expansion in an aircraft manufacturer, for example, may make it possible for aluminum producers to take advantage of economies of scale so that other metal fabricating firms also get the opportunity to buy cheaper aluminum. In either case, there is a difference between private and social returns—that is, the benefits accruing to society are greater than the benefits earned by the firm. Meanwhile, my neighbors could benefit if I maintain my house well or educate my children to make them more responsible citizens. The key in any case is that while the beneficiaries do not pay for the ancillary benefit.

All of the news is not good, however. Negative externalities can also be generated by either production or consumption when the actions of one economic actor could cause uncompensated harm for others. Firms may generate pollution that causes health and property damage downstream or downwind. People may cover on SUVs that consume excessive amounts of fuel and cause excessive amounts of damage in a collision. Again, in either case, the key is still that the people who are harmed are not compensated.

Example 18.4

Basic Research as a Public Good

The theory of positive externalities can shed some light on issues surrounding policies designed to promote publicly sponsored basic research. The critical question can be simply expressed: Why should the government be involved instead of relying on private enterprise? To answer this question, it is important to realize that basic scientific research can generate substantial external economies. Important additions to fundamental knowledge can have significant impacts in many fields. It follows that a firm whose employees make a scientific breakthrough cannot generally hope to realize the full value of the new knowledge that it might create. It cannot fully engage in the range of activities that might be supported, and so it can seldom capture the full social value. Indeed, some discoveries into the laws of nature cannot even be patented.

All of these insights support a view that a divergence between the private and social benefits of basic research can exist and that we should therefore expect a competitive economy to devote fewer resources to such efforts than would be socially optimal. On pure economic grounds, as a result, a good case for government support can be made. Indeed, the 1987 report of the Council of Economic Advisers made just that case when it noted that “the Federal Government has an important role (to play) in funding basic scientific research. Such research can often contribute to technological advance in the longer term. However, its benefits are often too diffuse and difficult to profit from it to be undertaken by private business.”

Similar considerations support a complementary argument that government support should extend to the technological underpinnings of broadly defined industrial areas. The National Advisory Committee on Aeronautics, for example, conducted research and development activities into wind tunnels, aircraft fuel, aircraft design, and other fundamental matters relevant to aviation. No individual firm would have had much incentive to do this work, because it could appropriate only a small share of the benefits. Nonetheless, principles of microeconomics suggest that it was the right thing to do. The same argument applies today in the debate about the government’s role, through the National Institutes of Health and the National Science Foundation, in sponsoring fundamental research in areas that help pharmaceutical companies develop new drugs for profit.

There is, however, a cautionary side to these arguments. Government-sponsored research can have private value, and private firms can occasionally be seen using public support to advance proprietary knowledge. The profit motive of private industry is therefore in direct opposition to the public-good motive that drives government involvement. This is why public support encourages and rewards the publication of research results and the rapid dissemination of data collected under its auspices.


ECONOMIC CONSEQUENCES OF EXTERNALITIES

How do externalities alter the efficiency of the allocation of resources under perfect competition? People who undertake actions that contribute to society’s welfare without compensation are likely to undertake these actions less frequently than would be socially desirable. The same holds true for firms. If, say, the production of a certain good, such as beryllium, were responsible for creating external economies and if the producers were not compensated fully for those benefits, then they would likely produce less than the socially efficient quantity under perfect competition. Producers are not going to increase the output of their product simply because it reduces costs for other companies. By the same token, people who undertake actions that impose costs on others are likely to undertake these actions more frequently than is socially desirable if they are not held accountable for those external costs. The same holds true for firms. If the production of a certain good is responsible for creating external diseconomies, then more of this good is likely to be produced under perfect competition than is socially efficient.

EXTERNALITIES: THE CASE OF ENVIRONMENTAL POLLUTION

Having argued in general that there is a role for government when externalities distort the workings of competitive markets, we now turn to the most persuasive example—the problem of what to do in the face of environmental pollution.

Divergence of private and social costs

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Many of our streams and lakes have historically served as depositories of chemical waste generated by industrial plants and mines. Some are cleaner now, but many still suffer damage from earlier discharges of chemicals, like PCBs, whose "half-lives" are measured in hundreds of years. Many pesticides, fertilizers, and detergents used by farms and homes find their way into our lakes and waterways, where they have damaged commercial and recreational fishing. Automobiles are a primary source of many air pollutants. The residue of their emissions can foul both the air that we breathe and the land located close to the road that we drive on. Factories generate particles of various kinds, often through the combustion of fossil fuels; these pollute the air and fall onto the ground—both near and far. Some of our pollution has even been shown to cause damage on a global scale. The production and emission of chlorofluorocarbons has damaged the ozone layer and exposed much of the planet to increased ultraviolet (UV-B) radiation from the sun; the emission of carbon dioxide and other greenhouse gases has begun to warm the planet at rates that many find alarming.

