7: Conservation

"Unless profound changes are made to lower oil consumption, we now believe that early in the 1980's the world will be demanding more oil that it can produce."
—President Carter in an address to the nation, April 18, 1977.

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7.1: Introduction

A natural resource is a production input that exists in nature even in the absence of the humans who provide capital and labor. Usually natural resources still require capital and labor to be made useful— a field of land needs a plow and a farmer, and iron ore is useless without digging equipment and miners— but we tend to think of natural resources differently that we do other inputs. It is not that natural resources are limited in extent, so we need to use them carefully. Capital and labor are also limited and should be used efficiently rather than wasted. The property rights to natural resources, though, present special questions. It is quite natural for person to own his own labor and be able to sell it to whoever will pay him enough, even though in times past people became enslaved by birth or through conquest or sale. Capital is the result of somebody having saved and invested, and so naturally would belong to that saver. Natural resources, however, do not always have such clear ownership, even though in many cases the obvious owner is whoever owns the land on which they are found.

Proper use of natural resources– conservation— is important for surplus maximization. Many people think conservation is good for its own sake, even if it costs more in total resources than it saves. Unless some form of market failure is at work, though, we must beware lest an effort to save one kind of resource ends up wasting some other resource. Economics is useful in pointing out where market failure and government failure are likely and how to make tradeoffs between different goods. It also can point out where the perceived problem is not market failure. In some cases a natural resource may be seen as too expensive, but the problem is not market failure, but markets working to give incentives to people to conserve it because it is so scarce. In other cases, the natural resource may be seen as overused— too cheap— but, again, it is simply markets working to show that the resource is not as scarce as it seems. Surplus maximization supports forcible conservation that is an answer to market failure, but surplus is diminished if the government uses its monopoly on force to overconserve a resource that is already being used efficiently.

7.2: Renewable Resources and the Common-Pool Resource Problem: Hunting and Fishing

Conservation is associated with a number of different ideas. The central idea is that without regulation natural resources will be used up too fast. As so often is the case with ideas, this is true in one sense and false in another. It is true that natural resources can be used up too fast when there is market or government failure, but the opposite can also be true. If the market failure is monopoly, for example, then the monopoly will overprice the natural resource and it will be used up too slowly. If the government failure is a restriction on use of a resource where there is no market failure but the government doesn't want the country to have to import the resource, that will result in using higher-cost substitutes unnecessarily. It is also quite possible for market and government failure to result in overuse of natural resources, and that is what we will start with.

A basic problem with natural resources is the **common-pool resource problem** This is a version of the free rider problem, which is itself a version of the prisoner's dilemma. The problem begins if there is a stock of a natural resource that nobody owns, where anyone who wants to can take from it till the stock is used up.

Suppose the resource is deer, and anybody may hunt deer without limit. The result will be that if too many deer are killed, there will not be as many deer next year because the breeding stock will be too low. If only one person had the right to hunt deer, that person would be careful not to overhunt. If there are 100 people, however, we are in the situation in Table 7.1. This table is different from our usual game matrix, because there is more than one player and the matrix focuses on the payoff of one player, Mr. Row. He and each of the other hunters has a choice between shooting one deer or two. If everyone holds back and just shoots one, Row will have a payoff of 10, because there will still be good hunting the next year. Row, however, can raise his payoff to 12 if he chooses to shoot two deer. If the other 100 players each shoot two deer, however, hunting is ruined for the next year. Row's payoff would be 2 in that case if he shoots just one deer, but 3 if he shoots two.

TABLE 7.1
THE COMMON-POOL RESOURCE PROBLEM

		99 other hunters	
		Shoot one	*Shoot two*
Row	*Shoot one*	10	2
	Shoot two	12	**3**

Payoff to Row

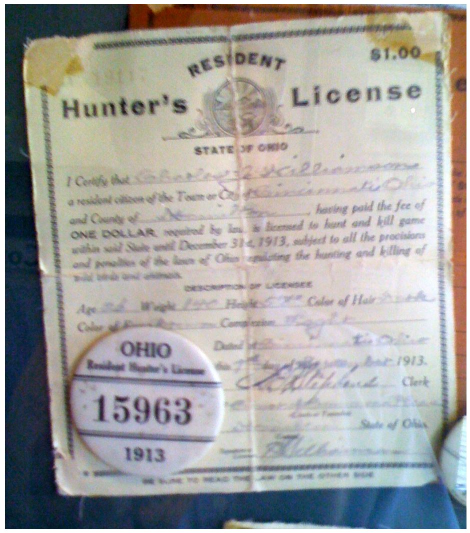
Total surplus is highest if each hunter shoots just one deer, but in equilibrium each of the hunters is looking at a game matrix like Row's, where his payoff is higher from shooting two deer rather than one, no matter what the other hunters do. Thus, without regulation each hunter will overhunt, ruining future years and a hunter's payoff will be 3 instead of the 10 that could be achieved if each were limited to one deer per year.

You can think about the market failure here in two ways. One way is that there is an externality when Row kills a deer: the deer will not have offspring, hurting all of the hunters slightly the next year even though the slight loss to the future deer population is too small to stop Row. The other way is that the problem is lack of a market because nobody owns the deer— the market failure of poor property rights. A hunter does not have to pay other hunters when he shoots a deer. If Row owned the forest and could charge fees to the other hunters, he would make the fee high enough for shooting a second deer that the deer population would not become depleted. He might make the fee high enough that no hunter would shoot two deer, or he might set it lower so that just a few of them would take a second deer. I haven't presented enough information for us to know, because that would require knowing how the different values between 100 and 200 deer killed would affect future hunting.

