Chapter 13
Positive Externalities and Public Goods

Introduction to Positive Externalities and Public Goods

As economist Mariana Mazzucato explores in her well-known work *The Entrepreneurial State*, what makes a smartphone smart? What allows its apps to help you navigate new towns while getting updates about your home, all while your hands are on the steering wheel and your children are in the back seat watching their shows? For starters, the internet, cell tower networks, GPS, and voice activation. Each of these, and many other technologies we rely on, were developed with intensive government support. For example, GPS, which enables many cell phone functions beyond the frequently used mapping and ride-sharing applications, was developed by the U.S. Department of Defense over several generations of satellite tracking and complex computer algorithm development. The U.S. government still provides GPS for many of the world's users.

We do not often think of the government when we consider our leading products and entrepreneurs. We think of Apple, Google, Lyft, Tesla, Fitbit, and so on—creative innovators who built on the tools provided by these government efforts, using them in transformative ways. We may not think of the estimated $19 billion per year that the U.S. spends to maintain the GPS system, but we would certainly think of it if it suddenly went away. (Beyond the impact on our daily lives, economists estimate U.S. businesses alone would lose about $1 billion per day without GPS.)

Mazzucato is one of several prominent economists advocating for an embrace of continued government-sponsored innovations in order to build economic prosperity, reduce inequality, and manage ongoing challenges such as drought, coastal changes, and extreme weather. She argues that competitive, private sector markets are often resistant to the risks involved with large-scale innovation, because failed experiments and lack of uptake lead to massive corporate and personal losses. Governments can take on riskier research and development projects. Because government spending is fueled by taxpayers, and all innovation leads to some level of employment change, these proposals are certainly complex and challenging to implement.

This chapter deals with some of these issues: Will private companies be willing to invest in new technology? In what ways does new technology have positive externalities? What motivates inventors? What role should government play in encouraging research and technology? Are there certain types of goods that markets fail to provide efficiently, and that only government can produce? What happens when consumption or production of a product creates positive externalities? Why is it unsurprising when we overuse a common resource, like marine fisheries?

13.1 Investments in Innovation

Market competition can provide an incentive for discovering new technology because a firm can earn higher profits by finding a way to produce products more cheaply or to create products with characteristics consumers want. As Gregory Lee, CEO of Samsung said, "Relentless pursuit of new innovation is the key principle of our business and enables consumers to discover a world of possibilities with technology." An innovative firm knows that it will usually have a temporary

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Greenlaw, S., Shapiro, D., & MacDonald, D. (2024, July 18). Principles of Economics 3E.
https://openstax.org/details/books/principles-economics-3e

edge over its competitors and thus an ability to earn above-normal profits before competitors can catch up.

In certain cases, however, competition can discourage new technology, especially when other firms can quickly copy a new idea. Consider a pharmaceutical firm deciding to develop a new drug. On average, it can cost $800 million and take more than a decade to discover a new drug, perform the necessary safety tests, and bring the drug to market. If the research and development (R&D) effort fails—and every R&D project has some chance of failure—then the firm will suffer losses and could even be driven out of business. If the project succeeds, then the firm's competitors may figure out ways of adapting and copying the underlying idea, but without having to pay the costs themselves. As a result, the innovative company will bear the much higher costs of the R&D and will enjoy at best only a small, temporary advantage over the competition.

Many inventors over the years have discovered that their inventions brought them less profit than they might have reasonably expected.

- Eli Whitney (1765–1825) invented the cotton gin, but then southern cotton planters built their own seed-separating devices with a few minor changes in Whitney's design. When Whitney sued, he found that the courts in southern states would not uphold his patent rights.
- Thomas Edison (1847–1931) still holds the record for most patents granted to an individual. His first invention was an automatic vote counter, and despite the social benefits, he could not find a government that wanted to buy it.
- Gordon Gould came up with the idea behind the laser in 1957. He put off applying for a patent and, by the time he did apply, other scientists had laser inventions of their own. A lengthy legal battle resulted, in which Gould spent $100,000 on lawyers, before he eventually received a patent for the laser in 1977. Compared to the enormous social benefits of the laser, Gould received relatively little financial reward.
- In 1936, Alan Turing delivered a paper titled, "On Computable Numbers, with an Application to the Entscheidungsproblem," in which he presented the notion of a universal machine (later called the "Universal Turing Machine," and then the "Turing machine") capable of computing anything that is computable. The central concept of the modern computer was based on Turing's paper. Today scholars widely consider Turing as the father of theoretical computer science and artificial intelligence; however, the UK government prosecuted Turing in 1952 for engaging in same-sex sexual acts and gave him the choice of chemical castration or prison. Turing chose castration and died in 1954 from cyanide poisoning.
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A variety of studies by economists have found that the original inventor receives one-third to one-half of the total economic benefits from innovations, while other businesses and new product users receive the rest.

