CHAPTER 11

Market Failures and Abiotic Resources

Now that we have seen the circumstances under which the market is an effective allocation mechanism, we can examine how the market performs with respect to the goods and services provided by nature. There are eight classes of these, as discussed in Chapters 5 and 6:

1. Fossil fuels (nonrenewable stock)
2. Minerals (partially recyclable, nonrenewable stock)
3. Water (nonrenewable stock, and/or fund, depending on use, recyclable)
4. Solar energy (indestructible fund)
5. Ricardian land (indestructible fund)
6. Renewable resources (renewable stock)
7. Ecosystem services (renewable fund)
8. Waste absorption capacity (renewable fund)

If a resource is excludable, its market allocation is possible. If it is rival, we understand all the impacts of its use and production and consumption generate no externalities, then market allocation is also efficient within the current generation. If the well-being of future generations is not affected by the use of the resource, then market allocation may also be intergenerationally fair. As we will see, however, no good or service provided by nature meets all of these criteria. In this chapter we examine abiotic resources and lay some of the groundwork for subsequent discussion of policies that can improve the allocation of these resources.

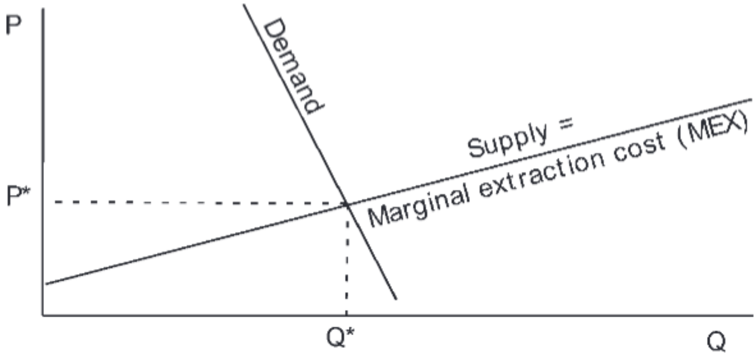

Figure 11.1 • Optimal extraction (Q*, P*) of fossil fuels in the absence of scarcity and market failures.

FOSSIL FUELS

Fossil fuels are both rival and excludable, and thus can be allocated by market forces. If we ignored resource scarcity (or the future) and market failures, the optimal allocation of fossil fuels would simply be the intersection of the demand curve with the supply curve, where the supply curve would equal **marginal extraction costs (MEX)**,[1] as depicted in Figure 11.1.

External Costs

However, problems arise. First of all, the production and consumption of fossil fuels generate serious externalities at the local, regional, and global levels. Most of these externalities are in the form of public bads. Examples of these externalities are categorized in Table 11.1 according to their spatial and temporal characteristics.

Many of these externalities have different impacts at different spatial levels. Optimal extraction of fossil fuels would need to include these marginal external costs, as shown in Figure 11.2, where MEC shows the cost of extraction including externalities. Because these externalities are so widespread, affecting not only virtually everyone in the world alive today but future generations as well, transaction costs for resolving these externalities through the market would be infinite. Given the inability of the unfettered market to address these externalities, extra-market institutions (e.g., government regulation) will be required.[2] However, these institu-

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[1] MEX include all costs, i.e., the costs of equipment and labor and the opportunity cost of money invested.

[2] This is not to say that government regulations cannot create market incentives for reducing externalities, as we will see in Chapter 17–18.

Table 11.1

SPATIAL AND TEMPORAL CHARACTERISTICS OF SELECTED EXTERNALITIES ASSOCIATED WITH FOSSIL FUEL EXTRACTION AND CONSUMPTION. (A SMALL X DENOTES RELATIVELY MINOR IMPACTS.)

Externality	Local	Regional	Global	Intergenerational
Global warming			X	X
Acid rain	x	X		X
Oil spills	X	X		X
Damage from extraction (see Table 11.2)	X			X
War[a]	X	X		X
Water pollution	X	X		X
Soil pollution	X			X
Air pollution (gaseous)	X	X	x	x
Air pollution (particulate)	X			

[a] The number of wars that have been fought and are currently being fought over the control of fossil fuels argues for the treatment of some wars, or at least some military expenditures, as an externality of fossil fuel production. See, for example, M. Renner, WorldWatch Paper 162: The Anatomy of Resource Wars. Washington, D.C.: WorldWatch (2002).

tions must be on the scale of the problem they address, as there is little incentive for governments (generally the most relevant institutions) to deal with externalities beyond their borders. At present, appropriate institutions for addressing international externalities either do not exist or are inadequate.

