Externalities

*This note discusses the problem of **externalities** created by "unpriced" economic activity, analogous problems inside a firm or organization, and how they can be resolved. Prior to class, please prepare your answers to the problem on pages 12-14.*

When the economic activity of a firm or an individual directly affects the welfare of others, that activity generates an *externality*. In business contexts, externalities typically refer to the consequences of a manager's actions that are beyond—that is, "external to"—that manager's assessment of his impact on others.

Externalities arise in many contexts. Common examples include:

- Polluting the air or water
- Driving on a congested highway
- Extracting oil from a common oil field
- Sending spam on the Internet.

The key feature that makes these actions a problem is that the party imposing costs on others typically does not compensate anyone for the costs they impose. That is, the market is not "doing its job" of compensating everyone for the impact a firm or individual has on others. In essence, *a market is missing.*

Externalities also arise and create problems *within* organizations. For instance, the Human Resources department of a large firm might impose bureaucratic hiring rules that are time-consuming for other divisions to comply with and counter-productive for the firm as a whole, simply to make processing a little easier for the HR staff. This results in inefficient decisions and a waste of resources within the firm.

From a managerial standpoint, the externalities likely to confront you or your firm during your career will take one of three forms:

1) An externality caused by your firm that affects the public at large. This will typically entail dealing with governments and regulatory agencies.

2) An externality arising between your firm and another firm. These are resolved through bargaining, which is an application of cooperative game theory.

3) Externalities that arise *within* your firm, because internal resources and synergies are not being accounted for correctly inside the firm, or transfer prices are wrong (or missing entirely).

This note explains the main concepts, with applications, for each of the three types of externalities that firms deal with. In doing so, we emphasize how markets and game theory can be used to resolve the externality in an efficient (value-creating) way.

1. *Theory and Concepts*

We first start off with the traditional theory of externalities in an important context: Pollution. Suppose a paint factory emits volatile organic compounds into the atmosphere (called "VOC emissions"), as a by-product of its operations producing paint. Let's examine the decisions of the polluting firm.

Consider Figure 1. Suppose, for simplicity, that the market for this type of paint is highly competitive and the paint-making firm is a price-taker facing the market price P. (So the flat line at P is the firm's demand curve *and* its MR curve for paint). The firm's marginal cost of making paint is the curve MC. Managers at this profit-maximizing firm produce at the quantity Q that sets MR = MC (= P as well, since managers take price as given).

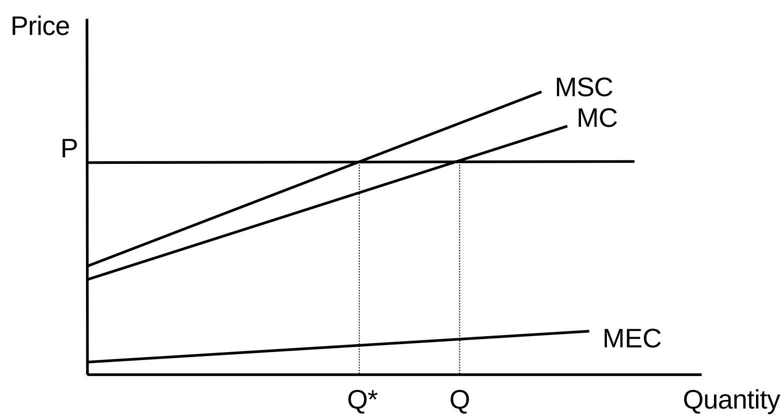

FIGURE 1. *Marginal Social Cost with Externalities*

The costs borne by others because this firm is polluting the air are not part of the firm's MC curve, of course. MC is just the marginal cost making paint; spewing VOC emissions into the air doesn't "cost" the firm anything here. However, it does impose a cost on others in society. The curve MEC is the paint-maker's *marginal external costs* on others. Conceptually, this curve summarizes the incremental cost imposed on everyone that is adversely affected by the pollution. MEC slopes upward because as more VOCs are emitted, the cost imposed on others typically increases at a progressively higher rate.

Clearly, the full costs of producing paint to society are higher than the firm's direct production costs. The full marginal cost curve will lie above the firm's MC curve by the amount of the MEC. This gives what is called the *marginal social costs* curve for producing paint, written as MSC. The MSC curve is the (vertical) sum of the firm's marginal cost curve (MC) and the marginal externality it imposes on others (MEC). For economic efficiency (that is, societies' best outcome), the firm should produce where the MSC curve (= MC + MEC) equals the market price for paint, P. When the firm does so, the optimal output is reduced to Q*.

This is the sense in which, when there are externalities, the unfettered marketplace may fail to produce a socially efficient outcome. The firm does not take into account its external effects on the welfare of others. In the case in Figure 1, where the externality negatively affects others in society, managers produce more than they would if their firm had to pay for cost of the adverse impacts on others.

In principle, this problem can be solved in either of two conventional ways. One is to regulate directly the quantity of pollution that the firm is allowed to put into the air (perhaps zero). The paint factory, facing this limit, would then have the choice of either reducing paint production (or, if pollution was completely prohibited, shutting down its operations completely); or, if technologically feasible, changing to a more expensive technology that does not produce (as much) VOC emissions. Alternatively, the firm could be required to pay a fee or fine per unit of pollution. This would raise the firm's MC curve. If the fee was set at the level where the firm's MC curve shifted upward to intersect the market price P at the quantity Q*, then the firm would be producing the correct amount (of paint and of pollution) to yield the socially efficient outcome. In this case, we would say the firm has *internalized the externality*.

How Do Markets Help Deal With This?

Now back to reality. In practice, we rarely know the position of the MEC curve very well. A lot of science, and a lot of debate, goes into how to quantify the external costs of pollution. What value do we put on a suspected increase in childhood asthma as a result of higher VOCs in the air? What weight do we put on the welfare of unborn generations? Until such issues are resolved, it might seem unclear how we should go about "fixing the markets"; that is, imposing fees, or setting quantity regulations using precise analytic tools. However, once a political consensus emerges to address the externality, questions about the mechanism to be used to resolve it come to the fore. And firms can benefit greatly from using, and advocating that everyone else in their industry support, a market-based system to solve the externality problem. Here is a real example of how this works.