Why does our society tolerate any pollution of the environment? We now know that an externality occurs when one person's (or firm's) use or abuse of a resource damages other people who cannot obtain proper compensation. When this occurs, a competitive economy is unlikely to function properly. For market prices to produce an efficient allocation of resources, it is necessary that the full cost of using each resource be borne by the person or firm that uses it. If this is not the case, so that the user bears only part of the full costs, then the resource is not likely to be directed by the price system into the socially optimal use. And why do people use resources like the environment? Because pollution is a by-product of activities that add to their welfare. These activities bring economic gain to producers and utility gain to consumers. We do not pollute the planet just for fun; we do it as part of activities that improve our welfare. The economist's view is that pollution creates another trade-off of cost and benefit that must be weighed on a case-by-case basis.

To explore this point a little further, recall from Chapter 16 that resources are used most efficiently in a perfectly competitive economy because they are allocated to the people and firms that find it worthwhile to bid the most for them. Underlying this scheme is the notion that the resulting prices of all resources would reflect their marginal cost. However, that the presence of external diseconomies made it possible that people and firms did not pay the true social cost for certain resources. Suppose, in particular, that some firms or people were using water or air or free even though other firms or people were incurring some cost from this use. Suppose, to be quite specific, that some firms were polluting the air or water and that others were suffering economic losses as a result. In this case, the private costs of using air and water would differ from the social costs. The prices paid by the user of water and air would be smaller than the true cost to society. But users of water and air would be guided in their decisions by the private costs of water and air—costs that would be reflected by the prices that they had to pay. Faced with this difference between private and point of view, because the prices that they would pay for air and water would be too low.

Note that the divergence between private and social costs occurs if and only if the use of water or air by one firm or person imposes costs on other firms or other people. A paper mill that uses water and then restores it to its original quality would not be responsible for creating a divergence between private and social costs; it would be paying the full social cost of using the water in the (presumably minimum) cost of running the restoration process. But if the same mill dumped untreated wastes into a stream so that firms and towns downstream had to pay to restore the quality of the water, then it would be responsible for creating a divergence between private and social costs. The same is true of air pollution. If an electric-power plant used the atmosphere as a cheap and convenient place to dispose of its emissions, but people living and working near the plant bore some costs (including poorer health and the more frequent need to paint their houses) as a result, then there would be a divergence between private and social costs.

Efficient Pollution Control

Any industry should, in general, be able to vary the amount of pollution that it generates at each level of output, especially in the long run. A representative firm may, for example, install pollution-control devices like scrubbers or electrostatic precipitators to reduce the amount of pollution that it generates at each level of output. What is the economically efficient level of pollution control for a specific level of industrywide output? This might appear at first blush to be a foolish question. Isn't it obvious that zero pollution is the best level? Strange as it may seem, the answer is no. Instead, the economically efficient solution for society generally involves a certain amount of pollution. This statement may not warm the hearts of some environmentalists, but it is true nonetheless.

To see why, consult Figure 18.3. It shows the total social cost of each level of discharge of industry's wastes, holding constant the industry's output. Clearly, the more untreated waste the industry dumps into the environment, the greater the total costs. Figure 18.3 also shows the costs of pollution control at each level of industry's waste. Just as clearly, the more the industry cuts down on the amount of wastes it discharges, the higher are its costs of pollution control. In addition, Figure 18.3 shows the sum of these two costs—the cost of pollution and the cost of pollution control—at each level of discharge of the industry's wastes.

From the point of view of society as a whole, the industry should reduce its discharge of pollution to the point where the sum of these two costs is minimized. Specifically, the efficient level of pollution in the industry is R in Figure 18.3. Why? Because increasing pollution from a level lower than R would improve social welfare. Discharging one more unit of pollution would increase the cost of pollution, but it would reduce the cost of pollution control. Given the industry's output, this trade-off indicates that the lowest social cost occurs at the point where pollution is at its minimum.
also improve welfare. In this case, discharging one fewer unit of pollution would increase the cost of pollution control, but it would reduce the cost of pollution by more.

