He also advocated government investment in education, and in public works such as bridges, roads, and canals.

QUESTION 1.1 Choose the correct answer(s)

Read the following statements about Adam Smith and select the correct option(s).

- ☐ Adam Smith believed in the role of the government to improve societal welfare.
- ☐ Adam Smith believed that all markets were characterized by perfect competition.
- ☐ Adam Smith argued that economic agents were guided entirely by self-interest.
- ☐ Adam Smith claimed that coordination among a large number of economic actors (producers, transporters, sellers, consumers), often unknown to one another, might spontaneously arise without any person or institution consciously attempting to create or maintain it.

EXTENSION 1.2

GDP per capita and living standards

In this extension we explore the reasons why GDP is not always a satisfactory measure of living standards. Not only does GDP leave out some things that are important for our daily lives, it also fails to take account of differences between people, and of the depletion of environmental resources.

1.3 Another hockey stick: Climate change

Using GDP as a measure of living standards ignores the importance of the environment for our current and future wellbeing. Evidence that our use of fossil fuels—coal, oil, and natural gas—has profoundly affected the natural environment of the planet is shown in Figures 1.2a and 1.2b. Each figure has the hockey stick shape. After having remained relatively unchanged for many centuries, increasing emissions of carbon dioxide (CO_2) into the air during the twentieth and twenty-first centuries have resulted in measurably larger amounts of CO_2 in the earth's atmosphere (Figure 1.2a (page 7)) and brought about perceptible increases in the northern hemisphere's average temperatures (Figure 1.2b (page 7)). Figure 1.2a (page 7) also shows that CO_2 emissions from fossil fuel consumption have risen dramatically since the late 1800s.

Figure 1.2b (page 7) shows that the mean temperature of the earth fluctuates from decade to decade. Many factors cause these fluctuations, including volcanic events such as the 1815 Mount Tambora eruption in Indonesia.

Since 1900, average temperatures have risen in response to increasingly high levels of greenhouse gas concentrations. These have mostly resulted from the CO_2 emissions associated with the burning of fossil fuels. And in each year of the twenty-first century, the average temperature has been higher than at any time in the previous millennium.

The human causes and the reality of climate change are no longer widely disputed in the scientific community. The likely consequences of global warming are far-reaching: melting of the polar ice caps, rising sea levels that may put large coastal areas under water, and potential changes in climate and rain patterns that may make

Mount Tambora spewed so much ash that the earth's temperature was reduced by the cooling effect of these fine particles in the atmosphere, and 1816 became known as the 'year without a summer' (https://tinyco.re/3530430).

The authoritative source for research and data about climate change is the Intergovernmental Panel on Climate Change (https://tinyco.re/8844088).

some densely populated parts of the world uninhabitable and destroy the world's food-growing areas.

We can see that the hockey sticks for GDP per capita and for atmospheric CO_2 have risen together. It is also the case that richer countries have, on average, higher emissions per capita. In Unit 2 (page 90), we explore this link between income and

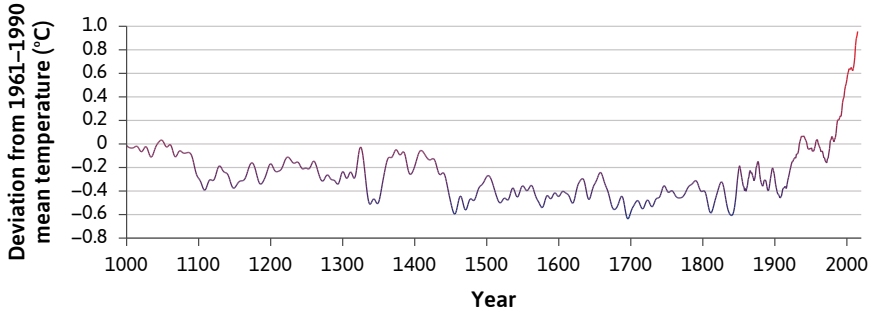

Figure 1.2b Northern hemisphere temperatures over the long run (1000–2019). The figure shows 5-year moving averages.

