THE CONTROL OF INTERSTATE ENVIRONMENTAL EXTERNALITIES IN A FEDERAL SYSTEM

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This Article seeks to develop a sound means to force the internalization of interstate environmental externalities in a federal system. The analysis focuses on how to perform such internalization within the context of the Clean Air Act's requirement that states meet the federal ambient air quality standards.[1] The discussion contemplates a procedure, like that provided by the Act's sections 110(a)(2)(D) and 126(b),[2] under which downwind states can seek injunctions against upwind pollution.

The presence of interstate externalities constitutes a market failure. In the absence of other market failures or public choice problems, correcting the externality leads to the maximization of social welfare. Under the approach contemplated here, however, this maximization is constrained by a requirement that the federal ambient standards be met, so social welfare gains that might result from ambient standards less stringent than the federal standards cannot be considered.

This objective of maximizing social welfare subject to a constraint is different from the objective of minimizing the costs of meeting the federal ambient standards because the states are free to choose more stringent state ambient standards.[3] In cases in which the federal ambient standards are constraining (that is, ambient air quality has been degraded to the level of these standards), the welfare-maximization and cost-minimization objectives yield identical results.

The analysis that follows assumes that there are no Coasian bargaining solutions, under which states could limit their pollution spillovers through interstate compacts without any federal intervention. If transaction costs were sufficiently low to permit such bargaining, there would be no need for federal regulation.[4] Federal regulation of interstate externalities is necessary precisely

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1. For an overview of the Clean Air Act, see Revesz, *supra* note *.
2. Clean Air Act §§ 110(a)(2)(D), 126(b) (codified at 42 U.S.C. §§ 7410(a)(2)(D), 7426(b) (1994)).
3. *See* Clean Air Act § 116 (codified at 42 U.S.C. § 7416 (1994)).
4. *See* Jacques LeBoeuf, *The Economics of Federalism and the Proper Scope of the Federal Commerce Power*, 31 SAN DIEGO L. REV. 555, 573–74 (1994). LeBoeuf notes: "The

because such bargaining does not occur.[5]

Part I provides a taxonomy for the analysis of the problem. Part II considers the situation in which the federal ambient standards in the downwind state are violated. Part III examines the situation in which the downwind state's ambient air-quality levels are better than the federal ambient standards.

I. TAXONOMY OF INTERSTATE SPILLOVERS

As background to the analysis that follows, it is helpful to construct a taxonomy defined by reference to whether the downwind state would meet the federal ambient standards if it did not have to face pollution transported from the upwind state and whether the downwind state actually meets the federal ambient standards despite the upwind pollution. There are three relevant categories.

In the first category, the downwind state would meet the federal ambient standards without the upwind pollution, and meets these standards despite the upwind pollution. In the second category, the downwind state would not meet the federal ambient standards even if there were no upwind pollution and, of course, does not meet the standards with the upwind pollution. In the third category, the downwind state would meet the federal ambient standards in the absence of upwind pollution, but does not meet these standards with the upwind pollution; here, the upwind pollution is the but-for cause of the violation of the federal ambient standards. This taxonomy is summarized in Table I.

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objection that the bargaining suggested by the Coase theorem would obviate federal intervention is in a sense nothing more than a dispute over semantics. Congress is, in a sense, the forum wherein states hammer out their differences." *Id.* at 574.

5. Thus, for example, the provisions that preceded sections 110(a)(2)(D) and 126(b), which relied on intergovernmental cooperation, were wholly ineffective. *See* William V. Luneburg, *The National Quest for Clean Air 1970–1978: Intergovernmental Problems and Some Proposed Solutions*, 73 NW. U. L. REV. 397, 400–21 (1978). Several reasons might explain why transaction costs are sufficiently high to prevent the formation of compacts. First, the baselines are not well defined in the current legal regime. Does an upwind state have the right to send pollution downwind unconstrained? Alternatively, does the downwind state have the right to enjoin all upwind pollution? Second, for different pollution problems, the range of affected states will vary. This shifting membership makes less likely the emergence of relationships favoring cooperation. Third, the causation questions are not likely to be straightforward. Considerable scientific work needs to be undertaken in order to determine what sources of pollution are having an impact on the downwind state. The federal government has the technical expertise to make such determinations because they are quite similar to the determinations that it must make under different provisions of environmental law—for example, in determining whether emission limitations in a State Implementation Plan (SIP) lead to the attainment of the National Ambient Air Quality Standards (NAAQS) in that state. This type of expertise would be costly for states to replicate in connection with their negotiations over compacts.

TABLE I: TAXONOMY OF INTERSTATE SPILLOVERS

	Violation Without Upwind Pollution	Violation with Upwind Pollution
Category I	No	No
Category II	Yes	Yes
Category III	No	Yes

As to each of these categories, two questions are relevant. First, should the federal government play a role in controlling the upwind pollution? Second, assuming that such a role is appropriate, how should the federal government determine the permissible amount of upwind pollution that can enter the downwind state?