User Costs

Another problem is that fossil fuels are a nonrenewable resource upon which the well-being and even the survival of future generations is highly dependent. Even ignoring future generations, economists agree that the use of a nonrenewable resource now increases scarcity (decreases supply) in the future. As supply goes down, price should go up. Therefore, if the owner of a nonrenewable resource extracts that resource today, she loses the option of extracting it in the future when the price is higher.

User cost is the opportunity cost of nonavailability of a natural resource at a future date that results from using up the resource today rather than keeping it in its natural state.

The more of a resource we extract today, the greater the current supply and the lower the current price. Also, greater extraction now means greater scarcity in the future, and a higher future price. All else being equal, the **marginal user cost (MUC)**—the opportunity cost of producing *one more unit* of the resource today instead of in the future—should therefore be increasing with total production.[3]

Marginal user cost is the value of one more unit of the resource in its natural state. In a perfectly competitive economy, marginal user cost would in theory equal the price of a resource minus its marginal extraction cost.

The marginal user cost is a real cost of production, and it must be added to MEC and MEX to give the full cost per unit that represents all

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[3] We caution that some theoretical studies suggest that rising marginal extraction costs and/or the presence of an inexhaustible substitute (a backstop technology) may lead to declining marginal user costs over time. Different sets of assumptions in mathematical models lead to different results.

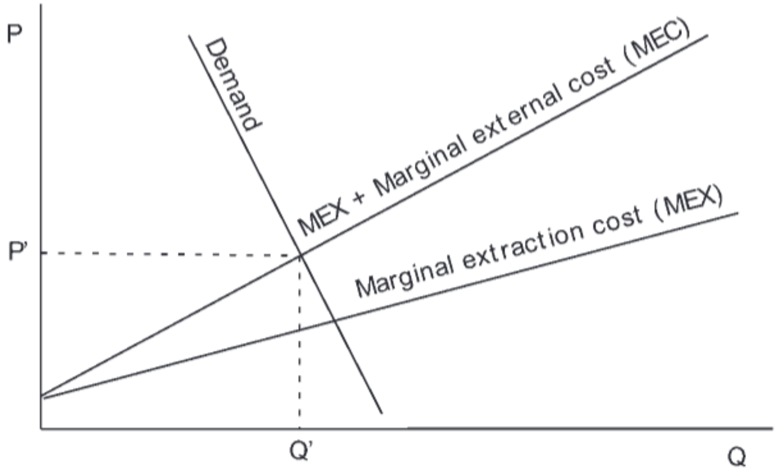

Figure 11.2 • Optimal extraction of fossil fuels (Q′, P′) in the presence of negative externalities (global marginal external costs), without scarcity.

marginal opportunity costs. The individual producer takes prices as given, and therefore should produce up to the point where marginal benefit (price) equals marginal cost (MEC + MEX + MUC), as shown in Figure 11.3. Of course, when the producer does not have to pay marginal external costs, she is likely to ignore them.

User cost can also be thought of as the value of the resource in its natural state, the in-ground value before it has been extracted. Marginal user cost

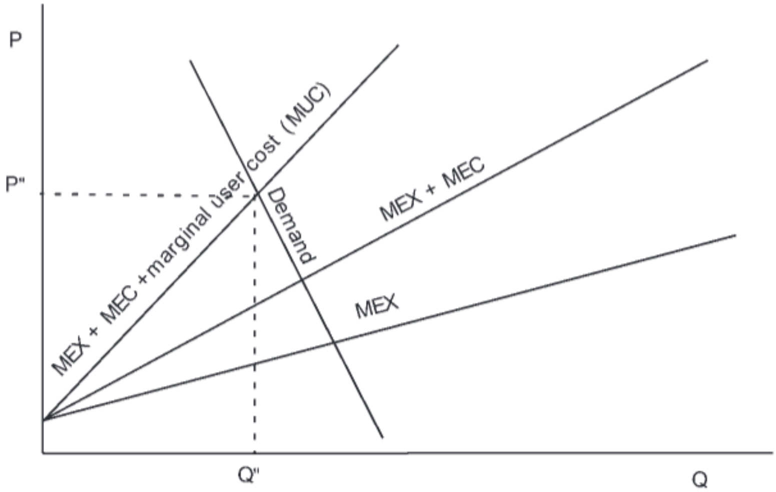

Figure 11.3 • Optimal extraction (Q″, P″) of fossil fuels in the presence of scarcity and negative externalities.

is the value of one more unit of the resource in its natural state. Theoretically, in a competitive market, producers would pay resource owners a per-unit fee for extraction rights precisely equal to the marginal user cost.