The usual form of hunting regulation, which has long been used in America is to require hunters to buy licenses like the illustration in Figure 7.1 and limit their annual take of game. This is a form of quantity regulation. The number of licenses can be reduced or expanded depending on how well the deer are thriving. It is not cap-and-trade regulation, just "cap", because a person cannot buy a license allowing him to kill one deer and sell it to someone else. The effect of not allowing trading of licenses is to increase the number of hunters, since otherwise some of them would sell their licenses to richer or more enthusiastic hunters who want to catch more than one license allows.

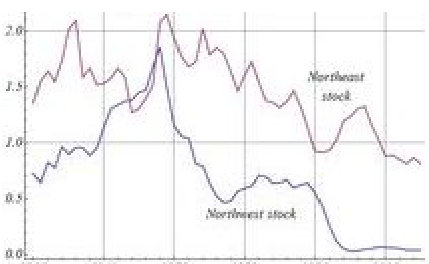
The common-pool resource problem is widely recognized, and has been recognized for many decades. Unfortunately, crept up on us because initially in the United States natural resources were so abundant relative to the number of people that there was no need for property rights, and the externality was trivial. Consider the passenger pigeon. This was once one of the most common birds in America, but mass hunting from 1870 to 1890 pushed it to extinction. This happened so quickly that people hardly realized there was a problem before it was too late. Similarly, hunting in the 1870's almost drove the buffalo to extinction. In both cases, commercial hunting was the main culprit, since "free" game in a species that gathered in large groups was a profitable commodity. Or, one might say that technology was the culprit, since railroads and improved rifles made hunting pigeons and buffalo much more profitable than they'd been in the past.

FIGURE 7.1
A 1913 OHIO HUNTING LICENSE



Source: A Ohio museum.

FIGURE 7.2
THE ATLANTIC COD CATCH: 1950-2005 (MILLIONS OF TONS)



The 20th century also provides examples where technology advanced so quickly that there was not time to assign property rights before the free rider problem destroyed a resource. Cod fishing is a tragic example. The cod fisheries off the coast of New England and Newfoundland were immensely productive. With 19th- century technology, fishermen did not overfish– indeed, could not overfish— even though there were no catch limits.[1] Figure 7.2 shows what happened later. Codfishing in the Northwest Atlantic peaked in the late 1960's, as new technology made it easier to catch cod. The new technology was its own undoing, however, because the new technology enable overfishing which caused the Canadian government to close the Newfoundland fisheries in 1992 after the cod population dropped so low that it was barely profitable anyway. As of 2017, the cod we eat comes not from the west Atlantic, but from the east Atlantic, where the United Kingdom and Iceland were more prudent in their regulation of fishing.[2]

[1] One of Rudyard Kipling's best novels, *Captains Courageous* (1897), describes the codfishing life.
[2] See "The Biological Collapse of the Atlantic Cod off Newfoundland and Labrador," Hutchings, Jeffrey

After the Newfoundland cod debacle, regulation of commercial fishing has become more farsighted. Fishing is perhaps unique in representing an important source of food that is caught from the wild. This does not mean it is unregulated, however—in fact, it is more regulated than most areas of the economy, since most areas of the economy lack the common-pool resource problem. And regulation has become more sophisticated. Early regulations restricted the length of the fishing season and required fishing to stop when the regulated quantity had been reached. Predictably, this meant that fishermen invested in as much equipment as they could and raced to be the first to catch fish before the yearly limit was reached. Although this did prevent overfishing, it made production inefficient, since every fisherman had incentive to invest in boats and equipment even though his boat would be useless once the season closed. In the case of Alaskan crabfishing, the season lasted for as little as three days before the catch limit was reached. Every minute was precious, even if someone was injured or safety had to be slighted. As one captain who appeared on the TV reality show "The Deadliest Catch" describes it: it:[3]

> As in a car race, boats used to line up for the minute the season began.
>
> This intense competition was thrilling but it was also incredibly dangerous. Crabbers worked around the clock, sometimes in terrible weather. There was no time to go back and forth to the docks, so some boats would be overloaded with too many crab pots, making them unstable. The result was that from 1990 to 2005 an average of five crabbers died a year.
>
> Part of my finger was cut off during a violent storm when I got knocked off of my feet and landed on an air compressor. I decided against going to the hospital to have it stitched back on because I knew the fishing season could end any day and my crew had mortgages to pay. I nearly lost my hand after developing a nasty infection.

In 2005 a new system called **catch shares** was adopted for crabbing. Each boat was assigned a share of the total catch limit, but boats could trade or lease their shares, so this is a version of "cap-and-trade" (though limits were placed on how much any one fisherman or company could acquire—why?). In addition, a 3% tax was imposed to help pay for the administrative cost, a significant cost of cap-and-trade. The number of snow crab vessels declined from 189 to 78 in four years, but the value of the average remaining vessel rose from $125 million to $177 million. The percentage of crabs landed alive— important for quality—rose by 16% for snow crab and 38% for king crab. [4] Thus, the same amount of crab could be caught, but more cheaply and with

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and Myers, Ransom 39–93 (1995); and Kurlansky, Mark,*Cod: A Biography of the Fish That Changed the World* (1997).

[3]"Making 'The Deadliest Catch' Less Deadly," Scott Campbell, *The Wall Street Journal* (November 14, 2011).

[4]"BSAI Crab Rationalization Program," NOAA Fisheries Service (viewed November 28, 2011). "New Study Finds Crew in Bering Sea Crab Fisheries Benefitted from Catch Shares," Joshua Abbot, Environmental Defense Fund (December 30, 2010).

better quality. Many other kinds of fishing have also moved towards using catch shares instead of limited season lengths.

