp_2, where x is the fraction of firms in sector 1 claiming offsets, A is a parameter reflecting the cost per audit in sector 2, and $A > 1$. Thus, given the government's budget constraint and the cost of these two types of audits,

$$B = p_1 + Axp_2. \tag{1}$$

Finally, let $c_i(a_i)$ represent the total cost of a units of pollution abatement in sector i, where $c_i^{'}(a_i) > 0$, $c_i^{''}(a_i) > 0$, and $c_i(0) = 0$. As a simple example, assume the following specific functional form:

$$c_i(a_i) = \frac{1}{2}C_i a_i^2, \tag{2}$$

where $C_i > 0$. Thus, the marginal cost of abatement in sector i equals $C_i a_i$.

2 A Comparison of the Policy Alternatives

Suppose that the government prohibits all emissions in sector 1. This policy amounts to a cap-and-trade scheme in which the number of pollution permits issued by the government equals zero. Under this policy, all pollution emitted by firms in sector 1 is illegal. Later we consider the case in which the government instead issues a positive number of pollution permits, and we find that this change in our assumptions has no qualitative effect on our results.

2.1 A Pollution Limit Without Offsets

If the government allows no offsets, then the government can maximize pollution abatement by devoting its entire enforcement budget to maximizing the probability of an audit in sector 1. Thus, if we let p_1^* denote the probability of an audit in sector 1 under this policy, then:

$$p_1^* = B. \tag{3}$$

Let a_1^* represent the quantity of abatement that emerges in sector 1 under this policy. Firms in sector 1 will choose to abate their pollution until the marginal cost of abatement in sector 1 equals the expected fine for a unit of illegal pollution:

$$C_1 a_1^* = f p_1^*. \tag{4}$$

Together, equations (3) and (4) imply:

$$a_1^* = \frac{fB}{C_1}. \tag{5}$$

By assumption, the expected fine fB is too low to deter all pollution, so we have an interior solution for the level of abatement in sector 1. Under this policy, there are no limits on emissions in the second sector, so there is no abatement in sector 2.

2.2 A Pollution Limit With Offsets

If the government instead allows offsets, then the response of firms in sector 1 will depend on the probabilities of audits of abatement claims in sector 1, p_1, and of audits of abatement claims in sector 2, p_2. These probabilities will depend on how the government allocates its scarce enforcement resources B between these two priorities. Suppose that the government can credibly commit to allocate its resources so as to generate any p_1/p_2 ratio announced in advance, perhaps because the game is repeated over an indefinite time horizon.

First, suppose the government announces that it will allocate these resources so as to ensure that $p_2 < p_1$. Under this scenario, all polluters will claim offsets, whether they have purchased valid offsets or not, because the government would be less likely to detect a false offset claim than a false claim of abatement in sector 1. Given that the fine f for illegal pollution is the same regardless of which claim a polluter makes, the polluter can minimize the expected penalty for pollution by claiming offsets for its emissions. A relatively large share of firms in sector 1 will claim offsets under this scenario. For simplicity, assume that if $p_2 < p_1$, then x is equal to a particular fraction x_H, where $0 < x_H < 1$. We assume that firms in sector 1 are "price takers" insofar as they emit too small a share of the pollution in their sector to consider the effect of their offset claims on the government's budget constraint, expressed in equation (1), and the resulting reduction in the probability of audits, an effect that would be a public good among polluting firms.

Under this scenario, polluters will face fp_2 as the expected penalty for each unit of illegal pollution. Firms in sector 1 will abate pollution until the marginal cost of abatement in sector 1 equals the expected penalty for illegal pollution:

$$C_1 a_1 = fp_2, \tag{6}$$

and the market price for offsets will ensure that the marginal cost of abatement in sector 2 also equals the same amount:

$$C_2 a_2 = fp_2, \tag{7}$$

assuming an interior solution. As long as the expected penalty is not so great as to exhaust all opportunities for abatement in sector 2, we will get an interior solution, and equality (7) will hold. Given this scenario, the government would seek to maximize p_2, in order to maximize abatement. Thus, in this scenario, the government would set p_2 as close as possible to p_1.

Second, suppose the government instead announces $p_1 < p_2$. Under this scenario, no polluter in sector 1 would claim an offset unless it had a valid claim, because the government would be more likely to detect a false offset claim than a false claim of abatement in sector 1. A relatively small share of firms in sector 1 will claim offsets under this scenario. For simplicity, assume that if $p_1 < p_2$, then this share x is equal to a particular fraction x_L, where $0 < x_L < x_H$. In this case, polluters with excess emissions will falsely claim lower levels of emissions and thus face fp_1 as the expected penalty for each unit of illegal pollution. By the same reasoning applied to the first scenario, the government would set p_1 as close as possible to p_2 under this second scenario.