II. DEALING WITH VIOLATIONS OF THE AMBIENT STANDARD IN THE DOWNWIND STATE

The design of a scheme to control interstate externalities must consider the manner in which pollution from an upwind state affects environmental quality in the downwind state. The impact upwind pollution has on a downwind state's air quality is the product of three principal factors: emissions, location, and stack height.[6] For a given stack height and location, the source's impact on ambient air quality increases with increasing levels of emissions. For a given stack height and level of emissions, the source's impact on ambient air quality in the downwind state increases as the distance between the source and the border with the downwind state decreases. For a given location and level of emissions, as stack height increases, the source has a smaller impact on ambient air quality within short distances and a greater impact on ambient air quality further away.

The first section deals with the situation in which the sources' location and stack height have been fixed and asks how emissions should be allocated between upwind and downwind sources—the only inquiry performed by the Environmental Protection Agency (EPA) and the courts.[7] In subsequent sections, these assumptions are relaxed. In all these instances, the objective is to minimize the aggregate cost of meeting the ambient standard.[8]

A. Selecting Desirable Levels of Emissions Where the Location and Stack Heights of Sources Are Fixed

The problem of allocating pollution control burdens between upwind and

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6. For water pollution, only effluent levels—the analog of emissions—and location are relevant.

7. The legal regime for the control of interstate environmental externalities is analyzed in Section I.C. of Revesz, *supra* note *.

8. *See supra* text accompanying notes 2–4 (discussing the relationship between welfare maximization and cost minimization).

downwind states to minimize the aggregate cost of meeting a given level of environmental quality is illustrated through a simple example in which there are only two sources: one, which I shall call *U*, in the upwind state and the other, which I shall call *D*, in the downwind state. The level of emissions of these sources is e_u and e_d, respectively. The impact of these emissions on ambient air quality is denoted by a_u and a_d, respectively. A simple relationship between a source's emissions and the impact of those emissions on ambient air quality at various distances downwind from the source is assumed: the impact increases linearly with distance up to a certain distance, *m*, downwind from the source and then begins to decrease linearly as the distance from the source continues to increase. The emissions have no impact upwind from the source and the downwind impacts occur along a single line. The distance between the two sources is *t*.

In both the upwind and downwind states, the ambient standard is set at a level *s*. Thus, in any given place, the sum of the impact of the two sources on ambient air-quality levels cannot exceed this level.

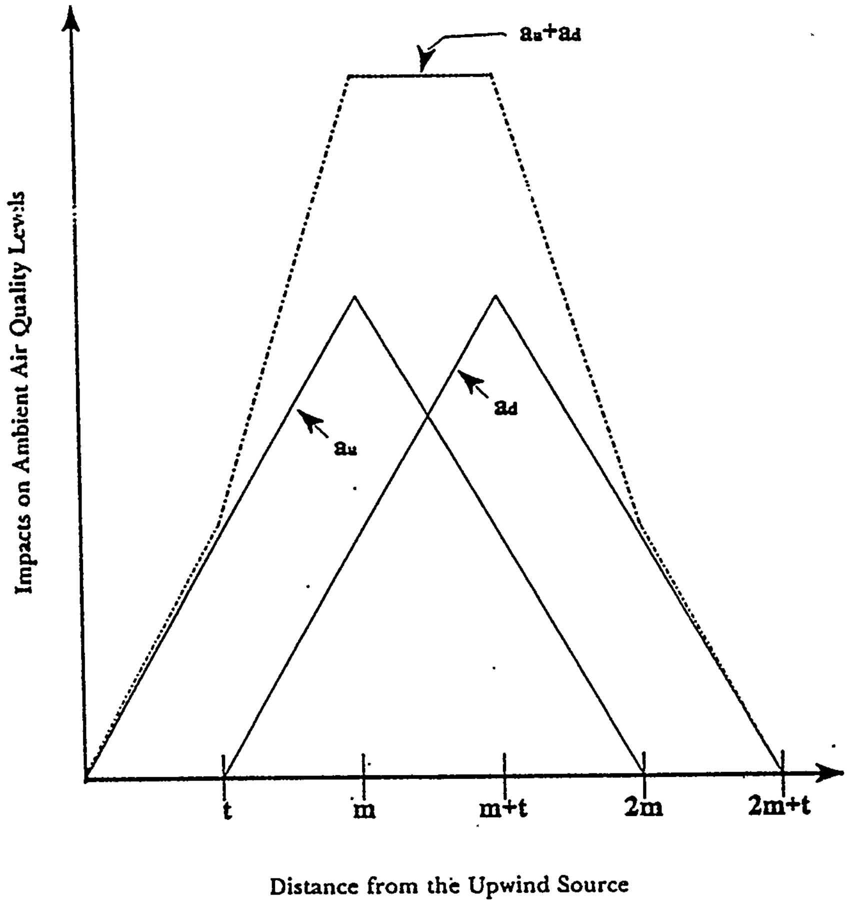
As indicated, the objective is to minimize the total cost of meeting the ambient standard, which is the sum of the pollution control costs, c_u and c_d, borne by the upwind and downwind sources, respectively. For each source, this cost is a function of the levels of emissions e_u and e_d. The cost rises as the level of emissions falls because the source needs to make more expenditures in pollution control. Moreover, the lower the level of emissions, the higher the increase in costs for an additional unit of emissions reduction. This assumption, which is standard, reflects the fact that a source will first reduce its emissions by the cheapest method, resorting to more expensive methods only when the cheaper reductions have been exhausted. So, for example, an electric utility might be able to achieve a moderate level of emissions reductions by the relatively inexpensive technique of washing its coal, but to achieve larger reductions it will have to utilize the far more expensive technique of installing stack scrubbers.