See more https://tinyco.re/8926412

Michael E. Mann, Zhihua Zhang, Malcolm K. Hughes, Raymond S. Bradley, Sonya K. Miller, Scott Rutherford, and Fenbiao Ni. 2008. 'Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia' (https://tinyco.re/1009800). Proceedings of the National Academy of Sciences 105 (36): pp. 13252–13257.; C. P. Morice, J. J. Kennedy, N. A. Rayner, and P. D. Jones. 2012. 'Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: The HadCRUT4 dataset' (https://tinyco.re/6765840), Journal of Geophysical Research 117. D08101, doi:10.1029/2011JD017187.

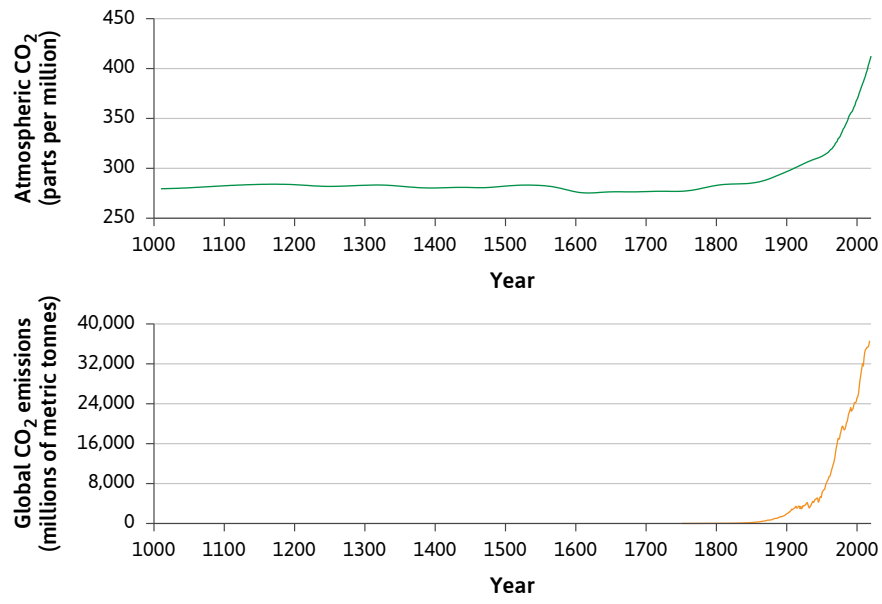

Figure 1.2a Carbon dioxide in the atmosphere (1010–2020) and global carbon emissions from burning fossil fuels (1750–2018).

Pierre Friedlingstein, Matthew W. Jones, Michael O'Sullivan, et al. 2019. 'Global Carbon Budget 2019' (https://tinyco.re/2898770). *Earth System Science Data* 11: pp. 1783–1838. doi: 10.5194/essd-11-1783-2019.; Pieter Tans NOAA/GML and Ralph Keeling, Scripps Institution of Oceanography. 2022. 'Trends in Atmospheric Carbon Dioxide' (https://tinyco.re/4421890).; D. Gilfillan, G. Marland, T. Boden, and R. Andres, R. 2021. 'Global, Regional, and National Fossil Fuel CO2 Emissions' (https://tinyco.re/3338780). Carbon Dioxide Information Analysis Center (CDIAC) Datasets. Accessed: September, 2021.

emissions, and consider whether it will be possible, in future, to raise living standards around the world without further damage to the climate.

EXERCISE 1.1 How much difference does a couple of degrees warmer or colder make?

Between 1300 and 1850 there were a number of exceptionally cold periods, as shown in Figure 1.2b (page 7). Research this so-called 'little ice age' in Europe and answer the following questions.

1. Describe the effects of these exceptionally cold periods on the economies of these countries.
2. Provide examples of groups of people within a country or region who were exceptionally affected by climate change.

QUESTION 1.2 Choose the correct answer(s)

Figure 1.2b (page 7) shows the northern hemisphere's temperature since year 1000, reported as the deviation from the 1961–1990 mean (average) temperature. Based on this figure, read the following statements and select the correct option(s).