Hunting and fishing are examples of **renewable resources**: natural resources which naturally increase over time if they are not depleted too soon. **Nonrenewable resources** such as oil or iron, on the other hand, exist in limited amounts in nature. They may still face common-pool resource problems, but they are different from those of renewable resources. For renewable resources, the central problem is that a user reduces the rate of renewal by his use. For renewable resources, the common-pool resource problem that sometimes arises is too-rapid extraction in a race to extract before someone else does; the resource could be extracted more cheaply if it were done slowly. The racing crab boats were an example of that—the catch limit was like a nonrenewable resource for the fishermen, so they fished as quickly as they could. We will talk more about nonrenewable resources below, after we talk about existence value and government failure.

7.3: The Existence Value of Hetch Hetchy Valley

The problems in hunting and fishing show that market failure in common-pool resources requires the remedy of either regulation or the assignment of property rights. The crabbing example of inefficient regulation via "raceboat" short seasons shows government failure—that the government doesn't always regulate as well as it might. It also shows that governments do learn, if the inefficiency is apparent enough and special interests do not block reform. As always, however, government failure is a threat in the background of regulation. For natural resources, government failure sometimes pits monetary interest against monetary interest, e.g., fishermen who do better with no catch limits or raceboat limits versus fishermen who do better fishing slowly and for more years. Natural resource government failure also arises from conflict between material interests that wish to use a resource for processing into goods and nonmaterial interests that want to preserve the resource for viewing and study or simply wish the resource never to be used. In economic analysis, we treat both interests the same, translating them into dollar intensity as best we can.

A case where this came up and led to a strange combination of political allies is the issue of whether Hetch Hetchy reservoir should be drained. Hetch Hetchy is one of two similar canyons created by glaciers. The other is Yosemite. Yosemite is one of the most popular parks in the world. Hetch Hetchy was dammed in 1913 and now is a reservoir that supplies water and electric power to San Francisco. Even in 1913, the damming of a natural wonder for the benefit of one city was controversial. Early environmentalist John Muir said, "Dam Hetch Hetchy! As well dam for water-tanks the people's cathedrals and churches, for no holier temple has ever been consecrated by the heart of man." But it was done. By the 1980's, the city of San Francisco was earning some $50 million per year in 1986 from selling electricity from the dam. Conservative Secretary of the Interior Don Hodel then suggested draining the dam, just as the environmentalist Sierra Club (founded by John Muir) was considering organizing a petition to have him fired. His attempt went nowhere, however, because of the vehement opposition of San Francisco's city government.[5]

FIGURE 7.3
THE HETCH HETCHY VALLEY BEFORE AND AFTER

Was this government failure? So it seems. The City of San Francisco was a concentrated interest facing a large loss of revenue. Environmentalists were well-organized, but it is difficult to quickly form an alliance with an old enemy (Hodel) against someone who is usually an ally (the Mayor of San Francisco). And perhaps Mr. Hodel was not serious, and just wanted to embarass the city, though he stuck by his position even

[5]Brower, David "Restoring Hetch Hetchy," from *For Earth's Sake: The Life and Times of David Brower*(1990). Dean E. Murphy, "An Effort to Undo an Old Reservoir," *The New York Times* (October 15, 2002). Carl Pope "Undamming Hetch Hetchy," *Sierra Magazine*, November/December 1987, pp. 34–38.

after leaving office. The main beneficiaries would be people who would be able to visit the Canyon as tourists, and people who simply liked the idea of there being another beautiful canyon similar to Yosemite. Most of these beneficiaries did not even hear about the issue and most would care very little, though a positive amount. I think that if the question were put up to a national vote, San Francisco would lose, but I could be wrong. It is notoriously difficult to measure **existence value**: the value people put simply on something such as a canyon existing. We all recognize that this kind of value exists—that people would pay some small amount to have the canyon exist—but how can we measure it? So perhaps my guess that value would be increased if Hetch Hetchy were drained is wrong; after all, there is diminishing marginal benefit for beautiful glacier-carved valleys in California and Yosemite might be enough.

7.4: Nonrenewable Resources

When **nonrenewable resources** are used, they disappear (as with burned oil) or at least diminish (as with aluminum that isn't 100% recycled). It appears that some of them, such as aluminum, are so common that their nonrenewability is unimportant because there is no prospect of their running out for centuries to come. Thus, their market is like that for a produced good; most the entire cost is for the mining and refining rather than for the raw materials. Other nonrenewable resources, such as oil, are uncommon enough that they could diminish at current rates to quantities economically unprofitable to extract.

What should we do about oil? Should we burn it up in our cars as if the amount in nature is infinite? Since economics is all about how to optimally consume scarce resources, it can address this question. First, though, let us use a fable to look at how to maximize the value of a scarce resource.

Using up a Finite, Nonrenewable Resource: The Mulch Problem

Suppose I've just had a delivery of 6 cubic yards of mulch for my backyard. This is special mulch, made up of bark from a grove of premium trees near town, and in the future all I'll be able to get is ordinary cedar mulch. I paid only $3 per cubic yard for the premium mulch, the same as the price for cedar mulch. Premium mulch is special, though: you only need to spread half as much to get the same weed suppression result as with cedar. Now I have a big pile of special mulch in a corner of my yard. I can take wheelbarrows of it to cover weeds in my flowerbeds as needed. The enjoyment of casual gardening just balances the cost in time for me spreading the mulch, so we can safely count my labor costs as zero.

For me, the premium mulch is a cheap, nonrewenewable resource. It is cheap, because I have already paid for it, and I can't resell it or return it, so its out-of-pocket cost is $0 per cubic yard. It is nonrewewable because no more of it exists for me—from now on, I'll have to use cedar mulch.

I have to decide how often to spread mulch. The more thickly I spread it, the better it will suppress weeds. Last year, I used cedar mulch. I decided to spread 4 cubic yards each month at the price of $3 per cubic yard, because I wouldn't get enough marginal benefit from a thicker layer. But what should I do this year? (1) I've already paid for the premium mulch, so I will have no out-of-pocket costs. So maybe I should spread more. (2) On the other hand, the premium mulch is nonrenewable, so maybe I should spread less. (3) Moreover, premium mulch is twice as effective as cedar, another reason to spread less.