> **THINK ABOUT IT!**
> *Can you explain why, in a competitive market, producers would pay resource owners a per-unit fee equal to the MUC for the right to extract a resource?*

This fee is known as a **royalty**; that is, the marginal user cost should be equal to the price of the resource minus the marginal extraction cost. Because no human effort is required to produce a natural resource in its natural state, user cost is unearned economic profit, also known as economic rent. As explained in Chapter 9, **rent**, or scarcity rent, is defined as unearned profits, or the payment to a firm for a product above and beyond what is required to bring that product to market.

Royalty is the payment to the owner of a resource for the right to exploit that resource. Theoretically, in a competitive market, the per-unit royalty should be equal to the marginal user cost.

We have explained that marginal user cost should be rising with increasing scarcity, but how fast will it increase? We must remember that user cost is the opportunity cost of extraction today, while the discount rate is the opportunity cost of leaving a resource in the ground instead of extracting it and investing the profits in the most profitable alternative productive activity. Conventional economists argue that, all else being equal, the optimal rate of resource extraction is one at which increasing in-ground scarcity drives the marginal user cost up at a rate equal to the usual rate of return on alternative (aboveground) investments.[4] This is known as the **Hotelling rule**, after economist Harold Hotelling who first stated it. As a result, extraction rates should decrease through time, causing the price to increase.

If we imagine that MEC and MEX are zero, then the price under an optimal extraction regime will increase at the discount rate. This is an intuitive result—if the price increased more slowly than the discount rate, the resource owner would maximize profits by extracting the resource faster and investing the profits, which would then grow faster than the value of the resource in the ground. Alternatively, if the price of fossil fuels is growing faster than the discount rate, then leaving the resource in the ground to appreciate in value generates the greatest profits. In other words, if the opportunity cost of leaving the resource in the ground (the discount rate times the current value of the resource) is greater than that of extracting it (the user cost), we extract, and vice versa.

In theory, the market mechanism automatically (through the invisible hand) incorporates marginal user cost into the market price, and is equal to the market price minus the extraction cost. In reality, as natural resource

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[4] H. Hotelling, The Economics of Exhaustible Resources, *Journal of Political Economy* 2: 137–175 (1931).

markets in general are highly imperfect because of cartels, an absence of competition, poorly defined property rights, and imperfect information, they will not reveal true user costs. As an alternative measure, economists can estimate the time of total depletion of the resource, the time when we'll have to turn to the best available substitute, assuming there is one. If there is a reasonable renewable substitute (e.g., solar power) or extremely abundant substitute (e.g., hydrogen fusion) for the resource in question (known as a backstop technology), the price of the resource can never rise above the price of the substitute. This reduces the opportunity cost of using the resource in the present—that is, it lowers the user cost, thereby leading to more rapid extraction and a lower price. To determine the user cost, the extra unit cost of the best substitute, over and above that of the depleted resource, is estimated. That amount is then discounted from the future date of exhaustion back to the present to tell us the marginal user cost.

In summary, the user cost will be low if (1) the discount rate is high, (2) the exhaustion is far in the future because either reserves are large or annual usage rates are low, and (3) good substitutes are expected to be available. And vice versa. We see once again the importance of the discount (interest) rate, expectations about substitutes, and uncertainty about stocks in the ground.

BOX 11-1

MARGINAL USER COST IN SUSTAINABLE INCOME ACCOUNTING

It is interesting that in discussing user cost, John Maynard Keynes, arguably the most influential economist of the twentieth century, was interested mainly in applying the concept to depreciation of the fund of manmade capital (in order to arrive at a proper measure of income). He made reference to the more "obvious" case of accounting for user cost in a copper mine (natural capital) as a way of clarifying his argument.[a] Nowadays, if texts discuss user cost at all, they refer to the more "obvious" necessity of accounting for depreciation of manmade capital as an argument for applying the same logic to natural capital. Perhaps this reversal is a measure of how much we have recently come to neglect natural capital.

In any case, recalling our terminology of previous chapters, it is clear that user cost is a necessary charge for the depletion of stocks (natural or manmade inventories) and the depreciation of funds (natural and manmade productive equipment). In proper accounting usage, both inventories and machines are capital. Inventories are depleted; machines are depreciated. Both require the accounting of user cost. If user cost is not deducted in calculating income, then income will be overstated and will not be sustainable. In most national accounts around the world, user cost is erroneously counted as income.[b] Keynes, as the major architect of modern macroeconomics, was very interested in getting a correct measure of national income.

Few nonrenewable natural resources are fund-service in nature. We will examine the implications of user cost for the stock-flows and fund-services provided by renewable resources in Chapter 12.