To make this more evident, curve AA’ in Figure 18.4 shows the marginal cost of an extra unit of discharge of waste at each level. Curve BB’ in Figure 18.4 also shows the marginal cost of reducing the industry’s discharge of waste by 1 unit. The economically efficient level of pollution for the industry occurs at the point where the two curves intersect. At this point, the cost of an extra unit of pollution would just equal the extra cost of reducing pollution by an extra unit. Regardless of whether we look at Figure 18.3 or Figure 18.4, the answer is the same: R is the economically efficient level of pollution.

Earlier we observed that the efficient level of pollution is generally not zero. It should now be clear why this is true. The costs of reducing pollution can exceed the associated benefits if control is pushed beyond a certain point. In Figures 18.3 and 18.4, this point is reached when pollution is limited to R. But could the efficient level of pollution be zero? Sure. Zero would be the right answer if the pollutant were so damaging that the marginal cost of even the first unit released into the environment exceeded the marginal cost of not allowing its release. Graphically, zero could be efficient in Figure 18.4 if marginal-cost curve AA’ starts from a point on the vertical axis that is higher than B (indicating that the cost of pollution would increase faster from zero than the cost of pollution control would fall).

Direct Regulation, Effluent Fees, and Transferable Emission Permits

Left to its own devices, the industry in Figure 18.4 would not necessarily reduce its pollution level to R. Why? Because it would not necessarily pay all of the social costs of its pollution. Indeed, if the industry paid no private cost for its pollution, then it would emit T units—the quantity for which the marginal cost of control would equal zero. This, of course, is the heart of the problem. How can the government establish incentives that would lead industries to choose the efficient amount of pollution control in their own best interest, even if they do not face all of the social costs of residual emissions?

Direct regulation of polluting activity (i.e., setting a legal limit for pollution) frequently comes to mind. The government could, for example, simply limit the industry’s pollution to R units by decree. Direct regulation of this sort was popular in the United States shortly after the passage of the first Clean Air Act in the 1970s. The decrees were generally associated with definitions of the “best available technologies” for pollution control, but they were criticized frequently for being too rigid to accommodate efficiently the changing landscape of modern industry and the diversity of the suppliers of modern markets.

Effluent fees offer governments a second approach to pollution control. An effluent fee is a unit price that a polluter must pay to the government for discharging waste. The idea behind their imposition is that they can bring the marginal private cost of polluting faced by firms closer to the true marginal social cost of their emissions. In Figure 18.4, for example, an effluent fee of E per unit of pollution discharge might be charged. If it were, then the (private) marginal cost of an additional unit of pollution

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discharge to the industry would be $E$, and so the industry would cut back its pollution to the efficient level, $R$. Why? Because it would be worth cutting back pollution so long as the marginal cost of reducing pollution by a unit were less than $E$. As you can see from Figure 18.4, marginal cost falls short of $E$ as long as the pollution discharge exceeds $R$. To maximize their profits, therefore, the firms in the industry would reduce pollution to $R$ units.

Effluent fees often have one major advantage over direct regulation. It is, of course, socially desirable to use the cheapest way to achieve any given reduction in pollution, and a system of effluent fees is more likely to accomplish this result than direct regulation. To see why, first consider a particular polluter facing an effluent charge. It would find it profitable to reduce its discharge of waste to the point where the (marginal) cost of reducing its emissions by 1 unit equaled the fee. The effluent fee would be the same for all polluters, so that imposing an effluent fee would guarantee that the marginal cost of reducing pollution by one extra unit would be the same for all polluters. And it is a simple matter to show that the total cost of achieving the corresponding reduction in total emissions across all of the polluters would thereby be minimized. To that end, suppose that the cost of reducing waste discharges by an additional unit were not the same for all polluters (as might be the case if they were given individual quantity limits). The cost of achieving the same amount of pollution control could then be reduced by allowing polluters whose marginal control costs were high to increase their emissions (and lower their marginal control costs) while encouraging polluters whose marginal control costs were low to reduce theirs (by an equal amount).

Effluent fees do not, however, guarantee the same constant level of total emissions that could be expected if a set of individual quantity limits were issued. Why not? Because firms will pay for the right to more or less pollution as they increase or decrease their outputs. So, although direct regulation would restrict total emissions regardless of business conditions, an equivalent effluent fee could, at best, guarantee that the expected value of total emissions over a long period of time would correspond to the same total. Variation in the level of total pollution can be harmful in some cases, and not in others. The point here is that preference for effluent fees is not quite so clear-cut when the reality of uncertainty is brought to bear on the discussions.