Finally, suppose the government announces that it will audit all claims with the same probability p, so that $p_1 = p_2 = p$. Under this policy, equation (1) implies that:

$$p = \frac{B}{1 + Ax}. \tag{8}$$

The optimal policy under either of the first two scenarios approaches this third policy, as p_1 and p_2 get arbitrarily close. The optimal choice among these three policies turns on the value of x, because the government can maximize the probability of audits by minimizing x, given the budget constraint expressed in equation (1). The value of x jumps from x_L to x_H as the government increases p_1 past p_2, which also implies a discontinuity in total abatement, which drops by a discrete amount at $p_1 = p_2$.

To simplify the exposition, we assume that if $p_1 = p_2$, then $x = x_L$, so that the optimal policy will be to set $p_1 = p_2 = p^{**}$, where p^{**} denotes the optimal probability of either audit under a policy with offsets. Thus, using equation (8), we can express this probability as follows:

$$p^{**} = \frac{B}{1 + Ax_L} \tag{9}$$

while keeping in mind that in reality, the government may need to keep p_1 slightly below this level and p_2 slightly above it to deter false offset claims. In general, the government would like to keep the expected penalty for false offset claims greater than the expected penalty for false claims of abatement in sector 1 while keeping these expected penalties as close as possible.[2]

Under the optimal policy with offsets, firms in each sector would abate pollution until the marginal cost of abatement in each sector equals fp^{**}. Thus, using equation (9) to solve

[2] In a more complex model, firms may be heterogeneous with respect to the probability of detection in one sector relative to the probability of detection in the other. In that case, x may increase continuously as the government shifts enforcement resources from sector 2 to the sector 1. The government would then face a tradeoff between equalizing the expected penalties for violations in the two sectors and deterring false offset claims, and the optimal policy would entail a shift of enforcement resources toward the offset sector in order to pursue the second objective.

for the level of abatement under this policy yields:

$$a_i^{**} = \frac{fB}{(1 + Ax_L)C_i}, \tag{10}$$

where a_i^{**} denotes the resulting level of abatement in each sector i. Using equation (10), we can express the total quantity of abatement under this scenario as follows:

$$a_1^{**} + a_2^{**} = \frac{fB(C_1 + C_2)}{(1 + Ax_L)C_1C_2}. \tag{11}$$

2.3 The Net Effect of Allowing Offsets

We can now see whether the net change in total pollution abatement is positive when we allow offsets, that is, whether

$$a_1^{**} + a_2^{**} - a_1^{*} > 0. \tag{12}$$

We can also ask whether compliance with pollution regulations improves when we allow offsets, that is, whether the total amount of illegal pollution decreases. The total amount of illegal pollution is simply the amount of illegal pollution in sector 1, because pollution in sector 2 is unregulated. Thus, the net change in illegal pollution when we allow offsets equals the net change in pollution in sector 1, which is simply the opposite of the net change in pollution abatement in sector 1, minus the increase in legal pollution in sector 1, which equals the increase in pollution abatement in sector 2. Thus, the net change in illegal pollution will be negative if and only if:

$$-(a_1^{**} - a_1^{*}) - a_2^{**} < 0. \tag{13}$$

Note that inequalities (12) and (13) are equivalent: the net change in illegal pollution is negative if and only if the net change in total abatement is positive. Thus, we can answer both questions simply by seeing whether inequality (12) holds.

Given our assumptions that $f > 0$, $B > 0$, and $C_1 > 0$, and using equations (5) and (11), we can show that inequality (12) will hold — and thus allowing offsets will reduce pollution — if and only if the following inequality holds:

$$C_1 > Ax_L C_2. \tag{14}$$

Inequality (14) is more likely to hold as either C_1 increases or C_2, A, or x_L decreases, holding all the other parameters constant. Thus, the difficulty of enforcement in sector 2, as expressed by the inequality $A > 1$, makes the offset alternative less attractive, but this disadvantage may be outweighed by other factors, expressed by the other three parameters: C_1, C_2, and x_L. For example, the offset alternative may be attractive if abatement in sector 1 is sufficiently costly relative to abatement in sector 2, so that:

$$\frac{C_1}{C_2} > Ax_L. \tag{15}$$

In that case, the increase in abatement in sector 2 will exceed the decrease in abatement in sector 1.

An abatement cost advantage, however, is not necessary for the offset alternative to be the optimal policy. Even if $C_1 = C_2$, for example, allowing offsets may be optimal despite $A > 1$ as long as x_L is sufficiently small to outweigh the higher cost of monitoring abatement in sector 2. Thus, without any abatement cost advantage, the advantage of allowing offsets depends crucially on $x_L < 1$. The offset alternative would double the abatement opportunities, but it would cut the expected penalty for illegal pollution by more than half by spreading enforcement resources too thin if $Ax_L > 1$.