There are three different situations, which are defined by the distance between the upwind and downwind sources. In the first, at the point at which the upwind source has its maximum impact (at a distance *m* from this source), the downwind source has an impact as well. In the second situation, the downwind source has no impact at the point at which the upwind source has its maximum impact, but both sources have an impact further downwind. In the third situation, there is no point at which both sources have an impact.

The analysis that follows focuses on the first situation, because it is the most complex.[9] Figure I illustrates this situation: the upwind source has its maximum impact at point *m*, and at that point the downwind source also has an impact. The extent of the impact from both sources can be broken down into five regions, defined by the distance from the upwind source.

9. The second and third scenarios are discussed briefly *infra* note 10.

FIGURE I: Impacts on Ambient Air Quality Levels
As a Function of Distance



t = distance between the two sources
m = distance from a source at which the source's emissions have the maximum impact on ambient air quality
a_u = impact of the upwind source on ambient air quality
a_d = impact of the downwind source on ambient air quality

First, for distances of less than *t* from the upwind source, the only impact on ambient air quality comes from the upwind source, and it increases with increasing distance. Second, for distances between *t* and *m* from the upwind source, both sources have an impact on ambient air quality, and the impact of each source increases with increasing distance.

Third, for distances between *m* and *m+t* from the upwind source, both sources have an impact on ambient air quality. The impact of the upwind source decreases as the distance from the source increases (because distance from the source is greater than *m*), whereas the impact from the downwind source increases with increasing distance (because throughout the relevant range the distance from the downwind source is less than *m*). Thus, if the emissions of the two sources are equal, as is shown in Figure I, throughout this range the impact on ambient air quality will be constant. In contrast, if the emissions from the upwind source are higher, the impact on ambient air quality decreases as the distance from the sources increases. Conversely, if the emissions from the downwind source are higher, the impact on ambient air quality increases as the distance from the sources increases.

In the fourth region, in which the distance from the upwind source is between $m+t$ and $2m$, the impact from each of the sources decreases as the distance increases. Finally, in the fifth region, in which the distance from the upwind source is between $2m$ and $2m+t$, the upwind source no longer has any impact on ambient air-quality levels; in turn, the impact of the downwind source decreases as the distance increases.

Because the optimization problem analyzed here is constrained by the requirement that the combined impact of the two sources not lead to the violation of the federal ambient standards, it is necessary to determine where the combined emissions have the maximum impact. If the emissions from the two sources satisfy the ambient standard at this point, it will follow, a fortiori, that they will satisfy the ambient standard everywhere else. Figure I reveals that the combined impact of the two sources on ambient air-quality levels will be greater at a distance of *m* from the upwind source than at any smaller distance, since in this range the impact of each of the sources increases as distance increases. Further, the impact will be greater at a distance of $m+t$ than at any greater distance, since in this range the impact of each of the sources decreases as distance increases. Finally, in the range between *m* and $m+t$, the combined impact of the two sources increases with increasing distance if the emissions from the upwind source are smaller than the emissions from the downwind source, and decreases with increasing distance if the emissions from the upwind source are greater than the emissions from the downwind source.

For example, if the marginal cost of emissions reduction of the upwind source is sufficiently greater than the marginal cost of emissions reduction of the downwind source, then the overall cost of meeting the ambient standard will be minimized if the emissions from the upwind source are greater than those of the downwind source. In that case, the maximum combined impact of the two sources will be at a distance of *m* from the upwind source. Conversely, if the marginal cost of emissions reduction of the upwind source is sufficiently smaller than the marginal cost of emissions reduction of the downwind source, then the overall cost of meeting the ambient standard will be minimized if the emissions from the upwind source are smaller than those of the downwind source. Then, the maximum combined impact of the two sources will be at a distance $m+t$ from the upwind source.

Thus, one needs to ensure only that the ambient standard is not violated at two points: at distances from the upwind source of *m* and $m+t$, respectively. If the ambient standard is met at both of these points, it will be met at all other points as well. One needs to ensure that the ambient standard is met at both of these points because one does not know until the problem is solved what the optimal relationship between the emissions of the two sources will be. The ambient standard, however, is going to be constraining only at one of these points (unless the optimal emissions from both sources are identical).

As indicated above, given that the federal ambient standards are binding, the objective is to minimize the aggregate costs of meeting these standards. To this point, for expositional convenience, the analysis has proceeded on the basis of a specific model of the impact of emissions on ambient air quality. It is easy to show, however, that the following results hold generally. The cost-minimizing allocation of the pollution control burden of meeting a given ambient standard occurs when, at the point at which the ambient standard is constraining, the ratio of the marginal cost of emissions reduction (the cost of abating one additional unit of emissions, where such a unit is infinitesimal) of the upwind source to the marginal cost of emissions reduction for the downwind source is equal to the ratio of the marginal impact (the impact of one additional unit of emissions, where such a unit is infinitesimal) of the upwind source to the marginal impact of the downwind source on the ambient air quality level in the downwind state.