Governments have recently learned that they can work the trade-off between the certainty of direct regulation and the efficiency of effluent charges by issuing a fixed number of transferable emissions permits—permits that allow the holder to generate a certain amount of pollution. The total number of permits can be limited, so that total pollution can be held below any targeted level. The economically efficient amount might be the pollution target, but there could be others (especially if it were difficult to collect the information necessary to identify the efficient level or if there were an emissions threshold beyond which damage would be severe). In any case, allowing permits to be bought and sold would mean that firms whose marginal control costs were high would probably try to buy some (so that they could increase their emissions) and firms whose marginal control costs were low would try to sell some (and make money even though they would have to reduce their emissions). In fact, the market would work to bring the marginal cost of pollution control at each firm equal to the market price of permits, and so it would bring the marginal cost of pollution control at every firm into line with the marginal cost at every other firm. Notice that this is exactly the condition for minimizing the cost of holding total emissions to a particular level.

Example 18.5

Alternative Pollution Policy Designs—Working a Problem

Consider a situation where an upstream farm pollutes a river with fertilizer runoff, and assume that a downstream town draws its drinking water from the same river. Figure 18.5 offers a generic portrait of the situation. Let line $0B$ represent either the marginal social cost to the town (or the marginal cost of cleansing the drinking water before it is distributed). Let line $CD$ represent the marginal private benefit derived by the farm by applying fertilizer. The socially optimal level of pollution would be $E$ units where the marginal benefit accruing to the farmer from his fertilizing would equal the marginal cost to the townsfolk of coping with the residual pollution from the associated runoff.

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Figure 18.5

THE COSTS AND BENEFITS OF CONTROLLING POLLUTING RUNOFF

$\begin{array}{c}
\text{Marginal private benefit to the farmer} \\
\text{Marginal social cost to the town}
\end{array}$

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The government could intervene with a wide range of different sorts of policies. It could, for example, simply charge the farmer a tax equal to $P$ for each unit of pollution that ran off into the river. The farmer would then decide how much to pollute by finding the level where his marginal private benefit equaled the tax; $E$ units would be chosen.

The government could, alternatively, require that the farmer pollute no more than $E$ units. If the penalty for violating this limit were sufficiently high, then the farmer could, indeed, fertilize up to the point where $E$ units could be expected to run off into the river. What would be sufficiently high? If a fine were imposed for each unit in excess of the limit, then it would have to exceed the expected benefit of violation. Otherwise, the expected benefit of violating the limit would exceed the expected cost. So, if the probability of being caught and successfully prosecuted were given by $PR$, then the fine would have to be at least $P/PR$. The marginal private cost of pollution to the farmer would then have three segments. It would correspond to the horizontal axis at $0$ from the origin to point $E$; that is, the farmer would get the first $E$ units of pollution for free. It would climb vertically at point $E$ to at least point $A$, and it would then be horizontal again at a level at least as high as segment $AF$. The farmer would then again, the marginal private benefit equal to this policy-driven marginal private cost to determine his level of pollution. The two curves would intersect at point $A$, and $E$ units would run off into the river.

**Microlink 18.2 Cost-Minimizing Conditions for an Externality**

The example of a multifirm monopolist in Chapter 10 made it clear that the cost of producing any quantity of any good from multiple sources would be minimized if the marginal cost of producing the last unit were the same at each source. This condition was met automatically in the perfectly competitive models of Chapter 8 because each profit-maximizing firm would react to the same market price by setting marginal cost equal to that price. Cast in the context of a multiple-source pollution problem, this result states that the cost of reducing total emissions to any specific target would be minimized if the marginal cost of reducing the last unit from the effluent were the same for all sources. This condition can be also be met automatically if the government intervened by imposing identical pollution charges on emissions from each source. Each polluter would then minimize the (now) private cost of pollution by setting the marginal cost of emissions reduction equal to the same “price.”

**PROPERTY RIGHTS AND THE SO-CALLED COASE THEOREM**

A perfectly competitive economy can sometimes allocate resources efficiently even in the face of seemingly severe external costs or extraordinary external benefits. To see how, consider a firm that pollutes a stream. If downstream users were endowed with well-defined property rights to suitable water, then the upstream firm might be able to purchase the right to pollute the stream to a certain extent. Or, if the firm were endowed with property rights over the stream, downstream users might be able to purchase improved water quality from the polluter. In either case, the welfare calculations of both interested parties would now include the externality so that the divergence between social and private costs could actually disappear. At the very least, the divergence should be diminished. These stories are encouraging, but they do not lead to a very strong conclusion. They simply suggest that competitive markets might be able to handle external effects. Neither arrangement could work, though, if the costs of negotiating compensation were too large.