Idea (1) was that the premium mulch is free, so I ought to use more. In fact, if it's completely costless, why not use it all in the first month? There's no reason to hold back when a good is free. But of course it's not really costless. It has an opportunity cost: if the premium mulch is used in the first month, it can't be used in the second month. Instead, I would have to pay $12 to buy 4 cubic yards of cedar mulch for the second month. The opportunity cost of the premium mulch is $6 per cubic yard, because I'd be willing to trade one cubic yard of it for 2 cubic yards of cedar mulch, which costs $3 per cubic yard.

Since the premium mulch is nonrenewable, how about idea (2), making it last by using it up slowly? How about using 1/2 cubic yard of premium mulch (which has the effect of 1 cubic yard of cedar mulch) and 3 cubic yards of cedar mulch each month? Then I'll get the same weed suppression as I did with 4 cubic yards of cedar mulch last year, and my pile of premium mulch won't run out till 12 months of use. I won't need it in the winter, but I can keep some till next year.

The problem with the 1/2-plus-3 plan is that I shouldn't worry about running out of premium . I can always buy cedar mulch and suppress my weed. I won't have to pay for cedar mulch till the premium mulch runs out, and with my positive discount rate I'd rather pay later than earlier. And I won't have a big pile of mulch taking up space on my land.

The optimal plan is to treat the premium as if it had a price of $6 per cubic yard, its opportunity cost, and use 2 cubic yards each month to get the same weed suppression as I did with 4 cubic yards of cedar mulch. After 3 months, the premium will run out, and then I can switch smoothly to cedar mulch.

The point of the story is that just because a resource is nonrenewable does not mean we shouldn't use it up. Rather, it should be treated just like any other good. We should not use it up all at once, because we wouldn't get as much benefit from it as if we used it up more gradually. But we should aim to use it up eventually, because it's useless if never used. And we shouldn't delay using it up if we'd then have to start using costly substitutes earlier.

There's a practical example of this principle: the special bottle of wine. You receive a bottle of 10-year-old Mouton Rothschild claret for your 21st birthday. It's ready for drinking, but you wait for a special occasion. College graduation isn't special enough.

The wedding isn't right— too many people at the wedding, and you feel bad about just the two of you drinking it on the honeymoon. First baby? Too tired. First grandchild? Well, let's wait for a really special occasion. Retirement? Not very special. And so you die without drinking the wine. Too much thrift ends up being waste. The solution? Well, a *Wall Street Journal* wine columnist invented "Open That Bottle Night". "On OTBN, which is celebrated on the last Saturday of February every year, thousands of bottles all over the world are released from prison and enjoyed.[6]

The Market for Nonrenewable Resources

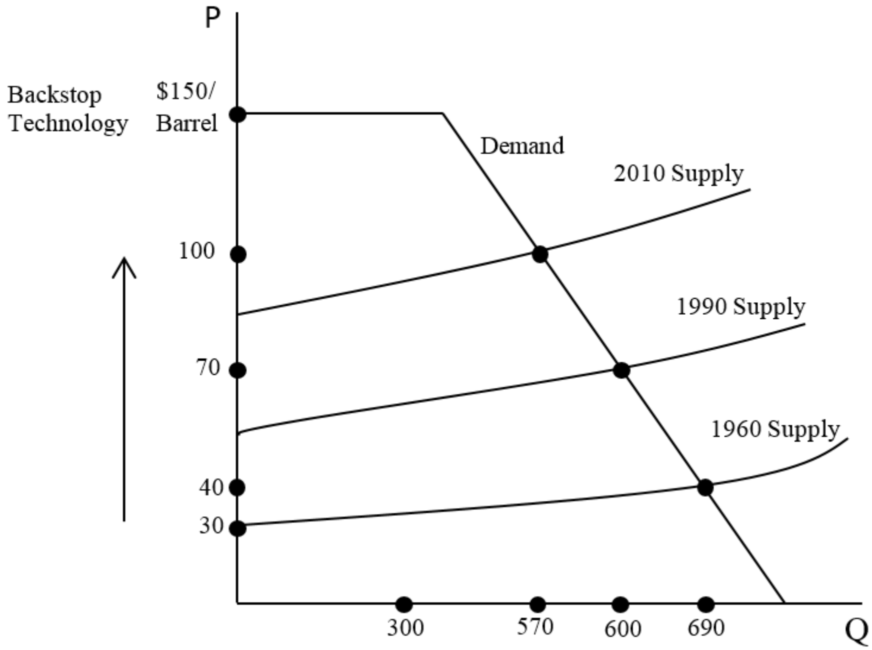
In the example of the premium mulch, we took the price of mulch as given. How does the market arrive at a price for a nonrenewable resource? It will all be gone if we do not reduce our rate of consumption, so does that mean the price will rise to infinity? On the other hand, we have lots of resources like wood that are renewable, and so can be supplied in infinite quantity, so why doesn't that drive the price of wood to zero?

Renewable resources are just like manufactured goods. If we use enough labor, capital, and time, we can produce any amount of cars we want. If we use enough labor, capital, and time, we can produce any amount of wood we want. Cars and wood aren't free, though, because the labor, capital, and time are costly. The price is determined by the marginal cost, on the supply side, and how much the marginal consumer is willing to pay, on the demand side.

Nonrenewable resources also have some cost to produce, and that cost depends on how much is left. The first oil wells will be drilled where it is cheapest to extract and transport the oil. When those wells are running dry and extraction gets costlier, engineers will be paid to find more oil or to drill in places where oil is known to be but is more expensive to extract. This is like using the premium mulch first and using it up before starting on the cedar mulch.

[6] "Open That Bottle Night," Dorothy J. Gaiter and John Brecher, *The Wall Street Journal* (January 2007).