The intuition behind this result is straightforward. Assume that when the federal ambient standards in the downwind state are met, one additional unit of emissions from the upwind source has twice the impact on the ambient air quality level in the downwind state as one additional unit of emissions from the downwind source, and that the marginal cost of emissions reduction is the same for both sources. In that case, the aggregate cost of meeting the federal ambient standards would be lowered if the upwind source were required to reduce its emissions further and the downwind source were permitted to increase its emissions. Alternatively, if one additional unit of emissions from the upwind source has the same impact on the ambient air-quality level in the downwind state as one additional unit of emissions from the downwind source, and the marginal costs of emissions reduction is twice as high for the upwind source, then the aggregate cost of meeting the federal ambient standards would be lowered if the downwind source were required to reduce its emissions further and the upwind source were permitted to increase its emissions. It is only when the two ratios are equal that the aggregate costs of meeting the federal ambient standards cannot be reduced by reallocating the emission reduction requirements.

This result differs in an important respect from the well-known result of how to minimize the costs of achieving an aggregate level of emissions. In the latter case, the costs are minimized when the marginal costs of emissions reduction are equal for all the sources. Otherwise the aggregate costs would be reduced by imposing more stringent controls on the source with the lower marginal costs and less stringent controls on the source with the higher marginal costs. Where, instead, the goal is not to minimize the cost of meeting an aggregate level of emissions, but rather to minimize the cost of meeting an ambient standard, the solution takes the more complex form described above.[10]

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10. In cases in which $t > m$, see *supra* text accompanying notes 8–9, at the point at which each source has its maximum impact on ambient air quality, the other source has no impact at all. If the ambient standard is met at the point at which each source has its maximum impact, it

The preceding discussion illuminates how to deal with situations in which there is a violation of the ambient standard in the downwind state and where both the upwind and the downwind sources are contributing to the violation. To summarize, the following steps need to be undertaken by a decisionmaker interested in minimizing the aggregate costs of meeting the ambient standard in the downwind state.

First, at a point at which there is a violation, the decisionmaker would determine the impact of one unit of emissions from each of the sources and calculate their ratio. Second, it would determine the marginal costs of emission reduction for each of the firms and calculate their ratio. Third, it would determine at what levels of emissions these ratios are equal; at these levels, the pollution control burden is allocated optimally. Fourth, it would ascertain whether the upwind source is polluting more than this amount and, if so, would order it to reduce its emissions accordingly.

If, in contrast, the upwind source was polluting less than this optimal amount, the decisionmaker would simply deny the downwind state's petition, and all the reductions would have to come from the downwind state. From the perspective of social welfare, too little pollution from the upwind source can be as undesirable as too much pollution, because it permits the downwind source to emit a suboptimally large amount of pollution without violating the ambient standard. Nonetheless, the reason for federal intervention—the concern about interstate externalities—is implicated only if the upwind pollution is excessive.

The work of the decisionmaker, however, does not end here. The fact that it was able to calculate the optimal allocation of the pollution control burden at a particular point does not mean that the corresponding levels of emissions will lead to the achievement of the ambient standard everywhere else. Even if the the basis for this calculation were the point where the ambient standard was violated by the largest amount, it may well be that the optimal level of emissions, from the perspective of minimizing the costs of meeting the ambient standard at that point, might nonetheless lead to violations elsewhere. The decisionmaker would then have to determine what additional reductions would need to be made, and in what proportion, so that the ambient standard was met everywhere.

A rule of thumb for how to carry out this process might be to start at the point of maximum violation and determine the optimal adjustment to emissions of the upwind and downwind sources consistent with meeting the ambient standard there. Next, one would check whether these adjusted levels of emissions lead to violations elsewhere. If so, one would focus on the point at which the adjusted levels of emissions produced the largest violation and determine, once again, the optimal adjustments. This process would be repeated until there were no further violations.

The inquiry becomes more complicated when there are multiple sources in the upwind and downwind states. The ratios of marginal costs of emissions reductions would have to be set equal to the ratio of the impacts of one unit of

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follows that it will be met everywhere else as well. Thus, the permissible level of emissions from each source is independent of the cost of achieving the emission reductions: it is simply the level necessary to meet the ambient standard. The solution is simply $e_u = e_d = s/m$, and is independent, for both sources, of the costs of pollution abatement.

emissions for each pair of sources. Any upwind source that had emissions that were excessive under this standard would be ordered to reduce them. Here, too, the decisionmaker would have to perform the iterations described above to ensure that the ambient standard was met at every point.

The preceding inquiry exposes fundamental misconceptions in the administrative and judicial approaches to the problem of interstate pollution.[11] First, it is not desirable to bar all upwind pollution from reaching the downwind state. Because of prevailing winds, for a given location and stack height, it may be inevitable that emissions from the upwind state will have some impact on ambient air quality in the downwind state. To prohibit any such impact is tantamount to prohibiting industrial activity in those locations.