The Positive Externalities of New Technology

Will private firms in a market economy underinvest in research and technology? If a firm builds a factory or buys a piece of equipment, the firm receives all the economic benefits that result from the investments. However, when a firm invests in new technology, the **private benefits**, or profits, that the firm receives are only a portion of the overall social benefits. The **social benefits** of an innovation account for the value of all the positive externalities of the new idea or product, whether enjoyed by other companies or society as a whole, as well as the private benefits the firm that developed the new technology receives. As you learned in Environmental Protection and Negative Externalities, **positive externalities** are beneficial spillovers to a third party, or parties.

Consider the example of the Big Drug Company, which is planning its R&D budget for the next year. Economists and scientists working for Big Drug have compiled a list of potential research and development projects and estimated rates of return. (The rate of return is the estimated payoff from the project.) Figure 13.2 shows how the calculations work. The downward-sloping $D_{Private}$ curve represents the firm's demand for financial capital and reflects the company's willingness to borrow to finance research and development projects at various interest rates. Suppose that this firm's investment in research and development creates a spillover benefit to other firms and households. After all, new innovations often spark other creative endeavors that society also values. If we add the spillover benefits society enjoys to the firm's private demand for financial capital, we can draw D_{Social} that lies above $D_{Private}$.

If there were a way for the firm to fully monopolize those social benefits by somehow making them unavailable to the rest of us, the firm's private demand curve would be the same as society's demand curve. According to Figure 13.2 and Table 13.1, if the going rate of interest on borrowing is 8%, and the company can receive the private benefits of innovation only, then the company would finance $30 million. Society, at the same rate of 8%, would find it optimal to have $52 million of borrowing. Unless there is a way for the company to fully enjoy the total benefits, then it will borrow less than the socially optimal level of $52 million.

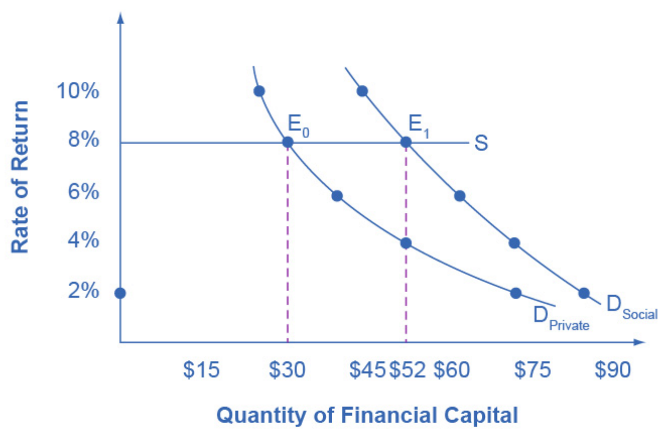

Figure 13.2 Positive Externalities and Technology Big Drug faces a cost of borrowing of 8%. If the firm receives only the private benefits of investing in R&D, then we show its demand curve for financial capital by $D_{Private}$, and the equilibrium will occur at $30 million. Because there are spillover benefits, society would find it optimal to have $52 million of investment. If the firm could keep the social benefits of its investment for itself, its demand curve for financial capital would be D_{Social} and it would be willing to borrow $52 million.

Rate of Return	$D_{Private}$ (in millions)	D_{Social} (in millions)
2%	$72	$84
4%	$52	$72
6%	$38	$62
8%	$30	$52
10%	$26	$44

Table 13.1 Return and Demand for Capital

Big Drug's original demand for financial capital ($D_{Private}$) is based on the profits the firm receives. However, other pharmaceutical firms and health care companies may learn new lessons about how to treat certain medical conditions and are then able to create their own competing products. The social benefit of the drug takes into account the value of all the drug's positive externalities. If Big Drug were able to gain this social return instead of other companies, its demand for financial capital would shift to the demand curve D_{Social}, and it would be willing to borrow and invest $52 million. However, if Big Drug is receiving only 50 cents of each dollar of social benefits, the firm will not spend as much on creating new products. The amount it would be willing to spend would fall somewhere in between $D_{Private}$ and D_{Social}.