FIGURE 7.5
THE SUPPLY OF OIL SHIFTING BACK OVER TIME

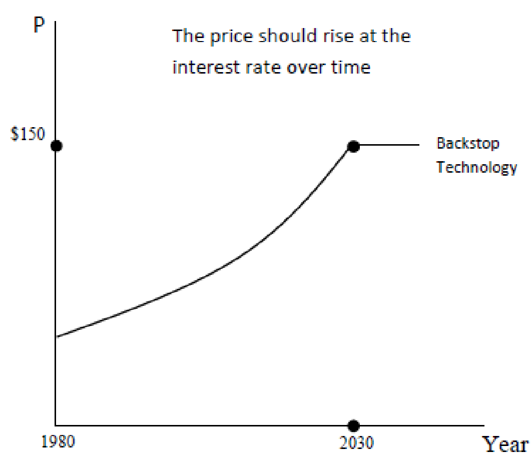


In Figure 7.5 we see the supply of oil shifting back over time, as it becomes more costly to drill in the less favorable sites. Note that the demand curve becomes flat, perfectly elastic, at a high enough price. That is the price of the **backstop technology**: some good that becomes a good enough substitute for oil at that price. In the case of natural oil, the backstop price might be oil artificially made from coal, or ethanol made from corn. The price of oil would not rise any higher, because the backstop technology would take over. In fact, when the price reaches the level of the backstop technology, all the oil must be used up, because nobody would want to keep holding it after the price stopped rising— it would have a higher present discounted value if sold earlier.

In fact, **synthetic oil**, made from coal, has been technologically feasible for a century and was used on a nationwide scale in World War II Germany. In 1938, Germany was using 44 billion barrels of oil per year. Imports from overseas were 28 million barrels, 3.8 million barrels were imported European sources (2.8 million barrels from Romania alone), 3.8 million barrels from domestic drilling, and 9 million barrels produced synthetically. By 1943, Germany was using 71 million barrels of oil, 36 million barrels of which was synthetic. That was the peak, because the Allies realized that this was a bottleneck for the German economy and that since manufacturing plants had to be large, they couldn't be protected from Allied bombers. Later studies concluded that almost all of the rest of Allied strategic bombing had little effect on Germany output, but the synthetic oil bombing crippled the German military.[7]

Figure 7.6 brings in a different aspect of what happens when a nonrenewable resource runs out: the price path over time. As we have just seen, the price rises to the backstop technology and then no further. Now suppose, to make things simple, that oil costs nothing to extract but everyone knows it will run out eventually if it keeps being used at its current rate. If you own an oilfield, and the current price of oil is $100/barrel, you have a choice. You can sell your oil now, or wait a year. If you think the price is going to stay at $100/barrel, you should sell immediately, so you can invest the $100 in some security that has a return better than zero. If your discount rate is 5%, you will sell immediately unless you expect the price to rise to at least $105/barrel. If you use the same discount rate as other oil owners, then if you expect the price to rise even more— to $106/barrel, say— then you won't want to sell *any* oil this year; you'll wait till next year. But we can't have an equilibrium with zero oil produced (because the price is growing too fast) or with all the oil in the world being dumped onto the market (because the price is growing too slowly). We can thus conclude that the price of oil must rise at the discount rate.

FIGURE 7.6
THE HOTELLING RULE AND THE PRICE OF OIL



But what about when the price of oil growing at 5% each year hits the backstop price of $150/barrel? Nobody will want to hold oil any more. Thus, we can conclude

[7]"The Role of Synthetic Fuel In World War II Germany: Implications for Today?" Peter W. Becker, *Air University Review,* July-August 1981. More recently, South Africa built synthetic oil plants in response to the international embargo against it for apartheid in the 1980's.

that all the oil will be used up by the time the price hits \$150. People will sell it earlier so as not to be left with a zero-return asset. It has to be used up *exactly then*, though, because if, say, it were used up the previous March 10 at a price, say of \$148/barrel, then at that moment the price would jump to \$150, yielding an overnight windfall for anybody who had the wisdom to hold onto some of their oil till March 11. So we know something else about the price path: it has to generate quantities demanded that will exactly use up the oil when the price hits \$150.

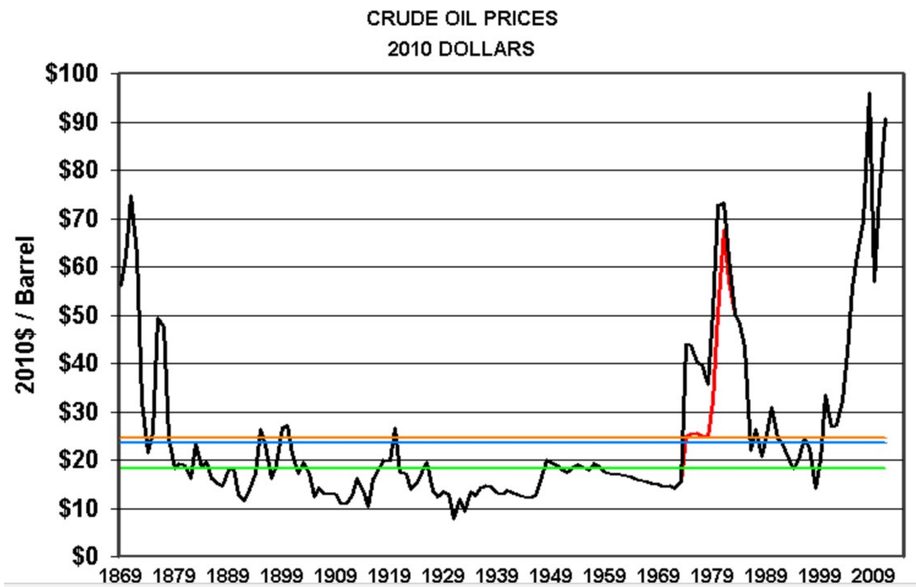
Using some advanced mathematics (calculus of variations, or some other kind of "dynamic optimization"), one can use our two equilibrium conditions— rising at the discount rate and being used up when the price hits the backstop— to calculate the initial price, though we will not do that here. The idea that if there are no production costs the price of oil would rise at the rate of interest is known as **Hotelling's Rule**.[8] If oil is costly to produce, then the idea needs a little elaboration. Suppose the extract cost is \$10/barrel for all oil. Then, the owner's profit from selling now is (P_0-10) and his profit from selling in a year is (P_0 + gP_0-10), where g is the growth in price. The *present value* of deciding to sell in one year is $\frac{(P_0+gP_0-10)}{1+r}$, which is what has to equal (P_0-10) for the owner to be indifferent between holding and selling. Equating the two and solving, we get