Second, the appropriate test is not dependent on which source is polluting more, whether in the aggregate or per unit of input into or output from the production process. Indeed, it is desirable for the upwind source to pollute more if its marginal cost of emissions reduction is sufficiently higher, or if one unit of its emissions has a sufficiently smaller impact than that of the downwind source at the point in the downwind state where the ambient standard is constraining.

Third, as already indicated, the well known condition that cost minimization requires that the marginal costs of emissions reductions be equal for all sources does not hold where the objective is to minimize the aggregate cost of meeting a given ambient standard rather than to minimize the aggregate cost of reducing the total level of emissions to a given level.

Fourth, it is inappropriate to rest the analysis solely on a comparison of which source has the larger impact on ambient air-quality levels in the downwind state. Given the location, stack height, and marginal cost of emissions reduction of the upwind source, the cost-minimizing solution might be for that source to have a larger impact.

Fifth, the prevailing judicial standard, under which upwind emissions are enjoined only if they significantly contribute to the violation of the ambient standard in the downwind state, is both overinclusive and underinclusive. It is overinclusive because there will be instances in which, as a result of the location, stack height, and marginal costs of emissions reduction of the upwind source, it will be socially desirable for that source to have a large impact on ambient air quality downwind.[12] The standard is underinclusive because, even if the contribution of the upwind source to a violation is small, the aggregate cost of meeting the ambient standard in the downwind state might be reduced by imposing more stringent controls on the upwind source.

To this point, the analysis has been static. It has assumed that the number of sources was fixed and has asked how the pollution control burden among these sources should be allocated to minimize costs. Significant complications arise when the problem is viewed dynamically, so that, over time, additional sources choose to locate in the upwind and downwind states. Neither the EPA nor the courts have addressed these complications.

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11. *See supra* note 7.

12. Of course, if these factors are taken into account in determining which contributions are significant, this problem does not arise.

The addition of a new source can be the but-for cause of a violation of the ambient standards. This violation would trigger the need to recalculate the optimal contributions of upwind and downwind sources by equating the ratios of marginal costs in the manner explained above.

Two features concerning the costs of emissions reduction suggest that it is likely to be considerably cheaper for a new source to meet a given level of emissions reduction than for an existing source to do so. First, new sources tend to install the technology that is optimal for the level of emissions reduction that they are required to meet and anticipate having to meet during the life of the technology. For example, if the standard prevailing when a source installs its technology requires emissions reductions of fifty percent (as compared with the level of uncontrolled emissions), the source is likely to choose the technology that works optimally at that level. While it may be technologically feasible to push that technology to meet a reduction requirement of sixty percent, the costs of doing so are likely to be higher than the costs a new source would incur in installing a technology chosen specifically to meet the sixty percent requirement.

Second, an existing source might need to change its pollution control technology altogether in order to meet a more stringent standard. For example, the technology used to reduce emissions by fifty percent might simply not be suitable to reduce emissions by ninety percent. If so, the source's investment in the original pollution control technology would be worthless and new technology would have to be purchased to meet the more stringent standard.[13]

Because of the nature of these cost functions, if, for example, the ambient air quality in the downwind state is degraded by upwind sources all the way to the level of the federal ambient standards, and the downwind state then attracts new sources, the cost minimizing solution has the following properties: it would call for tightening the emission reduction requirements for the existing sources in order to accommodate the new growth, while demanding even more stringent emission reductions requirements for the new sources than for the existing sources.

Although this approach will minimize the costs of meeting the federal ambient standards, given the nature of the existing sources, it will not minimize the aggregate costs over time of meeting the federal ambient standards. Instead, it would be less costly overall for the existing sources to be subjected initially to more stringent standards, thus "reserving" a margin for growth, to be consumed by the sources that the state now wants to attract.

If the sources affecting ambient air quality in the downwind state were all located in that state, the decision to "reserve" such a margin for growth would be quite straightforward because such a jurisdiction would capture the cost

13. For discussion of these features of control costs, see, e.g., Robert W. Crandall, *The Political Economy of Clean Air: Practical Constraints on White House Review*, *in* ENVIRONMENTAL POLICY UNDER REAGAN'S EXECUTIVE ORDER: THE ROLE OF BENEFIT-COST ANALYSIS 205, 212–13 (V. Kerry Smith ed., 1984); Matthew D. McCubbins et al., *Structure and Process, Politics and Policy: Administrative Arrangements and the Political Control of Agencies*, 75 VA. L. REV. 431, 467 (1989); Richard B. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CAL. L. REV. 1256, 1270 (1981).

savings that result from its actions. The situation is more complex when sources in an upwind state affect ambient air-quality levels in the downwind state. In that case, both states would have to agree about the likely levels of future economic growth in each state, and agree on how to divide the costs of future pollution.

If both states were a single jurisdiction, one would not worry about a decision to "reserve" a particular area for future economic growth. Unlike the downwind state, such a jurisdiction would not face the structural bias that arises when the costs of preserving a margin for growth are externalized outside its borders.