Why Invest in Human Capital?

The investment in anything, whether it is the construction of a new power plant or research in a new cancer treatment, usually requires a certain upfront cost with an uncertain future benefit. The investment in education, or human capital, is no different. Over the span of many years, a student and her family invest significant amounts of time and money into that student's education. The idea is that higher levels of educational attainment will eventually serve to increase the student's future productivity and subsequent ability to earn. Once the student crunches the numbers, does this investment pay off for her?

Almost universally, economists have found that the answer to this question is a clear "Yes." For example, several studies of the return to education in the United States estimate that the rate of return to a college education is approximately 10-15%. Data in Table 13.2, from the U.S. Bureau of Labor Statistics' *Usual Weekly Earnings of Wage and Salary Workers, Fourth Quarter 2021,* demonstrate that median weekly earnings are higher for workers who have completed more education. While these rates of return will beat equivalent investments in Treasury bonds or savings accounts, the estimated returns to education go primarily to the individual worker, so these returns are **private rates of return** to education.

	Less than a High School Degree	High School Degree, No College	Bachelor's Degree or Higher
Median Weekly Earnings (full-time workers over the age of 25)	\$651	\$831	\$1,467

Table 13.2 Usual Weekly Earnings of Wage and Salary Workers, Fourth Quarter 2021 (Source: https://www.bls.gov/news.release/pdf/wkyeng.pdf)

What does society gain from investing in the education of another student? After all, if the government is spending taxpayer dollars to subsidize public education, society should expect some kind of return on that spending. Economists like George Psacharopoulos have found that, across a variety of nations, the **social rate of return** on schooling is also positive. After all, positive externalities exist from investment in education. While not always easy to measure, according to Walter McMahon, the positive externalities to education typically include better health outcomes for the population, lower levels of crime, a cleaner environment and a more stable, democratic government. For these reasons, many nations have chosen to use taxpayer dollars to subsidize primary, secondary, and higher education. Education clearly benefits the person who receives it, but a society where most people have a good level of education provides positive externalities for all.

Other Examples of Positive Externalities

Although technology may be the most prominent example of a positive externality, it is not the only one. For example, vaccinations against disease are not only a protection for the individual, but they have the positive spillover of protecting others who may become infected. When a number of homes in a neighborhood are modernized, updated, and restored, not only does it increase the homes' value, but other property values in the neighborhood may increase as well. The appropriate public policy response to a positive externality, like a new technology, is to help the party creating the positive externality receive a greater share of the social benefits. In the case of vaccines, like flu shots, an effective policy might be to provide a subsidy to those who choose to get vaccinated.

Figure 13.3 shows the market for flu shots. The market demand curve D_{Market} for flu shots reflects only the marginal private benefits (MPB) that the vaccinated individuals receive from the shots. Assuming that there are no spillover costs in the production of flu shots, the market supply curve is given by the marginal private cost (MPC) of producing the vaccinations.

The equilibrium quantity of flu shots produced in the market, where MPB is equal to MPC, is Q_{Market} and the price of flu shots is P_{Market}. However, spillover benefits exist in this market because others, those who chose not to purchase a flu shot, receive a positive externality in the form of a reduced chance of contracting the flu. When we add the spillover benefits to the marginal private benefit of flu shots, the marginal social benefit (MSB) of flu shots is given by D_{Social}. Because the MSB is greater than MPB, we see that the socially optimal level of flu shots is greater than the market quantity (Q_{Social} exceeds Q_{Market}) and the corresponding price of flu shots, if the market were to produce Q_{Social}, would be at P_{Social}. Unfortunately, the marketplace does not recognize the positive externality and flu shots will go under-produced and under-consumed.

How can government try to move the market level of output closer to the socially desirable level of output? One policy would be to provide a subsidy, like a voucher, to any citizen who wishes to get vaccinated. This voucher would act as "income" that one could use to purchase only a flu shot and, if the voucher were exactly equal to the per-unit spillover benefits, would increase market equilibrium to a quantity of Q_{Social} and a price of P_{Social} where MSB equals MSC (which equals MPC given the assumption that there are no spillover costs in producing the vaccine). Suppliers of the flu shots would receive payment of P_{Social} per vaccination, while consumers of flu shots would redeem the voucher and only pay a price of $P_{Subsidy}$. When the government uses a subsidy in this way, it produces the socially optimal quantity of vaccinations.