- ☐ The 1961–1990 mean temperature was 0.2 to 0.6 degrees higher than the temperatures between 1450 and 1900.
- ☐ The negative numbers on the graph indicate that the temperature consistently fell between 1100 and 1900.
- ☐ A consistent rise in temperature is only a post-1980 phenomenon.
- ☐ The consistent rise in temperature after 1980 suggests that temperatures will continue to rise in every year following 2000.

To explore the latest data on extreme poverty, read Our World in Data's webpage on 'Poverty' (https://tinyco.re/9647535).

For example, 14% of the world's population live in countries with lower average income than India. Since 18% of the world's population live in India, a total of 32% live in countries with average income less than or equal to that in India.

purchasing power parity (PPP) PPPs are price indices that measure how much it costs to purchase a basket of goods and services compared to how much it costs to purchase the same basket in a reference country in a particular year, such as the United States in 2011.

1.4 Inequality in global income

Before the upward kink in history's hockey stick, some people were rich by the standards of their day, but most people in the world lived in extreme poverty.

Global poverty and income inequality

Mirroring the hockey sticks of income and carbon is the transformation from a world in which the vast majority of people were unable to meet their basic needs of minimal nutrition and adequately heated shelter to today, when that is true of around one in ten (Figure 1.3). These people are often hungry, don't have access to electricity (and therefore to light at night, for example), and have limited access to schooling or healthcare.

A thousand years ago, the world was flat, economically speaking. There were major differences in income within the world's countries and regions; but as shown in Figure 1.1 (page 3), the differences between countries were small, especially when compared to what was to follow.

Income inequality between countries

Nobody thinks the world is flat today, when it comes to income. Figure 1.4 provides a snapshot for 2019. The countries of the world are lined up from left to right by average income, the poorest (South Sudan) on the left and the richest (United Arab

ment provides resources that we consume directly, and the primary inputs to the production of goods and services within households and firms.

According to the *Living Planet Report 2020* by the World Wildlife Fund, there was an average 68% decrease in population sizes of mammals, birds, amphibians, reptiles, and fish between 1970 and 2016. And since 1970, humanity's *ecological footprint* has exceeded the earth's rate of regeneration. The report estimates that we are overusing the earth's biocapacity by at least 56%. Figure 1.22 illustrates projections for future biodiversity depending on whether we can make human production and consumption more sustainable.

We have seen that capitalist institutions—private property, markets, and firms—have facilitated the continuous technological revolution and rapidly rising living standards by encouraging innovation and successful adoption of new technologies. But many of the most important technological developments of the twentieth century (https://tinyco.re/9117566), from cars and aeroplanes to refrigeration and personal computers, have relied on carbon-based energy for their use as well as manufacture. Others, like plastics and chemical fertilisers, lead directly to ecosystem damage.

The evidence on biodiversity and climate change shows how dramatically the way we produce our livelihoods is now degrading the environment, and depleting the stock of natural resources—including clean air and a liveable climate.

An example is the Grand Banks cod fishery off the east coast of Newfoundland, which sustained the livelihoods of the US and Canadian fishing communities for 300 years. Cod stocks collapsed in 1992, after several decades of large-scale commercial fishing, and the fishery closed. We still do not know if the cod will come back in their previous numbers.

One reason for the environmentally destructive pattern of technological change and resource use is that goods or technologies that deplete or destroy natural resources are artificially cheap, so we overuse them. They are artificially cheap because the prices that users of natural resources pay do not include the depletion of the natural environment. For example, what consumers pay when they buy cod goes

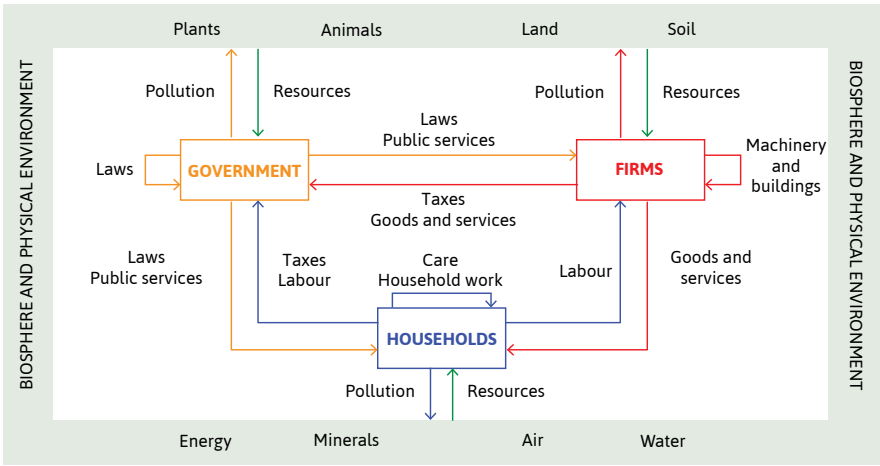

Figure 1.21 A model of the economy: Flows of resources.