Application: The US Sulfur Dioxide Market

The U.S. Environmental Protection Agency (EPA) regulates the total amount of sulfur dioxide emissions that can be released into the atmosphere each year. (Sulfur dioxide is produced when coal is burned in electric generation plants, and causes acid rain). Now, how should the EPA go about divvying up the total amount of pollution it will allow from each of the hundreds of electric power plants in the United States?

Ideally, the government should set allowed pollution levels in a manner that equates the marginal social cost across all plants and all firms. But the government is not particularly well informed about the marginal social costs of each plant, and not even well informed about the costs of installing new technology to reduce the sulfur dioxide emissions from existing plants (which varies from plant to plant, depending on the type of coal burned, age and type of the technology, and on and on). The government can ask the firms involved what these costs are likely to be, but the firms, knowing how these data will be used, have a strong incentive to overstate these costs.

Realizing as much, since the mid-1990s the EPA has used a market system to decide who gets to pollute sulfur dioxide each year. This market is based upon a system of *allowances:* One allowance give the allowance-owner the right to emit one ton of sulfur dioxide into the atmosphere during a specific calendar year. Power producers, and anyone else for that matter, can freely buy and sell these allowances for whatever price the market will bear. The idea is this: If Philadelphia Electric Company holds, say, 1000 tons' worth of permits and can, at relatively little cost, abate its pollution to only 400 tons per year, it will profit by selling 600 tons' worth of licenses to other firms that find it very expensive to curtail power production or install sulfur dioxide reduction technologies. The EPA started from existing levels of pollution in the early 1990s, and is tightening up the total amount of sulfur dioxide that can be emitted into the atmosphere nationally each year.

The market for these allowances is both well run and quite competitive—the permits trade among Wall Street firms, utilities, independent investors, and so on. Figure 2 shows the entities that are largest traders in this market. Familiar names like Morgan Stanley and JP Morgan are active, making a profit trading in this commodity market by arbitraging price differences over time, just like in any other smoothly-functioning commodity market. The result, in essence, is that an equilibrium market price for the right to emit sulfur dioxide pollution is established; each firm sets its level of pollution at the point where its marginal cost of reducing air pollution equals the market price for permits. In essence, the government has formalized a right to pollute up to a given level, and that right can be traded in the market.

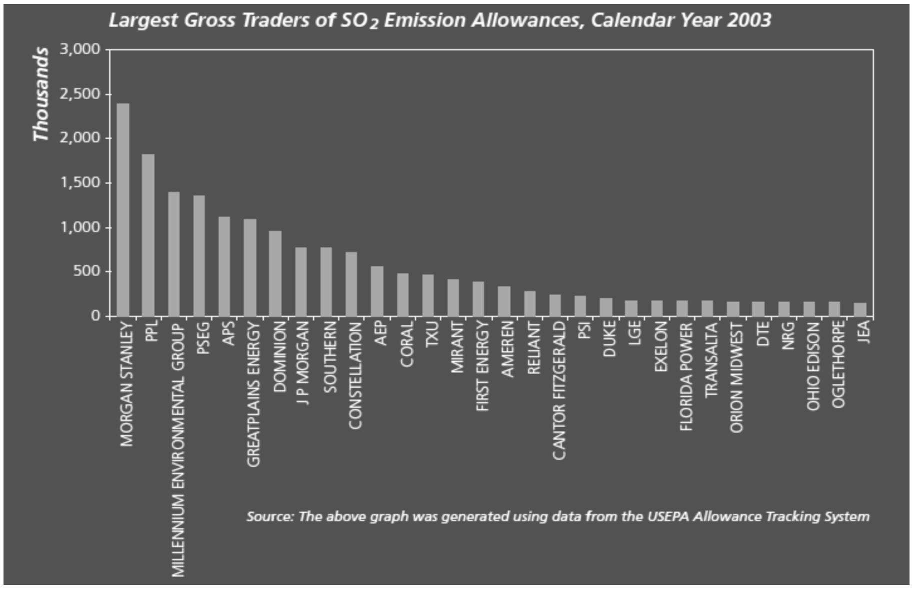

FIGURE 2. *The 30 Largest Traders in the US Sulfur Dioxide Allowance Market, 2003*

There are many more details to how this market works, but the point here should be clear. With this program, society solves the problem of how to find a cost-effective solution to achieving a given level of pollution by letting the market solve the problem for it. This is an example of how government regulation of externalities can effectively harness the "invisible hand" to advantage, in situations where other forms of regulation might impose far greater costs on businesses and, ultimately, society.*

Other Applications: Reducing Highway Congestion

Another externality of ever-growing concern is traffic congestion on roads and highways. When a driver of a vehicle enters a congested stretch of a highway, he or she imposes a negative externality on others: Each additional vehicle reduces the maximum traveling speed of the highway, increasing the travel time of everyone already on the road. A large number of studies have estimated the consequences of highway congestion to consumers and businesses, with astronomical-sized conclusions about the cost of traffic congestion to the economy.

Traditional solutions to this problem are two: (1) providing information (traffic radio reports) to drivers to induce them not to enter a congested highway, and (2) rationing entry onto the highway using "metering lights" and other devices. Do these solutions work well? The increasing frequency of congestion in most US cities suggests not.