The problem of allocating economic growth could be addressed through a regional planning authority, or through planning by the federal government. Neither outcome, however, is likely to work well. Because regional planning authorities are formed by representatives of the various affected states, relying on such a mechanism implies confidence in the ability of the states to take care of the problem of interstate externalities absent outside intervention. In seeking to justify the presence of federal regulation to address the problem of interstate externalities, one is assuming that, left to their own devices, states will not be able to solve the problem well.[14]

As an alternative, a federal planning process could take place when the downwind state complained about the upwind pollution by challenging the proposed permit of an upwind source. In theory, the inquiry could focus on the likelihood that each state would face a demand for industrial location in the future. The factors at stake, however, are too speculative and manipulable for the federal inquiry to have much credibility.[15]

B. Role of Stack Height

To this point, the analysis has proceeded on the assumption that the stack heights of sources are fixed. This section relaxes the assumption of fixed stack heights and determines both the optimal levels of emissions and the optimal stack heights for upwind and downwind sources.

For this purpose, the problem needs to be modified in some minor ways. First, the pollution control costs, c_u and c_d, are now a function of both the level emissions, e_u and e_d, and the stack heights, h_u and h_d. For a given level of emissions, higher stacks imply higher control costs. Moreover, the higher the stack, the greater the cost of an additional unit of stack height.[16]

Second, the impact of a source's emissions on ambient air-quality levels

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14. *See supra* text accompanying notes 4–5.

15. A possible solution, based on the use of marketable permits schemes in units of environmental degradation (as opposed to the more traditional marketable permit schemes in units of emissions) is explored in Part IV of Revesz, *supra* note *.

16. One manufacturer estimates that a 1000-foot stack costs more than three times as much as a 500-foot stack, in part because of the need to have a stronger base to support the larger structure. *See The Building of Tall (and Not So Tall) Stacks*, ENVTL. SCI. & TECH., June 1975, at 522, 525 [hereinafter *Tall (and Not So Tall) Stacks*]. For estimates of the costs of building tall stacks, see *Clean Air Act Oversight: Hearings Before the Subcomm. on Envtl. Pollution, Sen. Comm. on Public Works*, 93d Cong., 2d Sess. 516–17, 527 (1974); *Tall (and Not So Tall) Stacks, supra*, at 525.

depends on the height of the stack. Higher stacks imply smaller impacts on ambient air quality closer to the source and greater impacts further from the source.[17]

The cost minimizing solution to this problem requires that four conditions be satisfied at the point at which the federal ambient standards are constraining. First, as in the case where the level of emission reduction was the only decision variable,[18] cost-minimization requires that the ratio of the cost of an additional unit of emissions reduction of the upwind source to the cost of an additional unit of emissions reduction for the downwind source be equal to the ratio of the impact on downwind ambient air quality of an additional unit of emissions reduction from the upwind source to the impact of an additional unit of emissions reduction from the downwind source.[19]

Second, cost minimization requires that the ratio of the cost of an additional unit of stack height for the upwind source to the cost of an additional unit of stack height for the downwind source be equal to the ratio of the impact on downwind ambient air quality of an additional unit of stack height for the upwind source to the impact of an additional unit of stack height for the downwind source. Otherwise, as a result of an argument similar to the one made in the case of emissions, aggregate costs would be reduced by decreasing the height of one stack and increasing the height of the other stack.

For example, if, in contrast, one additional unit of stack height for the upwind source has the same impact on the ambient air quality level in the downwind state as one unit additional unit of stack height for the downwind source, but the cost of an additional unit of stack height is twice as high for the upwind source, the aggregate cost of meeting the federal ambient standards would be lowered if the upwind source had a smaller stack and the downwind source had a taller stack. The additional impact on ambient air quality of the upwind source would then be mitigated by the decreased impact of the downwind source.[20]

In contrast to the first and second conditions, which set forth the relationships across sources concerning, respectively, emission levels and stack heights, the third and fourth conditions define, for each source, the optimal tradeoffs between emissions and stack height. For each source, cost minimization requires that the ratio of the cost of an additional unit of emission reduction to the cost of an additional unit of stack height increase be equal to the ratio of the impact on ambient air quality of an additional unit of emissions

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17. *See* SAMUEL J. WILLIAMSON, FUNDAMENTALS OF AIR POLLUTION 219–25 (1973). Another complication arises because the impact of emissions on downwind ambient air quality depends not only on stack height but also on plume rise. If the emissions are warm when they leave the stack, they will continue to rise as a result of their buoyancy. In addition, the emissions can be induced to rise by means of fans—a common technique in the case of large steam-generating electrical power plants. The effective height of a stack is therefore equal to its physical height plus the amount of plume rise. *See id.* at 226–27. The regulations prohibit "manipulating" the production process to increase plume rise but do not specify what counts as manipulation. *See* 40 C.F.R. § 51.100(hh)(1)(iii) (1996).

18. *See supra* text accompanying notes 9–10.