Indeed, the fact that $x_L < 1$ may explain why the government might prefer to encourage abatement in sector 2 through offsets rather than simply subject sector 2 to a cap on pollution. Suppose that sector 1 and sector 2 are identical in all respects except for the higher costs of enforcement in sector 2: $A > 1$. In that case, subjecting sector 2 to the same pollution limit imposed on sector 1 would have the same effects as an offset alternative with $x_L = 1$, because the government would have to threaten all firms in sector 2 with audits in order to discourage violations by any firms in sector 2. Unlike the case with an offset approach, there would be no gain from reducing the number of audits required to achieve a given probability of detecting a violation. Whereas $A > 1$ would make it too costly to extend a pollution cap to sector 2, a sufficiently small x_L would make it worthwhile for the government to adopt the offset alternative.

If firms in sector 1 have heterogeneous abatement costs, this heterogeneity may imply a lower x_L, which may make a policy allowing offsets more attractive to the government. If firms have more heterogeneous abatement costs, then a given expected penalty for illegal pollution may lead many firms in sector 1 to abate pollution completely even while other firms in sector 1 still have an incentive to pollute more than allowed by law. A firm that can honestly report zero emissions in sector 1 has no need to claim offsets from sector 2. The more such firms exist in sector 1, the fewer offset claims there are for the government to audit, and the lower x_L is likely to be.[3]

3 Extensions

To simplify the exposition, we have assumed that the government prohibits all emissions in sector 1 unless the polluter can purchase offsetting pollution abatement in sector 2. We can extend the model to include the case in which the government issues a positive number of tradeable pollution permits to firms in sector 1, but there would be no significant qualitative change in our results. As long as the number of permits is not so great as to allow the

[3] In our simple model, the number of audits in sector 2 required to achieve a given p_2 is a function of the number of firms claiming offsets in sector 1. In a more general model, the cost of a given p_2 may also be a function of the number of firms in sector 2 selling offset claims. In this case, more heterogeneous abatement costs in sector 2 may make a policy allowing offsets more attractive to the government.

government to obtain full compliance with its pollution regulations, the only direct effect of the permits would be to legalize some portion of what would otherwise be illegal pollution. The level of pollution would still depend on the marginal cost of abatement in each sector and the expected penalty for illegal pollution, and the pollution permits would remove the expected penalty only from infra-marginal units of pollution. The net effect of allowing offsets on total pollution abatement and on the quantity of illegal pollution would still turn on inequality (14).[4]

Although we believe the general insights gleaned from our example are robust, our specific results may change if we modify some of the restrictive assumptions made in our simple example. For example, we have assumed that the marginal cost of abatement is proportional to the quantity of abatement in each sector. A different functional form could make the case in favor of allowing offsets stronger. For example, if

$$c_i(a_i) = C_i a_i^3, \tag{16}$$

then the convexity of the marginal cost function would imply that the decrease in abatement in sector 1 would be small relative to the increase in abatement in sector 2, even if $C_1 = C_2$ and $Ax_L = 1$. Other abatement cost functions, however, could militate against allowing offsets.

We have also assumed that enforcement costs are simply proportional to the probability of detecting a violation. A different functional form could make the case in favor of allowing offsets stronger. For example, if it instead becomes increasingly costly to increase the probability of detecting a violation, then the convexity of the enforcement cost function would

[4] A positive number of permits, however, could have an indirect quantitative effect on our results. If less pollution in sector 1 lacks permits and firms in sector 1 are heterogeneous, then fewer firms in sector 1 may need to claim offsets. This effect would reduce x_L, which would make allowing offsets more attractive for the government than it would be with zero permits. On the other hand, if the cost of audits in sector 2 is a function of the number of firms in sector 2 providing offsets rather than number of firms claiming offsets in sector 1, then even this indirect quantitative effect would be absent.

militate in favor of allowing offsets. If there is a large fixed cost of enforcement in the offset sector, however, then that fixed cost would militate against allowing offsets.

We have also assumed that B and f remain fixed regardless of the policy adopted by the government. If allowing offsets were to relax the constraints on B or f instead, then that effect would be an additional advantage to the policy allowing offsets. If allowing offsets were to tighten these constraints, however, then this effect would militate against a policy allowing offsets.[5]

4 Conclusion

We find that allowing offsets may not reduce compliance or increase pollution, even when the government has more difficulty detecting violations in the offset sector than the capped sector. Ease of monitoring and enforcement may be a consideration in deciding the range of activities to allow as sources of offsets. Our results suggest, however, that allowing offsets can either increase pollution or increase compliance, depending on the relative difficulty of enforcement and the costs of abatement in the two sectors. Furthermore, our model highlights a possible advantage of allowing offsets, rather than including these sectors in a pollution cap: the offset alternative may reduce the number of sources the government needs to monitor and thus may reduce the burden on public enforcement resources.

[5]Most emission trading systems require violators to surrender allowances equal in the amount of the violation in addition to paying a fine. Such a policy effectively adds the allowance price to the fine f. As a result, the effective fine will likely change with the availability of offsets, which we expect to reduce the allowance price.

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