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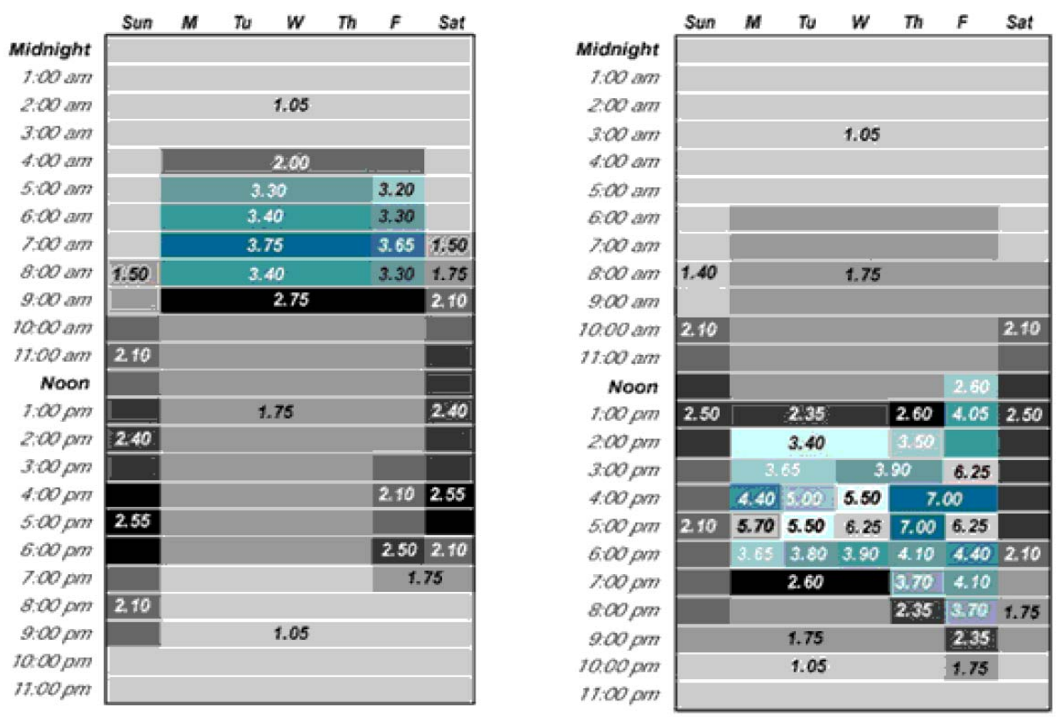
* A good summary of this market's structure and dynamics, including investment and trading issues, can be found on the Web at http://www.chicagoclimatex.com/education_ccfe/SO2_Background_Drivers_Pricing_PDF.

Consequently, there is a market-based solution to this problem that is receiving increasing attention. This is to use tolls that *vary with the current level of congestion on the road.* By pricing the right to enter the congested highway higher at hours when congestion is high, so the theory goes, some people will be induced to travel at other, less congested times of the day. Remarkably, experiments conducted to date suggest this effect is quite large, and modest tolls can dramatically reduce congestion if drivers can see the prices well enough in advance of when they would use the highway.

The best example of this system (in the US) is the toll system on a 10-mile stretch of Highway 91 in Orange County, California. This highway has four lanes in each direction. The outer two lanes in each direction are "free", and (as you might suspect) are congested for hours on end every morning and evening. The inner two lanes have electronic tolls that charge vehicles for each mile traveled. The toll price varies every hour in order to keep traffic flowing on the toll lanes at a target speed of 60-65 mph at all times. To do this, prices are varied between $1.05 and $7.00 to travel the total 10 mile stretch. Figure 3 shows the typical Westbound and Eastbound prices each hour by day of week on the Highway 91 Express Lanes.



(a) Westbound (b) Eastbound

FIGURE 3(a-b). *Congestion-minimizing toll prices in use on California's Highway 91*

Wait, you wonder. How do drivers know what the toll will be? And if they don't, why would this work? First, the transit authority that runs the toll system posts electronic signs listing the tolls for many miles beforehand, and on adjacent highways, giving en-route drivers adequate time to make decisions about whether to take the toll or free lanes. In addition, commuters can check current prices using their mobile phones and text messaging any time of day, or set up email alerts for (say) 5:50pm to tell them the price just before they leave work at the end of the day. Most importantly, however, once the market is up and familiar to drivers, people come to understand how the prices vary pretty well. Most regular commuters know what the prices tend to be during different times of the day, and have long since adjusted their commuting habits according to their individual willingness to pay and tolerance for sitting in traffic.

The *New York Times* article "Paying on the Highway to Get Out of First Gear," attached at the end of this note, discusses several other areas where this type of "dynamic tolls" are being implemented or considered. As you read it, think about why policy-makers often encounter public resistance to market-based solutions to externality problems like highway congestion.

2. *Externalities Between Firms*

We now turn to the second important situation in which externalities arise: Between firms. Actually, the key factor here is not that the externality involves companies but that it involves only a two (or a very few) organizations that recognize their interdependence. These types of problems can usually be resolved in an economically efficient manner through private bargaining. We illustrate the issues with an example.

Example. *Eddystone Golf and Aquanox Water*

The Eddystone Country Club sits on a high bluff overlooking the Schuylkill River. Several miles downstream is a water treatment plant owned by Aquanox Water, a privately-held company. Aquanox is the local water utility for several towns in the area, and it draws water into its treatment plant directly from the Schuylkill River downstream from the Eddystone Golf Course.

Several years ago Aquanox observed elevated levels of a pesticide in the river for days after any rainstorm. This pesticide is particularly costly to remove with the treatment plant's current equipment. Outside scientific consultants hired by Aquanox quickly traced the problem to the Eddystone Country Club. Eddystone had started using this pesticide to maintain its golf course, and whenever it rained the water would run downhill from the golf course into the river, carrying high levels of the pesticide with it.

From a technological standpoint, this problem could be resolved at either end. Eddystone could switch from the pesticide (called PowerPest) to another, less-effective method (OrgoNature) for maintaining its golf course. If Eddystone switched to OrgoNature, it would greatly reduce the costs of treating the water at Aquanox's facility. Or, alternatively, Aquanox could invest in additional equipment that would remove the pesticide more efficiently than its current plant. Both options are costly, however.

Imagine that the costs incurred by each party for the various actions that might be taken by each firm are the following:

Eddystone's Action: Switch Pesticide?	*Aquanox's Action:* Invest in Equipment?	Cost to Eddystone	Cost to Aquanox	Total Cost
Do not switch	Do not invest	$0	$500	$500
Switch	Do not invest	$200	$100	$300
Do not switch	Invest	$0	$400	$400
Switch	Invest	$200	$300	$500

TABLE 1. *Costs of Solving the Pesticide Problem* ($ in thousands)

The information that goes with the numbers in Table 1 is this:

- First, if Aquanox does not invest in additional equipment, it will incur a cost of $500,000 (on a NPV basis) to remove the PowerPest that Eddystone's golf course adds to the water supply. If it does invest in additional equipment, however, it will incur a net cost of only $400,000 (NPV) to remove PowerPest from the water.