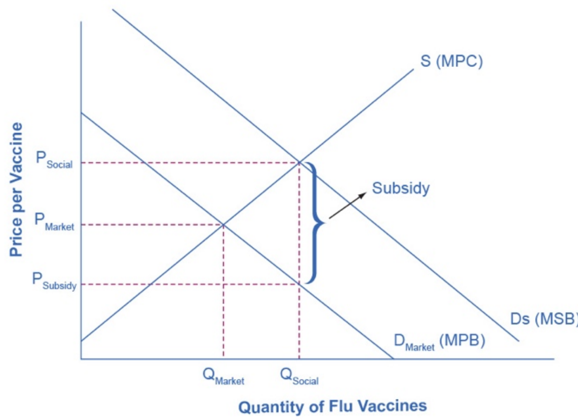

Figure 13.3 The Market for Flu Shots with Spillover Benefits (A Positive Externality) The market demand curve does not reflect the positive externality of flu vaccinations, so only Q_{Market} will be exchanged. This outcome is inefficient because the marginal social benefit exceeds the marginal social cost. If the government provides a subsidy to consumers of flu shots, equal to the marginal social benefit minus the marginal private benefit, the level of vaccinations can increase to the socially optimal quantity of Q_{Social}.

Societal Change as an Innovation Outcome

Economist Carlota Perez draws on the lessons of past innovations to understand the current state of our economy. She demonstrates that prior technological turning points, such as the proliferation of railroads and the emergence of mass production, created initial periods of employment and wealth shifting but eventually led to greater well-being and economic growth. After difficult transition periods and sometimes economic meltdowns during the "installment" phase of widespread new technologies, many economies and the people within them have benefited from prolonged periods of economic and lifestyle improvement, including lower unemployment and better quality of life.

Most prior innovation periods, such as the Industrial Revolution, had one significant downside: negative impacts on the environment, such as pollution and habitat destruction. Perez notes that our current revolution—in information and communications technology (ICT)—has the potential for significant positive externalities related to the environment. ICT is shifting many areas of society (and therefore industry) to digital experiences and services that do not require fossil fuels or similar natural resources. Vehicle sharing, product rental-reuse networks, and new manufacturing methods offer the promise of far less consumable consumption. And even though the appearance of delivery trucks and shipping boxes gives the impression of environmental damage, most studies indicate that online shopping is better for the environment than individuals shopping in person. (This is partly attributed to greater efficiency in a few trucks driving to a neighborhood rather than everyone in the neighborhood driving to several stores.) Consumers and governments can spur on those environmental benefits by choosing or partnering with companies that focus on furthering their environmental impact, such as by using solar power to fuel their computer servers or by using electrically powered delivery trucks.

Like other innovations, ICT has created some employment and economic opportunities while it has reduced others. Increased globalization and efficiencies have shuttered businesses and reduced wages in some areas. Perez's research indicates that those types of employment shifts can be managed through proper regulation and investment (especially in human capital), particularly as firms in the relevant industries become mature and profitable. The prospects aren't simple: ICT has created megafirms like Amazon and Apple, which despite pleasing their consumers can wield significant power over governments and employees. But on the environmental and societal front at least, ICT has offered a wealth of opportunities and externalities.

13.2 How Governments Can Encourage Innovation

Intellectual Property Rights

One way to increase new technology is to guarantee the innovator an exclusive right to that new product or process. **Intellectual property** rights include patents, which give the inventor the exclusive legal right to make, use, or sell the invention for a limited time, and copyright laws, which give the author an exclusive legal right over works of literature, music, film/video, and pictures. For example, if a pharmaceutical firm has a patent on a new drug, then no other firm can manufacture or sell that drug for 20 years, unless the firm with the patent grants permission. Without a patent, the pharmaceutical firm would have to face competition for any successful products, and could earn no more than a normal rate of profit. With a patent, a firm is able to earn monopoly profits on its product for a period of time—which offers an incentive for research and development. In general, how long can "a period of time" be? The Clear It Up discusses patent and copyright protection timeframes for some works you might know.

Figure 13.4 illustrates how the total number of patent applications filed with the U.S. Patent and Trademark Office, as well as the total number of patents granted, surged in the mid-1990s with the invention of the internet, and is still going strong today.