19. As in the prior subsection, all units are assumed to be infinitesimal.

20. This example assumes that the distance from both sources to the point at which their combined emissions produce the largest impact on ambient air-quality levels is such that for each source, a taller stack decreases the impact on ambient air-quality levels of one unit of emissions.

to the impact of an additional unit of stack height. Otherwise, aggregate costs could be reduced by intra-source tradeoffs between emissions and stack height: the aggregate costs of compliance could be lowered by lower emissions compensating for lower stack height, or vice versa.

C. Role of Location

This section relaxes the assumption that the location of the sources is fixed. That assumption would hold if the location of a source is determined independently of the impact of its emissions on ambient air-quality levels. But that is not so. Sources can choose their location, and states have an incentive to favor certain choices over others.

If a source's environmental effects were confined to a single jurisdiction, the source could pick the location that was most convenient for it in light of all the associated costs and benefits, such as the price of land, access to raw materials, proximity to customers, and availability of a suitable workforce, as well as costs of meeting the environmental requirements. For example, one location might be preferable on non-environmental grounds but might have associated with it higher costs of environmental compliance as a result of its greater proximity to other sources. Because the firm "sees" all the associated costs and benefits, it will be able to resolve the tradeoff in a socially desirable way. The only action required on the part of the state to produce this socially desirable outcome is for it to have a credible environmental enforcement scheme (or, alternatively, for there to be a credible federal enforcement scheme).

The situation is different when there are interjurisdictional externalities. Then, the state in which the firm wishes to locate has no incentive to worry about the interjurisdictional effects of the firm's pollution. Similarly, absent an interstate mechanism designed to control interjurisdictional spillovers, the firm's tradeoff will be skewed. It will take into account all the non-environmental costs and benefits of competing locations, but will consider only the environmental compliance cost over which the state in which it locates has a regulatory interest.

Thus, unless there is a well functioning scheme for controlling interjurisdictional pollution, the presence of interstate borders will affect the location of sources in a way that reduces social welfare. Specifically, other things being equal, a state will benefit if its sources locate as far downwind as possible, so that the state can capture the source's benefits in terms of jobs and taxes without suffering the full environmental and regulatory costs. Similarly, the source will benefit from less stringent environmental requirements.

When a source from an upwind state applies for a permit, the inquiry concerning the permissibility of the interstate impact must consider whether the proposed location of the source was affected by the presence of the border. If so, the source should be required to locate in the place where it would have located if its emissions had affected only one jurisdiction. Absent such an inquiry, the source, as a result of its suboptimal location, will have too large an impact on ambient air quality in the downwind state.

Thus, to solve the optimization problem, one needs to determine not only the optimal emission limitations and stack heights for the upwind and downwind sources but also the optimal locations of these sources. To perform this inquiry one needs to know the effect of location both on the impact of a source's emissions on ambient air-quality levels and on the interactions between the emissions of upwind and downwind sources.

Once again, at the point at which the ambient standard in the downwind state is constraining, several conditions must be satisfied. As before, the ratio of the cost of an additional unit of emission reduction from the upwind source to the cost of an additional unit of emission reduction from the downwind source must be equal to the ratio of the impact on downwind ambient air quality of an additional unit of emissions from the upwind source to the impact of an additional unit of emission reduction from the downwind source.

Also, the ratio of the cost of an additional unit of stack height for the upwind source to the cost of an additional unit of stack height for the downwind source must be equal to the ratio of the impact on downwind ambient air quality of an additional unit of stack height from the upwind source to the impact of an additional unit of stack height from the downwind source.

A similar condition applies to location: the ratio of the cost of one additional unit of departure from the location that would have been preferred absent environmental regulation for the upwind source to the cost of a similar locational movement for the downwind source must be equal to the ratio of the impacts of such departures on downwind ambient air quality.[21]

It might appear at first glance that only the upwind source would be motivated by the desire to externalize the effects of pollution to other states. But the downwind source can externalize costs as well, by locating in a place in which the effects of its emissions on ambient air-quality levels result in the need for the upwind source to undertake greater emissions reductions. In a single jurisdiction, a regulator would have an incentive to take this possibility into account in approving permits. In contrast, when two separate jurisdictions are involved, absent a regime for controlling spillovers, the downwind source would not pay attention to the impact of its locational choice on the pollution reduction costs of the upwind source.

This discussion underscores the difference between the static and dynamic considerations of the permissibility of interstate impacts. Once a source has been located, the cost of requiring it to relocate is likely to be prohibitive. As a result, the order in which sources locate matters a great deal. For example, one source might be fairly indifferent between two possible locations. If it chooses the location that is preferable, though only by a small margin, it might foreclose a later source from locating there even though, for that source, the location would have been preferable by a far larger margin. In a single jurisdiction, this problem might be taken care of through the planning process, where different sites could be reserved for predicted economic growth of different types. When there are interjurisdictional consequences, the coordination problems between the two jurisdictions are far more complex.[22] Absent such ex ante planning, the ex post remedies available in actions brought

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21. In addition, for each source there will be three intra-source conditions, concerning the relationships among emissions, stack height, and location. *See supra* text accompanying note 20.

22. *See supra* text accompanying notes 14–15.

by the downwind states against the upwind pollution will not lead to siting decisions that reduce the aggregate cost of pollution control over time.