- If Eddystone switches from PowerPest to the less-effective OrgoNature method, Eddystone will incur additional costs of $200,000 per year to maintain its course and grounds.

- If Eddystone switches to less-effective OrgoNature, then Aquanox can remove OrgoNature's by-products from the river using its current plant at a cost of only $100,000 (NPV). And, if Eddystone switches to OrgoNature *and* Aquanox still invests in additional equipment, then Aquanox will acquire simpler equipment and the total cost to Aquanox would be $300,000 (NPV).

Working Toward a Cooperative Agreement

Suppose you work for one of the two parties to this dispute. There are four steps you need to work through to reach a cooperative agreement that is beneficial to you. The analysis below will be done both for Eddystone and Aquanox, first under the assumption that Equinox has a (much) better bargaining position: The legal right to use PowerPest as it wishes, regardless of how that use affects the river and Aquanox. Then we'll examine the problem assuming Aquanox has the stronger hand: A legal right to prevent Eddystone from using PowerPest in a way that might enter the water supply.

Case 1: Eddystone has the right to use PowerPest without restriction

STEP 1. *What is the best alternative to negotiated agreement?* It is essential that you detail the default outcome, since it defines each player's next best option to the bargain and thus the worst possible allocation from the bargain itself.

EDDYSTONE: Uses PowerPest.
AQUANOX: (Plans to) invest in new equipment. COST = $400.

So any agreement you might arrange has to have a total cost (to all parties concerned) of less than $400 to be worth doing. You then bargain over the additional surplus an agreement creates to do something other than the default outcome. The better bargainer (viz., the party with the better bargaining position given the status quo) will get a larger share of the surplus created by an agreement.

STEP 2: *Is there an interdependency* whereby the actions of one firm affect the profitable alternatives of another firm? If no, the end. If yes, what is the interdependency?

Here the interdependency is that Eddystone's pesticide use imposes costs on Aquanox.

STEP 3: *If there is an interdependency, how might we cooperate to mutual benefit?* Here we are looking for the mutually highest pay-off. This is the action(s) that minimize(s) the total costs to both players. We will rely upon the courts to enforce any mutually beneficial agreement we might reach.

Find the best allocation/bargain. The best bargain, if they can find it, is for Eddystone to switch (to OrgoNature) and for Aquanox not to invest in new equipment. Notice that switching would cost Eddystone $200K, and Aquanox would still incur a cost of handling OrgoNature of $100K, for a total cost of $300K to all concerned. No other set of actions on the table has a lower total cost all parties.

STEP 4: *Allow the parties to bargain.* In this case Eddystone has a (much) stronger bargaining position—that is, a better position if no deal is reached at all.

Do the deal. Eddystone will offer to switch *if and only if* Aquanox agrees to pay for Eddystone's additional costs, plus a "sweetener" that Eddystone might call "compensation for inconvenience." If Eddystone switches it will incur a cost of

$$TC_{Eddystone} = \$200K – (\$200K + \sigma), \text{ where } \sigma = \text{“sweetener”},$$

where the first $200K is Eddystone's direct cost of switching and the term in parentheses is the compensation received from Aquanox. By inducing Eddystone to switch, Aquanox's cost would be only:

$$TC_{Aquanox} = \$100K + (\$200K + \sigma), \text{ where } \sigma = \text{“sweetener”}$$

where $100K is Aquanox's direct cost and the term in parentheses is the compensation it pays to Eddystone. In sum,

$$TC_{Eddystone} + TC_{Aquanox} = \$200K – (\$200K + \sigma) + \$100K + (\$200K + \sigma) = \$300K\ !$$

Now compare this to the costs each firm would incur under the next best alternative if no deal is reached. This is $0 in additional cost for Eddystone here, and $400 for Aquanox under its next best alternative to doing a deal. What is to be negotiated is the value of the sweetener, σ. We can set limits on the value of σ, but the exact value depends on which firm's representatives are the better bargainers.

To get the limits on σ, use the constraint that each party to the bargain needs to do as well as their outside option. The next best alternative for Aquanox is to build a plant for $400K, so a bargain saves Aquanox $300K *less* the amount it pays Eddystone. And it must pay Eddystone *at least* $200K to close a deal to switch pesticides. So the total economic surplus created by a bargain is $100, and $\$100 \geq \sigma \geq 0$. Since the status quo if a bargain is not reached favors Eddystone, we would expect that if Eddystone is a good bargainer then σ might be close to $100.

Case 2: Aquanox has the right to prevent pesticide water supply contamination

You fill in the words, but this is the simpler case. Now suppose Aquanox has the right to a water supply free of PowerPest, which prevents Eddystone from using PowerPest at all since (uncontrollable) storm-water runoff carries it into the river. Aquanox now has the stronger hand in this case. (We'll assume that the alternative, OrgoNature, is not a health hazard and Aquanox cannot force Eddystone to stop using that as an alternative).

STEP 1: *What is the status quo?* Eddystone has the obligation to stop using PowerPest, at a cost to it of $200K. Aquanox must deal with the cost of removing OrgoNature from the river, however, at a cost to it of $100K.

STEP 2: *Is there an interdependency?* Yes; Eddystone's decision affects the costs of operating Aquanox's plant, with Aquanox able to prevent Eddystone from using Eddystone's preferred pesticide.

STEP 3: *If there is an interdependency, how might we cooperate to our mutual benefit?* Look at the total costs for all four possible sets of actions (rows of Table 1). The lowest cost scenario to both parties is the status quo in this case.

STEP 4: *Allow the parties to bargain*. Is there a deal to be reached here? Look again at Table 1 and convince yourself the answer is no. Here there is nothing to be gained from working toward a different solution to the problem. What happens to the (implicit) "sweetener" now? Presumably Aquanox pays nothing to Eddystone. If it has to pursue its claim in court, however, then there is a cost of pursuing its right that may or may not be compensated (depending on the court's decision).