$$gP = r(P - 10)$$

Thus, the price has to rise at a rate that makes $(P - 10)$ rise at the discount rate. That's going to be a smaller rate than r. Think about it— if $r = 5\%$ and $P = 15$ and we need to make $(15 - 10)$ rise at 5%, all we need is growth of $.05(15 - 10) = .25$, so the price only has to rise to 15.25, which is much less than a 5% growth in price.

[8]Hotelling, Harold, "The Economics of Exhaustible Resources," *The Journal of Political Economy*, 39: 137–175 (Apr. 1931). For a nontechnical discussion, see "Oil As An Asset: Hotelling's Theory On Price," Robert Stammers (Oct. 13, 2008).

FIGURE 7.7
THE PRICE OF OIL FROM 1869 TO 2011



In actuality, the price of oil does not rise at the rate of interest. As Figure 7.7 shows, the price in 2010 dollars has sometimes gone up at much more than the interest rate, sometimes less, and sometime the price has fallen drastically. The price has behaved much more like that of a produced good than of Hotelling's natural resource. How can we explain that? It seems that sophisticated oil companies are missing the profit they could earn by storing away oil and waiting to sell until the price rises because it is running out. Part of the explanation is that oil may indeed be more of a produced good than a natural resource. Some oil is cheap to extract, but some is marginal, so difficult to extract that the cost eats up the entire profit from selling it, just as with produced goods in perfect competition. Also, we must lay other effect on top of the idea that producers look forward to the future exhaustion of the resource. The OPEC cartel, and especially Saudi Arabia, a large low-cost producer, has market power and knows that selling more would depress the price. Political turmoil has made it uncertain whether some producers will suddenly shut down—think of the two Iraq Wars and the Libyan revolution. World demand growth is hard to forecast. The price of the future backstop technology is also hard to forecast, and depends on technical change—as does the amount of oil that can be extracted. And new oil sources are always being discovered but hard to predict. Oil companies do not pay the cost of exploring for new oil if it seems existing reserves will not run out for too many years. What we can conclude, though, is that experts in the market do not really think that oil is really going to run out soon and have to be replaced by some backstop technology that costs

$150/barrel. If they did, any of the oil companies would be able to make tremendous profits by delaying production till everyone else had run out.

I wish I had data on guano, a natural resource less glamorous than oil but one largely exhausted in the 1800's. **Guano** is sea bird excreta that piled up over the eons to hills of 150 feet or more in Peru. It is an excellent fertilizer, but there are many other kinds of fertilizer that can achieve the same results but are more costly to produce. Thus, it was value-maximizing to use up all the hills and leave only scattered patches not worth collecting.[9]

To summarize, nonrenewable resources ought to be used up eventually, because to never use the resource would be a waste. Market forces will work as well in determining the rate of extraction as they do in determining the rate of production of manufactured goods. Value maximization does not require government intervention unless there is some market failure present such as the common-pool resource problem that property rights are not well-assigned and there is a race to extract first, Indeed, we should expect markets to work their best at optimal resource extraction because it is relatively simple. If it is fclear that the resource will be exhausted too soon, it must also be clear that the price will soon rise drastically. The resource owners could make tremendous profits simply by waiting to extract. Even if they were blind to those profits, others could make profits by buying the resource from the blind original owners and waiting for the price to rise before extracting it.

[9] "Peru Guards Its Guano as Demand Soars Again", *New York Times* (May 30, 2008). The author of this article does not, however, understand the idea of efficient extraction; he thinks guano was overexploited simply becuse it was all exploited.

7.5: Recycling

Related to the ideas of renewable and nonrenewable resources is the idea of re-using goods, recycling them. Recycling has an ancient history. We all own used goods—if nothing else, those which we bought new but are now used because of our own use. Nobody trades in a car for a new one every month. Antiques are fancy used goods. More commonly we think of recycling as being the destruction of used goods and the extraction from them of some of their components. Expensive materials are always recycled if they have been employed to make something which wears out. Nobody throws out a gold necklace just because the clasp broke. Rather, the necklace gets repaired or the gold is melted down to use again. Recycling of plastic, paper, glass, and aluminum follows the same principle: removing and re-using valuable materials from goods that people no longer want. "Curbside recycling" is common now, in which householders sort their garbage into different categories, and is compulsory in some places.

If people recycle out of self-interest, motivated by someone paying them for newspaper and plastic, recycling creates value. The self-interested person incurs a cost in terms of garbage sorting time and the transactions cost of selling, but he earns surplus if he is paid enough. In turn, if the purchaser can resell the recycled materials at a profit it must be that the ultimate buyer gets more benefit from them than the original self-interested person would have. Most likely, in such a case the first purchaser would do the sorting since there are economies of scale in separating out different recyclables from garbage. In past centuries and in poor countries today, this was a common occupation, that of the **"ragpicker."**

Curbside recycling works differently. It is driven not by market forces but by beliefs that it is virtuous—that though it is costly to the person recycling, that person is doing good for others. People think of different objectives—to avoid waste, to help the city government by allowing it to sell recycled materials, to help the environment. They feel good doing it, because they believe they are doing the right thing. In many cities, they feel it is right to force their neighbors to do the right thing too.