III. DEALING WITH INSTANCES IN WHICH THE AMBIENT STANDARD IN THE DOWNWIND STATE IS NOT VIOLATED

A wholly different set of issues is present in cases in which the downwind state meets the federal ambient standards but nonetheless would like to limit upwind pollution. There are two distinct scenarios. First, the downwind state might have a state ambient standard that is more stringent than the federal standard, and this standard might be violated as a result of the combined impact of the in-state and upwind pollution. Under section 116 of the Clean Air Act, states can set more stringent standards.[23] The statute, however, says nothing about whether a state can then invoke this more stringent standard in order to enjoin upwind pollution.

Second, the downwind state might wish to reserve a margin for economic growth in order to attract new industry in the future. Under this scenario, industry might not be currently interested in locating in the state. The state will believe, however, that economic conditions might change in the future and might want to insure that when this happens, its margin for growth will not have been consumed by pollution coming from the upwind state.[24]

The first scenario lends itself to the most straightforward analysis. The downwind state's attempt to invoke its more stringent state ambient standards against the upwind source might reflect an effort to externalize the costs of better environmental quality. Alternatively, it could be a policy that would have been undertaken even if the state had taken into account all the costs imposed outside its borders.

To address this scenario, one should first ask: if the upwind state and downwind state had been a single jurisdiction, would a decisionmaker interested in maximizing aggregate social welfare have adopted the more stringent ambient standard in the downwind state? Such a decision would be made if the preferences in the downwind state for more stringent environmental standards are such that the resulting net benefits to the downwind state outweigh the costs imposed on polluters in the upwind state. If that is the case, it should not matter that part of the costs are borne by the upwind state.

This inquiry reveals whether the more stringent state ambient standard is permissible. A state ambient standard that does not meet this test should not be the predicate for any action to enjoin upwind pollution, and any attempt by the downwind state to limit such pollution should rest exclusively on the federal ambient standards. If, in contrast, the state ambient standard survives scrutiny, the second step involves determining when upwind pollution that violates such a

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23. *See* Clean Air Act § 116 (codified at 42 U.S.C. § 7416 (1994)).

24. A similar situation arises in instances in which the downwind state might wish to attract new industry immediately, but might be unable to do so because it is in violation of the ambient standards for another pollutant. For example, sources that emit sulfur dioxide typically also emit particulates. Thus, for example, if a state is a non-attainment area for particulates, it would not be able to use its margin for growth with respect to sulfur dioxide. The question, then, is whether the upwind state should be allowed to consume this margin of growth without constraint.

standard is impermissible. The inquiry described in the previous subsections would then be performed, treating the more stringent state ambient standard as if it were the relevant ambient standard.

In the second scenario, the downwind state wishes to preserve its margin for growth in order to attract industry in the future. At first glance, it might appear that the state could adequately protect this margin for growth by relaxing the emissions limitations on its existing sources until the ambient standard is constraining. In the event of a later violation caused by upwind pollution, the downwind state could move to enjoin such pollution on the ground that it is the but-for cause of the violation. Subsequently, when new sources were ready to move in, the state could strengthen the emissions limitations on its existing sources.

Such a strategy is quite problematic. From the perspective of cost minimization, what matters is whether the marginal costs of emissions reduction among the sources have the correct relationships, not which source's pollution placed the emissions in the downwind state over the level of the ambient standards. The latter approach, moreover, creates undesirable incentives for states to offer their sources suboptimally lax standards in order to capture the margin for growth before the other state consumes it.

Alternatively, one could let the upwind state consume the margin for growth during the period in which there is no demand for industrial location in the downwind state. Subsequently, when economic conditions in the downwind state change, the downwind state could move to limit the upwind pollution. This strategy is problematic as well. As already indicated, it generally is cheaper to build a polluting facility designed to meet a stringent emissions standard than to build it with a less stringent standard in mind and, subsequently, require it to meet a more stringent standard.[25] It is true that the upwind sources might predict what the calculus would look like once the downwind state was able to attract new sources, but such an inquiry would be highly speculative.

Thus, neither of the polar solutions is desirable. Instead, it would be preferable to predict at the outset the future rate and location of economic growth. As discussed above, however, neither an interstate nor a federal planning process is likely to work well.[26]

CONCLUSION

The longer-term objective of my work is to lay the foundation for a more rational allocation of decisionmaking authority in the environmental arena between the federal government and the states. This Article did not question the existence of the federal ambient standards. It asked, instead, how to constrain interstate externalities desirably in light of these standards. A broader inquiry would ask, simultaneously, whether ambient standards should be set at the federal level and how interstate externalities should be constrained.

Finally, it is worth emphasizing that the issues studied here arise in any federal system. Thus, this project should be of direct interest to environmental policymaking in the European Union, where there is also a mismatch between

25. *See supra* text accompanying notes 12–14.
26. *See supra* text accompanying notes 14–15.

the rhetoric of interstate externalities and the Council Directives on ambient and emission standards that form the core of the Union's environmental policy. Moreover, the standards derived here should aid in the development of international environmental law, with respect to both regional pollution that crosses international boundaries, and to pollution that affects the global commons.