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[a] *J. M. Keynes,* The General Theory of Employment, Interest, and Money. *Orlando, FL: Harcourt Brace (1991) p. 73.*

[b] *See S. El Serafy, The Proper Calculation of Income from Depletable Natural Resources. In Y. J. Ahmad, S. El Serafy, and E. Lutz, eds.* Environmental Accounting for Sustainable Development, *A UNEP–World Bank Symposium, Washington, D.C.: World Bank, 1989; and S. El Serafy, Green Accounting and Economic Policy,* Ecological Economics *21: 217–229 (1997).*

Flaws in the Analysis

From the perspective of ecological economics, however, this analysis of fossil fuels is inadequate. First, it looks only at the net present value of the resource for the existing generation, ignoring any ethical obligations to leave some of the resource for future generations; that is, it focuses on efficiency, ignoring scale and distribution. Second, neither producers nor consumers currently pay marginal external costs. Third, empirical evidence contradicts the conventional theory; as Figure 11.4 shows, oil

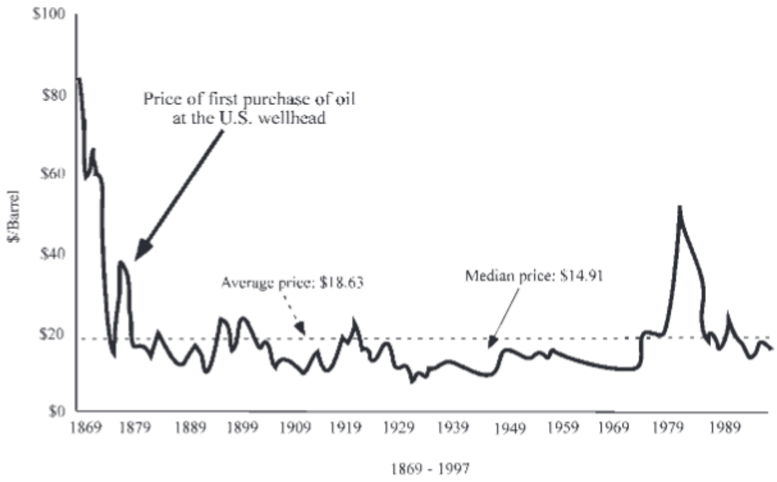

Figure 11.4 • Oil prices from 1869 to 1997, in 1996 dollars. These are the prices paid in the U.S. at the wellhead, net of transportation costs. The volatile nature of prices in the short run is obvious (note particularly the surge in prices in response to reduced OPEC production in the 1970s), but perhaps more noteworthy is the relative stability of prices over the last 120 years (Source: Adapted from WTRG Economics, 1998. Online: http://www.wtrg.com/prices.htm.)

prices have been fairly constant for the last 130 years. We'll return to this last point following our discussion of mineral resources.

MINERAL RESOURCES

Mineral resources are also rival and excludable and amenable to market allocation. As in the case of fossil fuels, their production and consumption generate serious externalities. In fact, mining accounts for nearly half of all toxic emissions from industry in some countries, such as the United States.[5] As many of these negative externalities are less well known than those associated with fossil fuel use, we have summarized them in Table 11.2.

Although many of these externalities are fairly localized compared to problems from fossil fuel emissions, they can be very persistent and severe. For example, acid mine drainage still occurs on mine sites worked by Romans over 1500 years ago. Over 500,000 abandoned mine sites exist in the U.S. alone,[6] with estimated cleanup costs of $32–$72 billion.[7] Again, transaction costs for resolving these externalities will be extremely high to infinite, depending on our concern for future generations, and they cannot be resolved by unregulated markets.

It is worth noting here an interesting anomaly. Within a generation, for the market to efficiently allocate resources, they must be rival. However, future generations cannot participate in today's markets. Thus, if a good is rival between generations—that is, its use by one generation prohibits use by another—the market will still not allocate it efficiently because future generations cannot participate. Fossil fuels are rival between generations. Mineral resources, to the extent they can be recycled, are rival within a generation, but less so between generations. Thus, if mineral resources were efficiently recycled and had no negative externalities associated with their production and consumption, market allocation could be both intragenerationally efficient and intergenerationally fair. The more efficient the recycling process, the lower the marginal user cost, and the less the theoretically efficient price would need to rise over time. However, the record shows low levels of recycling, enormous increases in demand (from 93 million metric tons in 1900 to 2900 mil-

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[5] P. Sampat, From Rio to Johannesburg: Mining Less in a Sustainable World. World Summit Policy Brief #9. World Watch Institute News Releases. Online: http://www.worldwatch.org/press/news/2002/08/06/.

[6] Center for Streamside Studies. Online: http://depts.washington.edu/cssuw/Publications/FactSheets/minec.pdf.