Figure 13.4 Patents Filed and Granted, 1990–2020 The number of applications filed for patents increased substantially beginning in the 1990s, due in part to the invention of the internet, which has led to many other inventions and to the 1998 Copyright Term Extension Act. (Source: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm)

While patents provide an incentive to innovate by protecting the innovator, they are not perfect. For example:

- In countries that already have patents, economic studies show that inventors receive only one-third to one-half of the total economic value of their inventions.
- In a fast-moving high-technology industry like biotechnology or semiconductor design, patents may be almost irrelevant because technology is advancing so quickly.
- Not every new idea can be protected with a patent or a copyright—for example, a new way of organizing a factory or a new way of training employees.
- Patents may sometimes cover too much or be granted too easily. In the early 1970s, Xerox had received over 1,700 patents on various elements of the photocopy machine. Every time Xerox improved the photocopier, it received a patent on the improvement.
- The 20-year time period for a patent is somewhat arbitrary. Ideally, a patent should cover a long enough period of time for the inventor to earn a good return, but not so long that it allows the inventor to charge a monopoly price permanently.
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Because patents are imperfect and do not apply well to all situations, alternative methods of improving the rate of return for inventors of new technology are desirable. The following sections describe some of these possible alternative policies.

Policy #1: Government Spending on Research and Development

If the private sector does not have sufficient incentive to carry out research and development, one possibility is for the government to fund such work directly. Government spending can provide direct financial support for research and development (R&D) conducted at colleges and universities, nonprofit research entities, and sometimes by private firms, as well as at government-run laboratories. While government spending on research and development produces technology that is broadly available for firms to use, it costs taxpayers money and can sometimes be directed more for political than for scientific or economic reasons.

The first column of Table 13.3 shows the sources of total U.S. spending on research and development. The second column shows the total dollars of R&D funding by each source. The third column shows that, relative to the total amount of funding, 22.7% comes from the federal government, about 69% of R&D is done by industry, and less than 4% is done by universities and colleges. (The percentages below do not add up to exactly 100% due to rounding.)

Sources of R&D Funding	Amount ($ billions)	Percent of the Total
Federal government	**$129.6**	**21.4%**
Industry	$426.0	70.3%
Universities and colleges	$20.7	3.4%
Nonprofits	$25.0	4.1%
Nonfederal government	$4.8	0.8%
Total	*$606.1*	

Table 13.3 U.S. Research and Development Expenditures, 2018 (Source: https://ncses.nsf.gov/pubs/nsf21324)

In the 1960s the federal government paid for about two-thirds of the nation's R&D. Over time, the U.S. economy has come to rely much more heavily on industry-funded R&D. The federal government has tried to focus its direct R&D spending on areas where private firms are not as active. One difficulty with direct government support of R&D is that it inevitably involves political decisions about which projects are worthy. The scientific question of whether research is worthwhile can easily become entangled with considerations like the location of the congressional district in which the research funding is spent.

Policy #2: Tax Breaks for Research and Development
A complementary approach to supporting R&D that does not involve the government's close scrutiny of specific projects is to give firms a reduction in taxes depending on how much research and development they do. The federal government refers to this policy as the research and experimentation (R&E) tax credit. According to the Treasury Department: ". . . the R&E Credit is also a cost-effective policy for stimulating additional private sector investment. Most recent studies find that each dollar of foregone tax revenue through the R&E Tax Credit causes firms to invest at least a dollar in R&D, with some studies finding a benefit to cost ratio of 2 or 2.96."

Policy #3 Cooperative Research
State and federal governments support research in a variety of ways. For example, United for Medical Research, a coalition of groups that seek funding for the National Institutes of Health, (which is supported by federal grants), states: "NIH-supported research added $69 billion to our GDP and supported seven million jobs in 2011 alone." The United States remains the leading sponsor of medical-related research, spending $117 billion in 2011. Other institutions, such as the National Academy of Sciences and the National Academy of Engineering, receive federal grants for innovative projects. The Agriculture and Food Research Initiative (AFRI) at the United States Department of Agriculture awards federal grants to projects that apply the best

science to the most important agricultural problems, from food safety to childhood obesity. Cooperation between government-funded universities, academies, and the private sector can spur product innovation and create whole new industries.