The Nobel laureate Ronald Coase was among the first to look at the externality problem in this context. Motivated by the stream example, he was able to argue that a competitive economy will allocate resources efficiently even in the face of significant external diseconomies if negotiations of this sort can be conducted with little or no cost. If downstream water users held the property rights to clean water, then an upstream firm that wanted to pollute would have to offer them compensation. How much pollution for what price? The firm, pursuing its own best interest, would not find it worthwhile to pollute more than the economically efficient level and would pay no more than the economically efficient price. Coase was also able to show that the efficient outcome could be obtained regardless of which party held the relevant property rights. Downstream water users would, more specifically, never find it in their best interest to negotiate water quality in excess of the economically efficient level; but they could never achieve that level without paying the economically efficient compensation.

The general result exhibited by the story of negotiating along a polluted stream is often referred to as the **Coase theorem**. It has attracted a lot of attention, and it is very important. We must, however, take special note of its applicability. It is essential to recognize that the Coase theorem assumes that the costs of negotiating and contracting by the interested parties are relatively small. It assumes, in the stream example, that the downstream water users can get together with the polluting firm and that they can negotiate effectively without prohibitive expense. When there are more than a relatively small number of interested parties, though, the costs of these sorts of negotiations may be so high that they are not feasible (especially when lawyers get involved). Indeed, negotiations of this sort may not be practical even with a relatively small number of interested parties. Unanimity might be impossible with a large number of interested parties, but the existence of mututally advantageous deals does not guarantee that they will be consummated even when only a few people are involved.

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The Coase theorem nonetheless suggests that the assignment of well-defined property rights might help to promote economic efficiency. To get around the difficulties caused by external diseconomies arising from waste disposal, society might find it useful to try to establish more unambiguous property rights for individuals and firms with respect to environmental quality. Assuming that the relevant negotiations are feasible, the interested parties in a particular area might then try to negotiate to determine how much pollution will occur. Note that these property rights must be exchangeable as well as unambiguous if these negotiations are to be effective. It must be possible for a person (or firm) to buy or sell his or her property rights.

**DEMONSTRATING THE COASE THEOREM FROM A GAME-THEORETIC PERSPECTIVE**

Return to the pollution problem of Example 18.5, but suppose now that the townspeople and the farmer were encouraged to negotiate a solution in lieu of government intervention. The first payoff matrix shown in panel A of Figure 18.6 depicts the outcomes (in terms of the points designated in Figure 18.5) of a negotiating game in which the farmer claims property rights to the river. The farmer could, in the absence of any negotiation, therefore fertilize his fields without regard to the resultant impact on water quality. Pollution in the amount \( D \) would run into the river with a total benefit equal to the area of triangle \( OCD \) accruing to the farmer and a cost equal to area \( 0BD \) imposed on the town. If the town and the farmer both agreed to negotiate, however, they would discover that the town would be willing to pay up to \( P \) for each unit of pollution that the farmer did not allow into the river.

As shown in the payoff matrix, the farmer would receive compensation in an amount equal to the area of triangle \( EAFD \) (price \( P \) for each of \( ED \) units now not released into the river) in exchange for lost benefits equal to the area of triangle \( EAD \) for reducing pollution from \( D \) units to \( E \) units; total benefits would then equal area \( OAE \) in remaining private benefits from pollution, plus area \( EAFD \) in revenue minus area \( EAD \) in forgone benefits. Meanwhile, the town would pay an amount equal to area \( EAFD \) but see its costs of water purification fall by an amount equal to the area of trapezoid \( EABD \). Since area \( EAFD \) — area \( EAD > 0 \), the farmer's net benefit would climb above area \( OCD \) by an amount equal to area \( AFD \). In addition, area \( EABD \) — area \( EAFD > 0 \), so the cost to the town would fall by area \( AEF \). Negotiating would therefore be a dominant strategy for both players, and a Nash equilibrium would be discovered in the lower right-hand box of the payoff matrix. Notice that it would support an efficient level of pollution equal to \( E \) units.

If the town held the property rights, however, a second payoff matrix would apply; it is portrayed in panel B of Figure 18.6. Without negotiation or intervention, pollution would be 0, and the farmer would now consider paying the town for the right to pollute up to \( B \) units (make sure that you can verify all of the entries by applying the same reasoning as before). Negotiating would still be a dominant strategy for both players, and the same \( E \) units of pollution would be sustained.

**GOVERNMENT INTERVENTION AND BENEFIT-COST ANALYSIS**

Government interventions into the workings of economies take many different forms. Governments provide public goods. They redistribute income. They regulate monopolies. They regulate polluters. Government officials (and more fundamentally, the general public) must continually decide whether it would be worthwhile for the government to carry out one