[7] Cleanup costs for some mines have reportedly been greater than the value of minerals extracted. Environmental Media Services, Mining Companies Profit from Public Lands While Taxpayers Pay for Cleanup, 2002. Online: http://www.ems.org/mining/profits_costs.html.

Table 11.2

PRODUCTION EXTERNALITIES OF MINERAL RESOURCE EXTRACTION, SPECIFICALLY FROM HARD ROCK MINES

Externality	What Is It?	What Does It Affect?
Acid mine drainage	Metal sulfides are common in mineral ores and associated rocks. When these rocks are mined and crushed, exposure to air and water oxidizes these sulfides, generating acids and toxic heavy metal cations.	Water required by oxidation also washes products into nearby surface water and aquifers; in addition to acidification effects, heavy metals build up in animal populations and humans.
Erosion and sedimentation	Heavy machinery, strip mines, and open pit mines destroy surface vegetation holding soils in place; water washes away small particles from erosion and waste materials, depositing it elsewhere.	Major impacts are on wetlands and other aquatic habitats; soil organisms, vegetation, and restoration efforts also affected.
Cyanide and other chemical releases	Cyanide and other toxic chemicals are regularly used to help extract minerals.	Cyanide released into ecosystem has adverse impacts on water, soil, aquatic, organisms, wildlife, waterfowl, and humans.
Dust emissions	Ore crushing, conveyance of crushed ore, loading bins, blasting, mine and motor vehicle traffic, use of hauling roads, waste rock piles, windblown tailings, and disturbed areas all generate dust.	Dust can be an air pollutant, and may also transport toxic heavy metals.
Habitat modification	Mining can have dramatic impacts on landscape and uses enormous amounts of water.	Ecosystem structure and function are affected.
Surface and groundwater pollution	Mining uses massive quantities of water, pumping water from mines affects water tables, and mine wastes pollute water.	Altered surface and groundwater flows, with accompanying impacts on wetlands and other water-dependent habitats.

Source: EPA Office of Waste Water Management, Hardrock Mining: Environmental Impacts, Online: http://www.epa.gov/owm/permits/hrmining/env.htm.

lion metric tons in 1998 in the U.S. alone), and substantial decreases in real prices.[8]

Do Prices Reflect Scarcity?

How do we explain the major anomaly between the empirical fact of falling prices of nonrenewable resources and the theoretical prediction of rising prices? Conventional economic theory generally assumes that prices

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[8] D. E. Sullivan, J. L. Sznopek, and L. A. Wagner, Twentieth Century U.S. Mineral Prices Decline in Constant Dollars. Open File Report 00-389, Washington, DC: U.S. Geological Survey U.S. Department of the Interior, 2000.

increase as a function of scarcity, and it is an unalterable physical fact that extraction has reduced the quantity of in-ground stocks of nonrenewable resources. This does not necessarily mean that prices do not reflect scarcity, as long as we assume that scarcity is defined not only by the physical quantity of a resource remaining. Scarcity is also determined by new discoveries[9] and by the availability of substitutes. Prices equilibrate supply and demand, and if supply increases from new discoveries or demand falls because substitutes are invented, scarcity is reduced, and prices fall as well. For example, fiber optic cables dramatically decreased the demand for copper in telephone lines, which might explain the fall in prices.

However, as we pointed out previously, oil discoveries peaked in 1962, production surpassed new discoveries in 1982, and consumption currently exceeds new discoveries by a factor of two to six. What's more, while we do have more potential substitutes for oil, relative to 100 years ago we have created far more technologies that depend on oil (complements) than technologies that substitute for oil. Just as substitutes reduce resource scarcity, complements increase it. Nonetheless, steady increases in the demand for oil have apparently not affected the price.

What is the explanation? First of all, we must recognize that if prices reflect in-ground scarcity, they do so very poorly, and for obvious reasons. There is considerable debate even among the experts about the precise amount of oil left in the ground (though less about ultimately recoverable reserves than about "proven" reserves), and estimates of "proven" reserves have changed dramatically over the years, often increasing substantially even in the absence of new discoveries.[10] If the experts do not know how much remains underground, how can prices tell us?

While prices cannot effectively equilibrate unknown in-ground supply with demand, they can equilibrate the available aboveground supply with demand. Available aboveground supply is determined solely by the rate of extraction, which depends on known deposits, existing infrastructure and technology, as well as the resource owner's decision of how much to extract. Hotelling suggested that a rational producer will limit current production to take advantage of higher prices in future years. However, if real prices are not increasing, the owner has no incentive to leave the fossil fuels in the ground, and would rationally extract the resource as long as the marginal

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[9] Remember, new discoveries do not increase the amount of resources in the ground; they just make it easier for us to get them! In the short-run market sense, new discoveries decrease scarcity, while in the long-run physical or geological sense, they increase the scarcity of resources remaining in the ground.