into the wages of the crew and others employed in the supply chain, and into the profits of the firms involved. But no fishing firm owner has an incentive to maintain the stock of cod on the Grand Banks. The cod stocks could be freely exploited while they lasted; if the owner of a trawler tried to conserve them by catching fewer fish per week, their own profits would be reduced and competing trawlers would catch the fish anyway.

This contrasts with a firm owner whose profits depend on a stock of privately owned resources and who has an incentive to maintain it in good condition: for example, a tour operator will maintain their fleet of buses because they are needed tomorrow as well as today, and are costly to replace.

Some environmental problems can be addressed by governments directly regulating the amount of emissions or other environmental damages. Examples are banning lead in petrol (gasoline) or issuing a limited number of permits to emit CO_2 and allowing firms to buy and sell these permits. Without regulation, electricity generators do not pay for using up the absorptive capacity of the biosphere. By limiting the total number of permits issued, this policy limits the total amount of emissions and puts a price on the use of CO_2 because firms emitting it have to buy permits. This also provides a profit motive for owners of firms to reduce carbon emissions that is absent when they are not regulated. These policies protect the environment by making goods produced in environmentally harmful ways either illegal or costly, so they will be used less.

One way that technological progress can contribute to mitigating climate change and biodiversity loss is by reducing the cost of goods and services that are compatible with environmental sustainability. Recent advances in technology have vastly reduced the cost of wind, solar, and other renewable sources of energy. We discuss some examples in the next unit.

The depleted cod stocks parallels the case of the depletion of the Indonesian forests in Extension 1.2 (https://tinyco.re/4703694), which is a cost of forestry there that is not deducted from GDP. In this case, the value of the fish sold is counted in GDP (of Canada, say), but the depletion of the stock of fish is not subtracted.

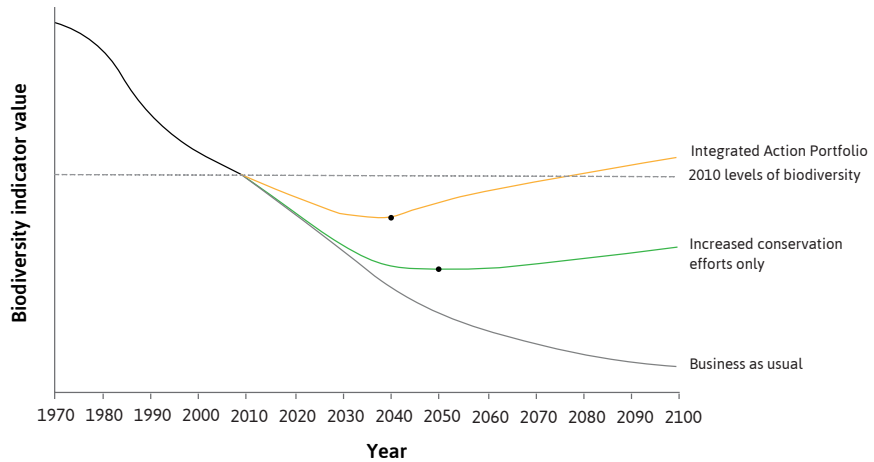

Figure 1.22 Global biodiversity loss under three different scenarios. (Integrated Action Portfolio refers to increased conservation efforts, increased agricultural land productivity, reductions in food waste, and changes in food consumption behaviour.) Labelled points indicate the year in which biodiversity is expected to start increasing.