13.3 Public Goods

Even though new technology creates positive externalities so that perhaps one-half or two-thirds of the social benefit of new inventions spills over to others, the inventor still receives some private return. What about a situation where the positive externalities are so extensive that private firms could not expect to receive any of the social benefit? We call this kind of good a **public good**. Spending on national defense is a good example of a public good. Let's begin by defining the characteristics of a public good and discussing why these characteristics make it difficult for private firms to supply public goods. Then we will see how government may step in to address the issue.

The Definition of a Public Good

Economists have a strict definition of a public good, and it does not necessarily include all goods financed through taxes. To understand the defining characteristics of a public good, first consider an ordinary private good, like a piece of pizza. We can buy and sell a piece of pizza fairly easily because it is a separate and identifiable item. However, public goods are not separate and identifiable in this way.

Instead, public goods have two defining characteristics: they are nonexcludable and non-rival. The first characteristic, that a public good is **nonexcludable**, means that it is costly or impossible to exclude someone from using the good. If Larry buys a private good like a piece of pizza, then he can exclude others, like Lorna, from eating that pizza. However, if national defense is provided, then it includes everyone. Even if you strongly disagree with America's defense policies or with the level of defense spending, the national defense still protects you. You cannot choose to be unprotected, and national defense cannot protect everyone else and exclude you. The second main characteristic of a public good, that it is **non-rival**, means that when one person uses the public good, another can also use it. With a private good like pizza, if Max is eating the pizza then Michelle cannot also eat it; that is, the two people are rivals in consumption. With a public good like national defense, Max's consumption of national defense does not reduce the amount left for Michelle, so they are non-rival in this area.

A number of government services are examples of public goods. For instance, it would not be easy to provide fire and police service so that some people in a neighborhood would be protected from the burning and burglary of their property, while others would not be protected at all. Protecting some necessarily means protecting others, too.

Positive externalities and public goods are closely related concepts. Public goods have positive externalities, like police protection or public health funding. Not all goods and services with positive externalities, however, are public goods. Investments in education have huge positive spillovers but can be provided by a private company. Private companies can invest in new inventions such as the Apple iPad and reap profits that may not capture all of the social benefits. We can also describe patents as an attempt to make new inventions into private goods, which are excludable and rivalrous, so that no one but the inventor can use them during the length of the patent.

The Free Rider Problem of Public Goods

Private companies find it difficult to produce public goods. If a good or service is nonexcludable, like national defense, so that it is impossible or very costly to exclude people from using this good or service, then how can a firm charge people for it?

When individuals make decisions about buying a public good, a **free rider** problem can arise, in which people have an incentive to let others pay for the public good and then to "free ride" on the purchases of others. We can express the free rider problem in terms of the prisoner's dilemma game, which we discussed as a representation of oligopoly in Monopolistic Competition and Oligopoly.
There is a dilemma with the Prisoner's Dilemma, though. See the Work It Out feature.

The Role of Government in Paying for Public Goods

The key insight in paying for public goods is to find a way of assuring that everyone will make a contribution and to prevent free riders. For example, if people come together through the political process and agree to pay taxes and make group decisions about the quantity of public goods, they can defeat the free rider problem by requiring, through the law, that everyone contributes.

However, government spending and taxes are not the only way to provide public goods. In some cases, markets can produce public goods. For example, think about radio. It is nonexcludable, since once the radio signal is broadcast, it would be very difficult to stop someone from receiving it. It is non-rival, since one person listening to the signal does not prevent others from listening as well. Because of these features, it is practically impossible to charge listeners directly for listening to conventional radio broadcasts.

Radio has found a way to collect revenue by selling advertising, which is an indirect way of "charging" listeners by taking up some of their time. Ultimately, consumers who purchase the goods advertised are also paying for the radio service, since the station builds in the cost of advertising into the product cost. In a more recent development, satellite radio companies, such as SiriusXM, charge a regular subscription fee for streaming music without commercials. In this case, however, the product is excludable—only those who pay for the subscription will receive the broadcast.

Some public goods will also have a mixture of public provision at no charge along with fees for some purposes, like a public city park that is free to use, but the government charges a fee for parking your car, for reserving certain picnic grounds, and for food sold at a refreshment stand.

In other cases, we can use social pressures and personal appeals, rather than the force of law, to reduce the number of free riders and to collect resources for the public good. For example, neighbors sometimes form an association to carry out beautification projects or to patrol their area after dark to discourage crime. In low-income countries, where social pressure strongly encourages all farmers to participate, farmers in a region may come together to work on a large irrigation project that will benefit all. We can view many fundraising efforts, including raising money for local charities and for the endowments of colleges and universities, as an attempt to use social pressure to discourage free riding and to generate the outcome that will produce a public benefit.