[10] In January 1988, Iran, Iraq, and Venezuela each reported a doubling of their reserves, presumably to earn higher quotas under OPEC. In spite of continuous extractions since then, their reported reserves have scarcely changed. C. J. Campbell, Proving the Unprovable, *Petroleum Economist*, May 1995.

extraction cost remains lower than the price. Essentially, the producer ignores MUC, as in the simplest static analysis depicted in Figure 11.1.

Even if the producer ignores MUC, we would still expect MEC to increase. As we suggested earlier, economic analysis typically assumes that nonrenewable resources will be mined from the purest, easiest-to-access sources first. As these are depleted, we then move on to sources that are more expensive to extract, again putting upward pressure on prices. However, there are two serious problems with this argument. First, as Norgaard has noted, when we begin to exploit a new resource, we typically know very little about where the best fields are. A great deal of chance is involved with the initial discoveries. Norgaard compared this to the Mayflower. If people always exploited the best resources first, the first pilgrims would have settled on the best land in America. However, prior to their arrival, the pilgrims knew virtually nothing about land resources in North America, and ended up where they did largely by chance.[11]

Second, as we exploit a new resource, we diminish the total stock, but we gradually acquire more information about where to find it and how to extract it, and more of the resource becomes accessible. Thus, there are two effects at work. The scarcity effect decreases the total amount of resource available, but the information effect increases the amount that is accessible and reduces the costs of extracting it. Thus, as long as the information effect is dominant, the price of the resource should decrease. Eventually, however, the scarcity effect must come to dominate, and the price must then increase. Rather than predicting a gradual price increase in a resource, this model suggests the likelihood of decline followed by sudden, rapid increases. If we combine this analysis with the estimates of petroleum geologists, we would predict a sudden and dramatic increase in oil prices in the next 2–20 years.[12]

This result is particularly important if we are concerned with sustainability. As we pointed out earlier, economists assume that price increases will trigger innovation and generate substitutes for any given resource. If resource owners are optimists, they believe new discoveries will be made and substitutes invented. This means that their resource will not become scarce and its price will not go up (and may even go down). Under such circumstances, it makes sense to extract the resources as fast as possible and invest the returns. If the resources are being extracted quickly, above-ground supply is large, and the price is low. This reduces the incentives for exploration and the development of substitutes. The problem is that

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[11] R. Norgaard, Economic Indicators of Resource Scarcity: A Critical Essay, *Journal of Environmental Indicators and Management* 19(1): 19–25 (July 1990).

[12] D. B. Reynolds, The Mineral Economy: How Prices and Costs Can Falsely Signal Decreasing Scarcity, *Ecological Economics* 31(1): 155–166 (1999); C. J. Campbell and J. H. Laherrère, The End of Cheap Oil, *Scientific American*, March 1998.

developing substitutes requires technology, technological advance requires time, and the less warning we have of impending resource exhaustion, the less time there is to develop substitutes. Perversely, then, in a world of optimists, the pessimist is most likely to be correct, and vice versa.[13] While these arguments are far from the only ones discrediting the belief that we can ignore resource exhaustion, they are important.

FRESHWATER

As the economically relevant characteristics of freshwater depend on the specific use to which it is put, and because it is used in most economic and ecological processes, the economics of water could fill a textbook on its own. Some relevant characteristics of specific water uses can be gleaned from discussions in other sections of this text. Specifically, water in fossil aquifers is a nonrenewable resource similar to fossil fuels with fewer externalities. Water as an ecological fund-service is similar to other ecosystem services discussed in Chapter 12. In this section, we'll limit our discussion to some unique attributes of water as a stock-flow resource. Specifically, we address the facts that water is 100% essential to human survival, that it has no substitutes,[14] and that water distribution systems generally show substantial economies of scale.

The scarcity of clean and available water has traditionally been experienced as a local matter, but international disputes over access to water are increasing, indicating a global dimension to water scarcity. These characteristics have important implications for water markets. Though traditionally supplied by the public sector at least since early civilization's first large-scale irrigation projects, water is a rival good that can be made excludable under most circumstances and therefore technically amenable to market allocation. Indeed, in recent years, more and more cities, states, and even countries are turning their water supplies over to the private sector in the name of greater efficiency, and many neoclassical economists applaud this trend.[15] However, the fact that water is nonsubstitutable and 100% essential means that there are serious ethical implications to the market allocation of water, and it therefore makes a good case study of why just distribution precedes efficient allocation in ecological economics.