The evidence on biodiversity and climate change shows how dramatically the way we produce our livelihoods is now changing the environment, and depleting the stock of natural resources. By treating them as free, and using them up, we affect future (human) living standards and wellbeing. From global climate change to local resource exhaustion, these effects are results of both the expansion of the economy (illustrated by the growth in total output) and the way the economy is organized (what kinds of things are valued and conserved, for example).

Addressing environmental problems to enable those in low-income countries to transition out of poverty and to sustain living standards in rich ones requires governmental and other collective solutions, whether local, national, or international. Local communities can organize recycling schemes, or agree on regulations for the use of a lake. Governments can limit or prevent the sale of damaging products, as some have done in the case of incandescent light bulbs or petrol- or diesel-powered cars; or subsidise beneficial investment, for example in public transport infrastructure, solar and wind power, or home insulation. Climate change, and the conservation of oceans and some rivers, requires not only individual government action, but international agreement.

Although governments are far more able than individuals and firms acting singly to take action to protect the environment, they often fail to do so. The centrally planned economies of Eastern Europe, where governments controlled production, had a particularly poor record on pollution control. Per capita mortality from air pollution in Eastern Europe (outside the EU) and China remains high relative to the EU and North America. But although democratic governments have been more active in reducing pollution that negatively affects the lives and health of their citizens, they have been reluctant to adopt environmental policies that restrict individual choice—for example, to tax or limit the use of private cars—or that would reduce profits of companies providing carbon-based energy.

EXERCISE 1.11 Earth Overshoot Day

Earth Overshoot Day, an initiative by the Global Footprint Network, marks the date when global demand for environmental and natural resources in a given year exceeds what the earth can regenerate in that year. In 2022, that day was July 28. However, each country uses the earth's resources at different rates.

1. Check the Earth Overshoot Day website's diagram (https://tinyco.re/9767876) of country-specific overshoot days to find out the date for your country (or the country you live in) in the latest year available.
2. Take this Ecological Footprint Calculator survey (https://tinyco.re/3239841) to find out your personal overshoot day (or equivalently, how many earths we would need if everyone lived a similar lifestyle to you).

1.14 Summary

- For most of human history, living standards remained at what we would today consider to be a low level with temporary ups and downs associated with variations in weather, disease, and social conflicts.
- Beginning in the 1700s in Great Britain, rising average material living standards have become a continuous feature of economic life in many countries; but one in ten people in the world still live in extreme poverty.

- The rising level of global output has contributed to climate change, biodiversity loss, and other threats to the environment, especially since the beginning of the twentieth century.
- Contributing to both rising affluence and environmental threats was the introduction of new methods of production, increasing the amount a person can produce in an hour by harnessing energy based on burning carbon.
- The technological revolution and resulting continuous increases in output were facilitated by a new economic system called capitalism, which combines three institutions: private property, markets, and firms hiring others to produce goods in order to make a profit.
- Differing forms of capitalism and differing political systems have led to differences in economic performance between countries.
- Many countries that were colonized, like India, did not experience substantially rising living standards until well after independence. For other countries, many in Latin America, for example, independence from colonial rule (in the early nineteenth century) did not bring about a change in economic fortunes.
- Economics is the study of how people interact with each other and with the natural environment in producing their livelihoods.
- Climate change and biodiversity loss mean that we need new non-carbon technologies and new policies and institutions to sustain our planet, and at the same time eliminate global poverty.
- Malthus's economic model, combining the concept of the diminishing average product with a theory of population growth, helps explain the long, flat part of history's hockey stick. It shows why (under the conditions Malthus described) technological improvement does not raise income permanently.

Concepts and models introduced and applied in Unit 1

- **Gross domestic product (GDP)**, growth in GDP per capita, global **income inequality**, and **climate change**
- **Technology**, **factors of production** and **production functions**; the **continuous technological revolution** (such as the **Industrial Revolution** in Britain)
- **Capitalism** is an **economic system** that is characterized by three **institutions**: **private property**, **markets**, and **firms**
- **Structural transformation**, whereby a part of the economy organized on capitalist lines expands and other sectors shrink
- The **Malthusian model**, diminishing **average product** of labour with **subsistence level** output being the **equilibrium**

1.15 References

Acemoglu, Daron, and James A. Robinson. 2012. *Why Nations Fail: The Origins of Power, Prosperity and Poverty*, 1st ed. New York, NY: Crown Publishers.