Bottom Line. There are two key observations about this example. The first is that regardless of which firm has the bargaining power, both firms have a strong incentive to resolve the externality through bargaining. The second observation is that, *from an economic efficiency (i.e., total value creation) standpoint, it doesn't matter who has the bargaining power.* Either way, the firms will serve their individual profit-maximizing interests by getting to an outcome in which the most efficient solution—the lowest total cost to all concerned—is reached. With any other outcome, there would be money left on the table.

That said, what does bargaining power affect? *The division of the surplus created by a deal that implements the efficient solution.* The size of the surplus depends on each player's next best alternative—their outside options. The final division of the surplus will depend on the status quo—who has the "right" to do what if no deal is reached—and the parties' skills at bargaining.

About Externalities and Property Rights

Property rights are the legal rules that describe what people or firms may do with their property. Let's examine the association between property rights and externalities more closely. In Case 1 of our example, it was assumed that Eddystone has the right to use a pesticide that enters the river, and that Aquanox does not have a legal right to a supply of water without this pesticide. That is, Aquanox does not have a legally-enforceable *property right* to pesticide-free water. Because of this, the resolution to this problem is for Aquanox to pay Eddystone directly to stop using the pesticide. By doing so, the two firms found an efficient (from a total cost standpoint) solution to the externality. The market—in this case, "buying" a cleaner water supply from an offending party—resolves the problem in the most cost-effective manner (to all, that is).

Suppose instead that Aquanox had a right to water supply from the river that is free of PowerPest—that is, the court (or legislature) gave Aquanox *property rights* to pesticide-free water. Now Aquanox could demand the golf course pay Aquanox for the right to use the pesticide that will end up in the river. Eddystone then has the choice of either switching, or (in principle) paying for the cost that it's pesticide use imposes on others. This cost of the pesticide is now internalized, and an evaluation of those costs leads Eddystone not to use the pesticide. Market participants acting in their own self interest achieve the identical outcome with respect to pesticide use, and again at the lowest possible cost to all parties concerned.

A theorem due to Ronald Coase—another Nobel Prize winning effort—states that when all affected parties can freely bargain with one another to mutual advantage, the resulting outcome will be an internalization of the externality and an economically efficient outcome—*regardless of how property rights are specified or who has bargaining power.* This is often a counter-intuitive concept for many people, so the next example is a problem to help you see how it works. Only the allocation of surplus between the parties depends on who-has-what property right.

That said, however, there are some assumptions buried in Coase's theory. In simplest terms, these assumptions acknowledge that bargaining does not always work. The two parties must 1) be willing to negotiate; and 2) have good information about their own and their competitor's gains from the different outcomes they might reach. In practice, these conditions need not always hold.

Still, let's see how you do. We'll do the next problem in class on Tuesday.

Lucky Last Problem to Prepare for Class

Please be prepared to explain your answers in class. As usual, you do not need to turn in your work on class-session problems, and you may work with others if you wish.

The Quarry, the Bridge, and The Town of DuBois

DuBois is a town in central Pennsylvania that sits astride a river. The two parts of the town are connected by a single bridge across the river. The road on one side of the bridge heads to Interstate 80 a few miles away. The road on the other side of the bridge head up into the hills, where there is a quarry. This quarry mines Pennsylvania Bluestone, one of the finest grades of flagstone in the U.S.

Because this is a hilly region, the quarry must ship all the finished stone it produces by truck. The quarry's trucks rumble down the mountain, through the center of town and across the bridge, then down to I-80 and off to the quarry's buyers. These trucks are huge: 80,000-pound flatbed tractor-trailers loaded 13 feet high with pallet after pallet of bluestone. The quarry loads its trucks to exactly 80,000 pounds because that is the weight rating of the bridge in DuBois. There is no other route for trucks this size between the quarry and I-80.

The size of the quarry's trucks has raised concerns of their impact on town's bridge. An assessment by several engineering consultants determined that the bridge, which is officially rated to handle 80,000-pound vehicles, had been deteriorating under the stress of the quarry's trucks and is badly in need of a retrofit. In fact, the engineers recommended that the bridge be downgraded to a maximum capacity of 30,000 pounds until a retrofit can be completed. Needless to say, the quarry's managers were up in arms.

With the help of the outside engineering consultants, the town and the quarry's managers sat down to look at a couple options. The bridge engineers indicated that retrofits could be performed to achieve any weight rating up to 80,000 pounds. No retrofit is also an option, but would limit the bridge's capacity to 30,000 pounds indefinitely. The costs of retrofitting rise steeply with the weight the bridge is to handle.

From the quarry's perspective, the problem of downgrading the bridge's capacity is that there are economies of scale in trucking. A lower weight rating increases the number of truck trips required to ship the quarry's total output to buyers, increasing labor costs, fuel costs, truck wear, and so on, eating a fair bit of the quarry's bottom line.

The middle column in the table below summarizes the impact of different weight ratings on the profit of the quarry, *excluding the cost of retrofitting the bridge*. The quarry's profit increases linearly with the capacity it can load on its trucks after 40,000 pounds, which is the minimum rating to run a large tractor-trailer. The final column summarizes the cost of completing a retrofit to raise the bridge's capacity to the weight rating in each row. The outside engineers supplied the initial retrofit cost estimates for the five different weight ratings listed, in 10,000-pound increments (GVWR means "gross vehicle weight rating" of the bridge). All dollar figures in the table are given in present value terms (you can ignore discounting in completing this problem).

Because the town and the quarry had worked together for many years, the town officials were able to put together this table based on the selling price of the quarry's bluestone and their knowledge of the quarry's operations. Quarry managers did not dispute the figures in the table.

Retrofit Option (GVWR, in pounds)	Quarry's Profit (thousand $)	Retrofit Cost (thousand $)
No retrofit	$100	$0
40,000	$150	$25
50,000	$175	$40
60,000	$200	$55
70,000	$225	$85
80,000	$250	$120

Questions

Scenario A. Township's Property Right

Suppose that you work for the quarry's management. The time has come to sit down around the bargaining table with the town and figure out how to resolve the problem of what retrofit option should be undertaken. You are the lead negotiator for your side.