In many places, water is very abundant and is used for fairly unimportant activities; it is even wasted. Higher prices for water would reduce this waste. However, because in its most important uses water has no substi-

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[13] P. Victor, Indicators of Sustainable Development: Some Lessons from Capital Theory, *Ecological Economics* 4: 191–213 (1991).

[14] Though technology can, of course, increase the efficiency of water use in some applications.

[15] For example, the International Monetary Fund and the World Bank often make privatization of water supply a requirement for loans.

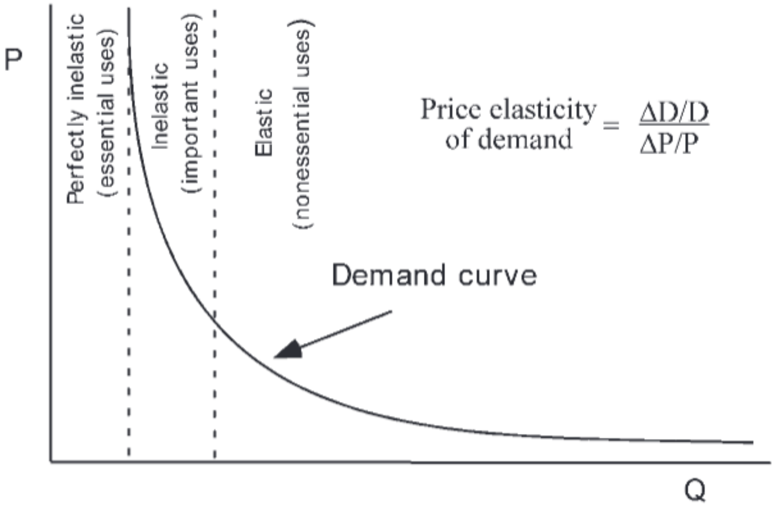

Figure 11.5 • The elasticity of water with respect to price (% change in quantity demanded with respect to % change in price), for different quantities of water.

tutes and is essential to our survival, as water supplies become scarce or prices increase, the demand for water becomes extremely inelastic with respect to price.[16] A 1% increase in price will lead to less than a 1% decrease in demand (Figure 11.5). When water is abundant, we use it for nonessential activities, and demand is price elastic. As water becomes scarcer, we use it only for more important activities, and it becomes inelastic with respect to price. As water becomes still scarcer, it will be used exclusively for essential activities, such as raising food and drinking, and demand becomes perfectly inelastic.

This situation leads to two very serious problems. First is the distribution issue. In the market economy, the most "efficient" use is that use which creates the highest value, and value is measured by willingness to pay. In a world with grossly unequal income distribution and a growing relative scarcity of water, many people have very limited means to pay. "Perfect" market allocation of water could easily lead to circumstances in which a rich person could pay more to water a lawn than a poor family could pay to water the crops it needs to survive. While economically a green lawn might be more efficient, ethically most people would probably agree that survival of the poor should take precedence.

The second issue is efficiency. Markets are rarely perfect, and, in the case of water, they are likely to be less perfect than most. Providing water

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[16] This issue has played an important role in the history of economic thought, usually discussed under the heading of the "diamonds-water paradox." See Box 14.1, footnote 1 for an explanation in the context of distinguishing use value from exchange value.

requires substantial infrastructure that would be very costly to duplicate. For this reason it makes sense to have only one provider, so even where water is privatized, there is typically not a competitive market but rather a natural monopoly. A natural monopoly occurs when the marginal cost of production is decreasing, which is the case for many public utilities. Dealing with inelastic demand, the monopoly provider knows that a 10% increase in price will lead to less than a 10% decrease in quantity demanded, leading to higher revenue and lower costs. Moreover, everyone needs water and cannot exit the market no matter how inefficient and expensive the monopoly supplier is. With no threat to their market share, firms bent on maximizing short-term profit may delay needed improvements in infrastructure. Only extensive regulation will deter the private supplier from increasing prices and decreasing quality. With no competition to drive down prices, nor regulation to control costs, private sector provision of water is likely to be less efficient than public sector provision—as well as less just.

RICARDIAN LAND

As we explained in Chapters 4 and 5, by Ricardian land we mean land simply as a physical space capable of capturing sunshine and rainfall, and not the various productive qualities inherent to the land itself. The latter qualities, such as soil fertility, we class as ecosystem services. Within a generation, Ricardian land is both rival and excludable, and hence can be allocated by markets. Between generations, it is nonrival, which suggests the market allocation of land might meet the criterion for both efficiency within a generation and fairness between generations.