Common Resources and the "Tragedy of the Commons"

There are some goods that do not fall neatly into the categories of private good or public good. While it is easy to classify a pizza as a private good and a city park as a public good, what about an item that is nonexcludable and rivalrous, such as the queen conch?

In the Caribbean, the queen conch is a large marine mollusk that lives in shallow waters of sea grass. These waters are so shallow, and so clear, that a single diver may harvest many conch in a single day. Not only is conch meat a local delicacy and an important part of the local diet, but artists use the large ornate shells and craftsmen transform them. Because almost anyone with a small boat, snorkel, and mask, can participate in the conch harvest, it is essentially nonexcludable. At the same time, fishing for conch is rivalrous. Once a diver catches one conch another diver cannot catch it.

We call goods that are nonexcludable and rivalrous common resources. Because the waters of the Caribbean are open to all conch fishermen, and because any conch that *you* catch is a conch that *I* cannot catch, fishermen tend to overharvest common resources like the conch.

The problem of overharvesting common resources is not a new one, but ecologist Garret Hardin put the tag "tragedy of the commons" to the problem in a 1968 article in the magazine *Science*. Economists view this as a problem of property rights. Since nobody owns the ocean, or the conch that crawl on the sand beneath it, no one individual has an incentive to protect that resource and responsibly harvest it. To address the issue of overharvesting conch and other marine fisheries, economists have advocated simple devices like fishing licenses, harvest limits, and shorter fishing seasons. One approach that has been turned to more recently is the implementation of catch shares, whereby regulators establish a total allowable catch, and then fishermen are allocated a portion of that total allowable catch. Catch shares appear to slow the race to fish. When the population of a species drops to critically low numbers, governments have even banned the harvest until biologists determine that the population has returned to sustainable levels. In fact, such is the case with the conch, the harvesting of which the government has effectively banned in the United States since 1986.

The tragedy of the commons is a frequent economic and social framework for discussions about a range of common resources, even extending into digital resources such as open media repositories and online libraries. Prominent economist Elinor Ostrom, the first woman to receive the Nobel Prize in Economics, proposed an alternate version, sometimes referred to as the "non-tragedy of the commons." After extensive fieldwork in areas as diverse as Indonesia, Kenya, Maine (U.S.), and Nepal, she challenged the notion that people would only avoid depletion of common resources if they were forced to by regulatory laws and property rights. She noted that farmers working shared land could communicate and cooperate in order to maximize and preserve the fields over time. She argued that when those who benefit most from a resource are in close proximity to it (like a farm field that directly serves a town), the resource is better managed without external influence.

Positive Externalities in Public Health Programs

One of the most remarkable changes in the standard of living in the last several centuries is that people are living longer. Scientists believe that, thousands of years ago, human life expectancy ranged between 20 to 30 years. By 1900, average life expectancy in the United States was 47 years. By 2015, life expectancy was 79 years; due to COVID-19, life expectancy declined slightly to 77 years in 2020. Most of the gains in life expectancy in the history of the human race happened in the twentieth century.

The rise in life expectancy seems to stem from three primary factors. First, systems for providing clean water and disposing of human waste helped to prevent the transmission of many diseases. Second, changes in public behavior have advanced health. Early in the twentieth century, for example, people learned the importance of boiling bottles before using them for food storage and baby's milk, washing their hands, and protecting food from flies. More recent behavioral changes include reducing the number of people who smoke tobacco and precautions to limit sexually transmitted diseases. Third, medicine has played a large role. Scientists developed immunizations for diphtheria, cholera, pertussis, tuberculosis, tetanus, and yellow fever between 1890 and 1930. Penicillin, discovered in 1941, led to a series of other antibiotic drugs for bringing infectious diseases under control. In recent decades, drugs that reduce the risks of high blood pressure have had a dramatic effect in extending lives.

These advances in public health have all been closely linked to positive externalities and public goods. Public health officials taught hygienic practices to mothers in the early 1900s and encouraged less smoking in the late 1900s. Government funded many public sanitation systems and storm sewers because they have the key traits of public goods. In the twentieth century, many medical discoveries emerged from government or university-funded research. Patents and intellectual property rights provided an additional incentive for private inventors. The reason for requiring immunizations, phrased in economic terms, is that it prevents spillovers of illness to others—as well as helping the person immunized.