Assume that the township owns the bridge in its entirely, and is under no legal obligation to undertake any retrofit at all. The town has also determined that it perceives no benefit from increasing the weight rating of the bridge above 30,000 pounds (no one but the quarry has vehicles anywhere near that size in DuBois). Both parties—the quarry and the town—realize that if the township takes no action to raise the weight rating, the default outcome of 30,000 pounds will apply indefinitely and the quarry's trucks will have to be loaded to that level only. Because the town legally owns the bridge, the town would have to perform (or contract for) any work done to retrofit the bridge.

You know that the town has been reasonable in the past, and is likely to be receptive to an offer that (1) adequately compensates it for any costs they incur to retrofit the bridge, plus (2) their time and trouble to deal with a problem that, ultimately, they regard the quarry's fault. You, of course, would like to get a deal done to achieve the best outcome you can for the quarry.

What retrofit option and compensation to the town would you propose initially? What rating and compensation do you expect they would counter-propose? Privately, what would you settle for as the negotiations draw to a close if no deal is yet reached?

Scenario B. Quarry's Property Right

Now assume instead that the property right is reversed. Specifically, a state "public facility" law requires the town to maintain its bridge at its original specification of 80,000 pounds "if any commercial interest shall enjoy continued use of the public facility." In plain language, this legalese means that if the quarry decides to use only (say) 60,000 pound trucks, then the town would have to retrofit the bridge (at its expense) only to a 60,000 GWVR level. But if the quarry decides to keep using 80,000 pound trucks, then the town is obligated to undertake an 80,000 GWVR retrofit, again at the town's expense.

Imagine the time has come to sit down around the bargaining table and figure out how to resolve the problem of what retrofit option should be undertaken. You are the lead negotiator for the quarry's management. Now what weight rating and compensation to the town would you propose initially? What rating and compensation do you expect they would counter-propose? Privately, what would you settle for as the negotiations draw to a close if no deal is yet reached?

3. *Externalities Within the Firm*

We now come to the third setting in which you are likely to encounter externality problems in your business careers: Inside your firm or organization. Think, for instance, of a large, multidivisional firm. Often, to allow for efficient decentralization of decision making, divisional management is given the authority to make operating decisions for its own division. Divisional earnings are measured, and division top management is rewarded based on the performance of the division.

The problem is that each division, seeking to maximize its own earnings, may lower the earnings of other divisions. To the extent that this is true, the first division exerts a negative externality on the second, and earnings maximization by each division leads to lower profit for the firm as a whole.

How can one division's activities affect the profit of another? One obvious mechanism involves competition among divisions for customers. When the Chevrolet division of General Motors advertises heavily to sell its cars, it depresses the sales and earnings of the Pontiac division. Or different units within a corporation may compete for scarce factors of production. It is not unheard of, for instance, for one division to compete with other divisions for specific human resources. Division A may hire away from Division B an employee crucial to Division B but merely useful to Division A, offering the employee a promotion or higher salary or both.

Example: *Information Technology Support*

To take a concrete example, imagine a corporation with three identical divisions that have a shared service facility. Think of this 'shared facility' as a cost center in the firm that provides service to all others: The computing support and information technology (IT) unit of the firm. Let y_i for $i = 1, 2$, and 3 be the level of services received from the IT unit by Division *i*. Suppose that the gross benefit to Division *i*, in terms of improved divisional earnings, is given by the function

$$y_i - 0.25y_i^2 - 0.1(y_1 + y_2 + y_3) ,$$

in millions of dollars. The first two terms here mean that the benefit of IT support is increasing in how much support is provided, but at a decreasing rate. The key is the last part of this expression, however: The term $- 0.1(y_1 + y_2 + y_3)$ captures the effect that the more total demand placed on the IT unit, the smaller the value received by each other division.

In addition, the shared service facility must be paid for. When the demands placed on the facility are y_1, y_2, and y_3, the total cost of the IT unit is

$$0.5 + 0.2(y_1 + y_2 + y_3)$$

That is, the IT unit has 0.5 in fixed costs plus a marginal cost of 0.2 for each unit of service provided.

What are the best utilization levels from the perspective of the entire corporation? You can solve this problem using a spreadsheet, but it is faster to do so using algebra. Taking into account the divisional benefits and the cost of the facility, we can sum the benefit function for each of the three divisions and subtract the costs of the IT unit to get the total benefits to the corporation as a whole:

$$(y_1 - 0.25y_1^2) + (y_2 - 0.25y_2^2) + (y_3 - 0.25y_3^2) - 0.3(y_1 + y_2 + y_3) - [0.5 + 0.2(y_1 + y_2 + y_3)]$$

which, collecting terms, is

$$(0.5y_1 - 0.25y_1^2) + (0.5y_2 - 0.25y_2^2) + (0.5y_3 - 0.25y_3^2) - 0.5$$

What is the optimal level of service to provide to each division? Taking derivatives and maximizing this in the three variables gives $y_1 = y_2 = y_3 = 1$, for a net gain to the corporation of $0.25 million.

Now, think about how this works in practice: Each division puts its own demands on the IT unit, effectively "choosing" its own level of service. Imagine, first, that the firm does not charge the divisions anything for the service and each division chooses its utilization level to maximize its gross divisional earnings. The divisions are identical, so we can figure out what happens by focusing on Division 1: It chooses y_1 to maximize its benefits,

$$(y_1 - 0.25y_1^2) - 0.1(y_1 + y_2 + y_3).$$

Since y_2 and y_3 are outside this division's control, we can hold those constant while finding division 1's choice of service level here, which will be $y_1 = 1.8$. The same holds for Divisions 2 and 3 each, since they have the same benefit function. If you plug these back into the total benefit corporation for the firm as a whole, you will find that this gives a gross benefit of $0.45 million to each division and a cost of providing these services to the corporation of $1.58 million. The net benefit to the corporation is therefore 3($0.45) – $1.58 = – $0.23 million. The firm actually loses money by providing centralized IT support!