Before we reach this conclusion, however, we must ask: What is it that makes Ricardian land valuable? Certainly in market terms, the most valuable land in the world is found within the borders of big cities, where prices may pass $100,000 per square meter, and the least valuable land is generally found in the most deserted areas. What makes land valuable would appear to be proximity to other humans. Some might reply that the low value of land in uninhabited areas is due to other factors, such as extreme cold or extreme heat, and those same factors prevented people from settling there in the first place. But if we look at some of our planet's less-inviting habitats, we find that where they are inhabited, land prices are highest at the sites of densest habitation and lowest where population is thinnest, even if the sites are otherwise virtually identical.

Why would the presence of other humans make land more valuable? Humans are social animals, dependent on each other for both psychic and physical needs. Living near others allows individuals to specialize, and the economic benefits of specialization are common knowledge. Empirically, in a growing economy with growing populations, land appreciates in value even in the absence of improvements by the landowner. As cities grow, the land on their peripheries becomes more valuable. If the government builds a subway system or road, the value of adjacent land can skyrocket. Proximity to new infrastructure, such as sewage systems, electric grids, highways, and subways, can similarly increase land value.

The truth is that land attains value as a positive externality of the decisions of others. Land values thus result from a market failure, and we cannot simply assume that markets are the best means for allocating even Ricardian land. These insights into land value were first popularized by the nineteenth-century economist Henry George.[17]

The origin of land value is not just an academic argument; it is directly related to important policy debates. For example, some time in the early 1990s, a case was widely discussed in which an elderly woman on the outskirts of Chicago owned land worth some $30 million. An endangered butterfly was found on her land, imposing serious restrictions on development and causing the value of the land to plummet. Many people argued that this was entirely unfair, and the government should be forced to compensate the woman for "taking" the value of her land. However, what was it that caused her land to be worth so much in the first place? The woman had owned the land for decades, during which time Chicago had grown considerably. Government-built roads, sewage, and electric grids had gradually expanded, making her formerly remote piece of land highly valuable. Government action created the value in her land, and a different government action subsequently reduced its private value through an effort to meet important public needs. This raises an important question: Are individuals entitled to wealth created by society or by nature, rather than through individual effort, or should this wealth belong to society as a whole?

In addition to the market failure associated with land values, there is another reason that market magic does not work with land. Land is present in a fixed amount, and supply is perfectly inelastic—it does not respond to changes in price. With fixed supply and increasing demand (as populations and wealth increase), land prices trend upward. Thus, whoever manages to acquire land will in general see the value of that land grow through no effort of her own. This makes land the subject of speculative investment. Land purchased for speculation is often left idle, but the demand for land for speculative purposes must be added to demand for land for productive purposes, driving up the price even further, and reducing the ability of people to buy land for production. In other words, under certain circumstances, speculative markets in land can reduce the production from land. None of this means that land ownership and land

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[17] H. George, Significant Paragraphs from Henry George's *Progress and Poverty*, with an introduction by John Dewey. Garden City, NY: Doubleday, Doran, 1928.

markets are necessarily bad—it simply means that we should not automatically attribute all the theoretical virtues of markets to markets in land.

SOLAR ENERGY

Primarily for completeness, the final abiotic resource we will consider is the flux of a solar energy that continuously warms the Earth and turns its biogeochemical cycles. Obviously, neither human institution nor human invention (short of giant mirrors or umbrellas in space) can directly change the allocation of sunlight on the Earth, nor the supply. Indirectly, however, market forces can have significant impacts on the scale, distribution, and allocation of solar energy.

In terms of scale, human impacts on ecosystems appear to be degrading their capacity to capture solar energy—for example, forests sickened by acid rain capture less solar energy than healthy ones. In terms of distribution, land is an essential substrate for the capture of solar energy in most forms other than heat, and markets thus determine indirectly who can utilize the solar energy striking the Earth. Allocation—to what uses sunlight is put—is also determined in part by who owns the land it strikes. In this sense, solar energy is both rival and excludable. Also something of an allocation issue, land uses affect the spatial distribution of solar energy—recall how the evapotranspiration from the Amazon transports solar energy in the form of heat to the temperate zones. In terms of policy considerations, however, these issues can be treated as attributes or externalities of the use of other resources.

BIG IDEAS to remember

- Eightfold classification of natural goods and services: fossil fuels (nonrenewable stock); minerals (partially recyclable, nonrenewable stock); water (nonrenewable stock, recyclable); solar energy (indestructible fund); Ricardian land (indestructible fund); renewable resources (renewable stock); ecosystem services (renewable fund); waste absorption capacity (renewable fund)
- Stocks (depletion), funds (depreciation)
- Renewable, nonrenewable
- Rival, nonrival, excludable, nonexcludable
- Extraction cost, marginal extraction cost
- External costs, marginal external costs
- User cost, marginal user cost
- Royalty
- Hotelling rule
- Price as problematic measure of resource scarcity
- Henry George