Is recycling really a good way to reduce government costs and help the environment? Unlike with market-driven recycling, the people incurring the costs of curbside recycling are not matching the costs against benefits to themselves, but against benefits they believe are being generated for someone else and by a government that uses tax money to finance its share of the costs. The householder rarely asks what the city is actually doing with the plastic bottles, whether the city is is really reducing its costs, or whether the benefits are worth his effort in sorting garbage and the aesthetic and monetary cost of increasing the number of garbage bins. Even if the city can sell the recycled material, if first it msut be collected separately from other garbage, then separately, and then transported to a buyer, the city may lose money on net.

How about helping the environment? What it means to help the environment, and why that is a good thing to do, are hard questions. The environment is not a person, so it does not have surplus we can try to maximize. In practice, people say that using less water, paper, and oil helps the environment, as does mining fewer natural resources, burying less garbage, and generating less pollution.[10] The connection is more remote than in the common-pool resources we were talking about earlier, though, and it is therefore harder for voters to pin down whether recycling is the best way to address a problem. If the problem is that landfills leak pollutants from garbage, for example, one solution is to require everyone to throw away less garbage, in the hopes that this will reduce the amount of the kind of garbage that leaks. A more straightforward solution, however, would be to regulate pollution outflow from landfills. And indeed, landfills are highly regulated, and their price per ton of garbage accepted is higher because of it. If the city collects household garbage, then this means it makes sense for the city to charge for that service depending on how much garbage the household throws away— which in fact is done in many cities, by requiring households to purchase a sticker to attach to each garbage can each week.

In the case of recycling, a major concern is whether people understand that recycling can be wasteful as well as frugal, using up resources rather than conserving them. They may think they are donating their time for a good cause that has significant benefit, but they have only a hazy idea of what that benefit might be. When we throw things away, we hate to waste them. This is clearest in the case of throwing away some working product— it seems terrible to throw away a gigantic old TV set that still works, because you are replacing it with a flatscreen high-definition TV. Yet thrift shops will not accept those old TV's, because their economic value is zero— nobody wants them. It also seems a shame to throw away a perfectly good glass bottle, or even plastic bottle. If only something useful could be done with it! And so we are happy to recycle, thinking that throwing away the bottle won't be a waste. The problem is that the labor and energy used in recycling may end up costing more than making an entire new bottle. Recycling effectively doubles the amount of containers picked up and the recycled materials require some processing before being sold. Googling newspaper articles quickly shows that when city councils discuss recycling, the concern is over paying for the extra cost—they do not expect to earn any profit.[11] In addition, the unprofitability of recycling has increased as recycling has become more common, because an increase in the supply of recyclable plastic bottles reduces the prices cities can get for them.

The costs to the city governments are not the only costs. Households perhaps incur the biggest costs, if we combine the time and effort of all of them. Science news writer

[10] See "Ways to Help the Environment," http://library.thinkquest.org/11353/gather/help.htm.

[11] See, e.g. "Council Questions Coleman's Recycling Plan," . "Lansing Council Approves New Trash Contract". "Campaign OK'd for New Trash System".

John Tierney describes his attempt to quantify the costs:[12]

> "I tried to estimate the value of New Yorkers' garbage sorting by financing an experiment by a neutral observer (a Columbia University student with no strong feelings about recycling). He kept a record of the work he did during one week complying with New York's recycling laws.
>
> It took him eight minutes during the week to sort, rinse and deliver four pounds of cans and bottles to the basement of his building."
>
> "If the city paid for that work a typical janitorial wage ($12 per hour), it would pay $792 in home labor costs for each ton of cans and bottles collected
>
> And what about the extra space occupied by that recycling receptacle in the kitchen? It must take up at least a square foot, which in New York costs at least $4 a week to rent. If the city had to pay for this space, the cost per ton of recyclable would be about $2,000.
>
> That figure plus the home labor costs, added to what the city already spends on its collection program, totals more than $3,000 for a ton of scrap metal, glass and plastic. For that price, you could find a one-ton collection of those materials at a used-car lot—a Toyota Tercel for instance—and drive home in it."

Thus, if one looks at costs and benefits, it seems that recycling is generally a cost to cities and citizens, a cost that is disguised because the cities fold their recycling expenditures into the garbage disposal budget generally and households are not paid for their work. Is there a corresponding benefit to recycling? Less landfill space is used. But that is taken into consideration in cost-benefit analysis. Doe landfills have externalities? They certainly do, but they are heavily regulated, and if they were not, the solution would be to increase regulation, not to put less garbage in them but let them be unsfe. In any case, materials that are recycled such as paper and plastic are not those that we worry about leaking from landfills. We do not recycle disposable diapers, though we could at some price.

Nor is landfill space running out. This idea arose in the 1980's, when the EPA and media focussed on a decline in the number of landfills. They failed to notice that the landfills that remained had grown so much in response to tightening EPA regulations that created economies of scale that capacity actually was increasing. J. Winston Porter, the EPA Assistant Administrator responsible, has since admitted that the EPA's key study was misleading. One of the authors of the study, Allen Geswein, said, "I've always wondered where that crap about a landfill-capacity crisis came from." The trade association for landfill and recycling companies has estimated that it would take 20 years for current landfills to reach capacity at current disposal rates. By then, it would be profitable for companies to open new capacity, even though if presently there is too much excess capacity for new landfills to be profitable. To the extent that landfill

[12] "Recycling Is Garbage," John Tierney, *The New York Times Magazine* (June 30, 1996). Tierney's article inspired tremendous outrage. One response is "Commentary on 'Recycling is Garbage,' " Richard A. Denison, John F. Ruston (July 18, 1996). See also "Think Globally, Act Irrationally: Recycling," Michael Munger (July 2, 2007).

space is scarce, landfills raise their prices, so any scarcity is already reflected in the price per ton of garbage.[13]

How about the waste of resources from burying recyclables? If such waste existed, it would be reflected in the price of recyclables: companies would pay you to recycle. If the profit from recycling is negative, we can conclude that recycling itself is wasteful. It does not waste plastic, but it wastes labor, trucks, and gasoline.