Solving Externalities Within the Firm: Transfer Prices, Revisited

It should be clear why this is happening. The divisions do not internalize the total variable cost $0.2(y_1 + y_2 + y_3)$ of providing this service. What's the solution? *Transfer pricing!* Suppose that the corporation charges each division a "transfer price" of 0.2 times the demands they place on the facility, in the accounts maintained on divisional profit. If the firm does this, Division 1 will now choose y_1 to maximize

$$(y_1 - 0.25y_1^2) - 0.1(y_1 + y_2 + y_3) - 0.2y_1$$

Since Division 1 regards the demands y_2 and y_3 of the other two divisions as outside its control, it takes them as given and maximizing this comes down to maximizing $0.7y_1 - 0.25y_1^2$ and that gives $y_1 = 1.4$. Divisions 2 and 3 (being symmetric) also come up with this utilization level. And the net earnings gain for the firm is $0.13 million. (Check the math if you are unsure where that number comes from.)

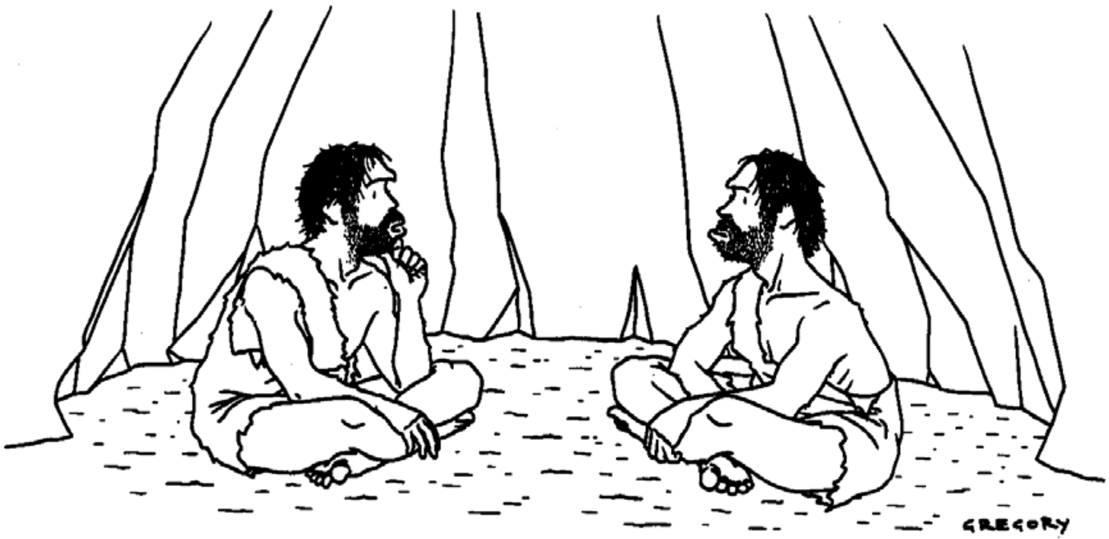
This is better than in the previous paragraph but still not as high as we got two paragraphs ago; the divisions still overuse the IT unit. *Why?* Because while each division now internalizes the direct variable costs incurred by the firm in providing the service, the division fails to take into account the impact of its demand on the *quality of service* received by the other two divisions. There is, in essence, a congestion effect whereby the more one division uses the IT group, the lower the quality of service received by the other divisions.

What are the remedies? Just as in the regulation of pollution—or back when we did transfer pricing in Session 2—two basic remedies are available. The firm can dictate the utilization levels for each division, rationing each division to 1 unit of service. Or it can raise the transfer price for the service to a level sufficiently high that each division internalizes the external effects it has on its fellow divisions. This means raising the transfer price from 0.2 per unit to 0.4 per unit. If it uses this transfer price, each division, on its own, chooses $y_i = 1$, and the firm's total profit is maximized.

Of course, in this example corporate headquarters can work out both optimal amount of IT service to provide each division (in "top down" fashion), or proscribe transfer prices that cause each profit-maximizing division, on its own, to "do the right thing. In real life, however, where there is uncertainty in the mind of headquarters about the true costs and benefits attending to this sort of problem, the case is often made that neither solution works well. However, to the extent that headquarters cannot accurately estimate how valuable the shared service is directly to each individual divisions, but is has a rough handle on the size of the externality each imposes on the others, then using transfer prices and decentralizing the decision is better.

A parting shot…

Life in a world without markets:



"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."

Good Luck!

April 28, 2005

Paying on the Highway to Get Out of First Gear

By TIMOTHY EGAN

RIVERSIDE, Calif. - It is a California still life. In this land of mobile ambition and instant communities, life is on hold in the parking lot that is the Riverside Freeway, 10 miles or more going nowhere at all hours of the day on one of the most congested auto corridors in the world.

But like a mirage in the exurban desert, a narrow river of traffic moves swiftly down the middle of this highway. The fast lanes, the 91 Express, are sometimes called Lexus lanes, first class on asphalt. They can turn a two-hour commute to work into a 30-minute zip. For a solo driver, on-time arrival comes with a price: nearly $11 per round trip, a toll collected through electronic signals.

The freeway in places is no longer free. From the backed-up pools of frustration in Chicago's adjacent counties, to the farthest Virginia fringes of the commute to Washington, to Texas, where plans are under way to build a 4,000-mile network of toll roads, the United States has outgrown its highway system.

But state and federal governments, beset by deficits, say they have barely enough money to service the existing system, let alone build new roads. As a result, nearly two dozen states have passed legislation allowing their transportation systems to operate pay-as-you-go roads, and in many cases, letting the private sector build and run these roads.

Social engineering is merging with traffic engineering, creating new technologies that charge people a variable toll based on how many cars are on the road - known as congestion pricing - or reduce toll rates for high occupancy to encourage car-pooling. The White House wants to allow states to charge user fees for virtually any stretch of an interstate.

It is shaping up as one of the biggest philosophical changes in transportation policy since the toll-free interstate highway system was created under President Dwight D. Eisenhower in 1956. It mirrors changes taking place overseas as well. London began charging tolls two years ago to enter the center of the city during weekday business hours.

"It's a big and important shift, and we in the Bush administration think its time has come," said Mary E. Peters, the federal highway administrator, in an interview. The administration is trying to make it easier for states to convert car pool lanes to toll lanes, and to allow private investors to build and operate highways - and charge for their use.

In just five years, the number of regular highway bottlenecks has increased by 40 percent, with 233 daily choke points across the map, according to several auto and trucking organizations. The average commuter now loses 46 hours a year sitting idle in a car. And the number of miles driven has gone up more than 80 percent over the last two decades while the number of new highway lanes has increased by just 4 percent.

So Virginia is negotiating with a private company to build and operate 14 miles of toll lanes in one of the most congested parts of the Capital Beltway. Chicago just leased its 7.8-mile skyway toll bridge to a private operator for $1.8 billion.

And the vast Trans-Texas Corridor project, which would be the largest private highway system in the country, would allow corporations to charge tolls for 50 years as a way to pay for high-speed lanes in the state.

In a sense, the trend is a throwback to when toll roads connected many major cities. Those turnpikes still charge for driving on them, and belong to the Interstate System, but they receive no federal money. As the Interstate System was built - more than 46,000 miles of interconnecting highways - it was financed with gas taxes and came with prohibitions against charging tolls.

Now the era of the big new public highway project is over, federal authorities say. But states are still crying out for new roads - or at least ways to make the old ones work - without any signs that gas tax revenue can meet their needs.

"Californians can't get from place to place on little fairy wings," said Gov. Arnold Schwarzenegger in announcing a plan in January that could allow private investors to build toll roads. "We are a car-centered state. We need roads."

California adds nearly 500,000 vehicles a year to its roads, state officials say. Commuters in the Los Angeles area spend about 93 hours a year stuck in traffic - the worst of any region in the country, according to tallies kept by the Texas Transportation Institute.

Here in the far eastern edge of the Los Angeles metropolitan area, the population has tripled in 25 years, and the region is growing by 12,000 people a month. The commute, from the cheaper homes of Riverside County to the jobs of Orange and Los Angeles Counties, is known as the Santa Ana Crawl, and about 300,000 cars make it every day on the Riverside Freeway.

Charging tolls on the road's express lanes has been a big hit in this laboratory for congestion pricing. On the 91 Express, the prices vary from hour to hour in a system where traffic is constantly monitored and costs are adjusted accordingly. The car pool lanes, which are still free, are enforced by state patrol cars. But critics say it sets up a class system for motorists. Or that it amounts to a double charge, since state and federal gas taxes were levied to pay for road construction in the first place.

"We already paid for these roads," said Angela Washington, a teacher who takes the torturous commute from this sprawling bedroom community to a job in Orange County, and uses the toll lanes on occasion. "I guess the idea is you buy your way out of congestion, but you do pay."

But people say they like the fact that there are no toll booths, and they can virtually guarantee being on time - for a child's soccer match, job appointment or doctor's visit. Average peak hour speeds on the 91 Express lanes were 60 to 65 miles an hour last year, versus 15 to 20 m.p.h. on the free lanes, according to federal officials.

"It's like everything else: you can fly coach, or you can fly first class," said Caleb Dillon, an X-ray technician in Riverside whose commute is an hour each way. "I'm not a rich guy, but I like having the option of saving time when I really need it."

The tolls have also succeeded in doing what no amount of cajoling and public service announcements could do: get people to car-pool. The 91 now has the highest occupancy per vehicle of any major road in California, state officials said. The reason is that toll lanes here are still free for people who car-pool, offering an incentive to travel together - a savings in tolls of more than $50 a week.

The new tolls rely on radio technology to debit an account instantly, and they are priced to ensure maximum flow of traffic and pay for the road but still make it worthwhile for a driver to leave the free road.

"It's a big cultural shift for people all of a sudden to get used to paying for roads that were free," said Robert Poole, of the libertarian Reason Foundation. But, he said, "people are so fed up with congestion" that they are open to change. For 17 years, Mr. Poole has been the chief theorist for private solutions to gridlock. His ideas are now embraced by officials from Sacramento to Washington.

Texas has taken the most ambitious step, under Gov. Rick Perry. The Trans-Texas Corridor, pegged to cost up to $185 billion, would be financed by private investors, who expect to be repaid through tolls.

A consortium, the Spanish firm Cintra, has already been chosen to build the initial segment, from Dallas to San Antonio. The corridor would be nearly a quarter-mile wide, for rail, truck and auto traffic along with oil, gas, electric and water lines, to be built over the next 50 years. But an unusual alliance of opponents - ranging from the conservative Texas Farm Bureau to the Sierra Club - is fighting the plan, saying it will slice up farms and lead to further deterioration of declining rural towns.

The Bush administration has endorsed the Texas plan, saying it represents the future for highways.

"This is an opportunity to bring in the private sector," said Ms. Peters. "It's all about having options."

But there are some cautionary stories, based on California's experience. The 91 Express was initially run by a private consortium, which agreed to operate it with a provision that the state could not add other competing lanes of traffic. This brought a lot of anger, worsened traffic and led to a regional government buyout of the lanes, which then threw out the clause about competing lanes. The buyout cost $207 million.

Another toll road in this region, the 73 in Orange County, is facing a potential default on its bonds because it is not meeting traffic or revenue projections. Commuters say they shun it because it does not save much time compared with nearby free roads.

Some highway user groups are concerned that the toll roads will be used simply as a way to raise taxes, without any guarantee that the money will go into roads. These groups and their allies in Congress tried, unsuccessfully, to have a provision inserted into the House version of the transportation bill now moving through Congress that would allow charging for only new lanes - not converting free lanes into pay lanes.

Minnesota will do just that next month on Interstate 394, converting car pool lanes into paid express lanes on a road that carries commuters to and from the suburbs west of Minneapolis. The fee will vary according to traffic and car pools will still be free.

State officials are promoting the system as the wave of the future - an on-time auto commute, for a price.