What about the fact that recycling means we can reduce our use of costly inputs such as oil for plastics and sand for glass, and our use of energy? We certainly can reduce those costs—but only by increasing other costs. The major cost is labor. Take, for example, the household labor used in sorting recyclables from garbage. Isn't it worth a little effort to reduce the amount of oil used to make plastic bottles? It is worth it, but only if the effort really is small enough since the amount of oil is trivial too. A dime's worth of labor effort is no smaller a cost than a dime's worth of oil.

Nor is labor any more renewable than oil. As novelist Michael Crichton put it:

> From your point of view, your time is a nonrenewable resource. If you use up an hour, it is gone forever. Of course, from the point of view of the government, your time is a renewable resource. Stalin could view human labor as an input much the same as cattle—scarce, but renewable, as long as he didn't use up too much at once. For Ivan Ivanovich, however, a year in a work camp was a year less of his time on earth.**Indeed, human time is more clearly in short supply than oil, and more vulnerable to wasteful depletion. Burning oil practically always has some value,but burning time often is completely useless.** Moreover, you cannot be sure whether oil will run out within your lifetime—but you can be sure your time will, by definition. You can be absolutely certain that all of your time will be used up within 130 years—and it might be used up twenty minutes from now, if your heart is weaker than you think.[14]

This idea that the cost of inputs is shown by their prices is perhaps the most important economic point to be made about recycling. It is a variant on Chapter 1's idea that value is maximized at the market equilibrium. If the price of raw materials is low, that shows that they are cheap to produce and the marginal buyer does not value them enough as a substitute for other goods to pay more than a low price. It is easy to confuse the role of prices in signalling which inputs to use and what outputs to produce with the value of goods in terms of the value of the first unit consumed. Food is not infinitely expensive, even though it is necessary for life, because it is cheap enough to produce that we are not willing to pay an infinite price for the quantity supplied.

When we look at the price of an input, we should think of it as the value of the marginal unit, not as the value of all the units of that input. It is not necessary to conserve water just because water is necessary for life. The question is rather whether

[13] "Recycling Myths Revisited," Daniel Benjamin, PERC Research Study No. 47 (2010), p. 7.

[14] Michael Crichton, "Environment as Religion," speech. Commonwealth Club, San Francisco, California (September 15, 2003).

slightly reducing the amount of water you use is worth the cost of giving up something else— how clean you get in the shower, for example, or the extra soap needed to get just as clean with less water. So too with recyclables: their value is shown by their market price. If the market price is negative, they are more accurately considered as garbage than as raw materials, and consumers will have to give up more goods and services to recycle them than to treat them like other garbage.

The most important resource in the modern economy is labor, which is also the highest cost for garbage disposal and recycling. Over the centuries, or even the decades, labor has been becoming more expensive relative to raw materials. Production of goods increasingly has substituted cheap raw materials and machinery for scarce labor. The prices reflect how people value these things in exchange. From the viewpoint of surplus maximization, it is wasteful to use people's time to save slightly on cheap raw materials. Each hour of labor is far more productive than it used to be, but the usefulness of raw materials has not increased proportionately.

Thus, the test for whether recycling maximizes surplus is simple. If recycling makes the most efficient use of all resources, human and natural then the buyer of the recycled materials is able to break even even if it pays enough to compensate for the consumer's time.

7.6: Conclusion

Conservation of natural resources presents the standard issues of surplus maximization with a few twists. The key to understanding them is to look for market failure. Many resources encounter the common-pool resource problem— that property rights are ill-defined, so people use the resource now, because they know that if they wait other people will use it up. If property rights are well-defined, though, the problem of using up a natural resource is the same as that of consuming any other good. Nonrenewable resources ought to be used up, because leaving them unused is a waste. The big question is when to use them. If someone owns a piece of the resource, market prices tell him how much to use and how much to save. As with ordinary goods, market prices synthesize the information about costs and benefits of everyone in the market, enabling them to make surplus-maximizing decisions. The same is true of recylable goods. There is a cost to recycling a product that can be compared to the cost of making a completely new item. The company's cost of making a new item has a market price, but the cost of recycling is more difficult to assess because not all parts of the cost enter into the price the company pays for the used materials. Part of that cost arises from household effort, and part from subsidy by the city government. Recycling maximizes surpus if it would be profitable after subtracting those costs, and otherwise consumes surplus and is not thrifty, but wasteful.

Review Questions

1. What is the common-pool resource problem?
2. When should a good or resource be used up?
3. What does the Hotelling model say about the path of consumption and price of a nonrenewable resource over time?
4. How can we tell if recycling a particular product increases total surplus?
5. Why do people recycle?

Readings

1. "4 Big Recycling Myths Tossed Out: No, "blue bins" are not what's causing America's trash problem," Luke Whelan, *Mother Jones*.
2. "Industry, Not Environmentalists, Killed Incandescent Bulbs," Timothy Carney, *The Washington Examiner*.
3. "Recycling Eyeglasses Is a Feel-Good Waste of Money," Virginia Postrel, *BloombergView*.
4. "The American Recycling Business Is a Mess: Can Big Waste Fix It?" Claire Groden, *Fortune*.
5. "Recycling: Can It Be Wrong, When It Feels So Right?" Michael C. Munger, *Cato Unbound*.