Allen, Robert. 2000. 'Economic structure and agricultural productivity in Europe, 1300–1800'. *European Review of Economic History* 4 (1): pp. 1–26.

Augustine, Dolores. 2013. 'Innovation and Ideology: Werner Hartmann and the Failure of the East German Electronics Industry'. In *The East German Economy, 1945–2010: Falling behind or Catching Up?* by German Historical Institute, eds. Hartmut Berghoff and Uta Andrea Balbier. Cambridge: Cambridge University Press.

Britain had escaped from the Malthusian trap. This process would soon be repeated in other countries, as Figure 1.1 (page 3) shows.

In our 'Economist in action' video, Suresh Naidu, an economic historian, explains how population growth, technological development and political events interacted to produce the real wage hockey stick.
https://tinyco.re/3012875

QUESTION 2.10 Choose the correct answer(s)
Figure 2.17 (page 88) plots real wages against population in England from the 1280s to the 1860s.

According to Malthus, with diminishing average product of labour in production and population growth in response to increases in real wages, an increase in productivity will result in a larger population but not higher real wages in the long run. Based on the information above, read the following statements and select the correct option(s).

- ☐ The data from the 1800s and the 1860s is consistent with Malthus's description of the economy's growth, because the population grows as real wages rise.
- ☐ There is clear evidence of a persistent and continuous Malthusian trap between the 1280s and the 1800s.
- ☐ The Malthusian traps seem to occur in a cycle of 60 years.
- ☐ The Malthusian model does not take into account the possibility of a persistent positive technology shock that may offset the diminishing average product of labour.

EXERCISE 2.13 The basic institutions of capitalism
The escape from the Malthusian trap, in which technological progress outstripped the effects of population growth, took place following the emergence of capitalism. Consider the three basic institutions of capitalism in turn:

1. Why is private property important for technological progress to occur?
2. Explain how markets can provide both carrots and sticks to encourage innovation.
3. How can production in firms, rather than families, contribute to the growth of living standards?

2.11 Capitalism + carbon = hockey stick growth + climate change

The Industrial Revolution marked the transition from an economy in which photosynthesis is the source of most energy, so that land is a constraint on growth, to an energy-rich economy based on fossil fuels. The switch to coal was a necessary condition for the Industrial Revolution. By 1800, replacing the use of the energy stored in coal in England by energy from living trees would have required the use of one-third

4. Workers' power
The supply of labour fell when business owners were stopped from employing children. The combination of higher labour demand and lower supply made it easier for workers to gain higher wages.

5. The escape from Malthusianism
The wages of working people increased as they gained the right to vote and formed trade unions. These workers were able to claim a constant or rising share of the increases in productivity generated by the continuous technological revolution.

6. A summary of how technological progress led to higher wages.
The Industrial Revolution, combined with changes in institutions (labour market regulation and extension of the right to vote), eventually led to rising real wages.

of the surface area of the country. By 1913, British coal production was equivalent to four times its land area.

The benefits for the people of countries escaping the Malthusian trap are clear from the historically unprecedented increases in per capita income illustrated by the hockey sticks (Figure 1.1 (page 3)). But equally unprecedented has been the rise in surface temperature of the earth (Figure 1.2b (page 7)). This threatening side-effect results from the particular combination of technologies and institutions that propelled the continuous technological revolution, which we summarize as 'carbon plus capitalism'.

Carbon plus capitalism has brought unprecedented increases in material well-being to billions, but most of the people of the world remain poor by the standards of the higher income countries. Climate change induced by burning carbon means that an ongoing reduction in global poverty cannot be accomplished by the same carbon plus capitalism that accounted for rising income in the now-rich countries.

In an EconTalk podcast (https://tinyco.re/7088528), Martin Weitzman argues there is a substantial risk of a catastrophe from climate change.

Capitalism plus carbon: End of the road?

For 100,000 years or more, humans—like other animals—lived in ways that modified the biosphere, but did not substantially and irreversibly degrade its capacity to support life on the planet. Starting in the eighteenth century, humans learned how to use the energy available from nature (burning carbon) to transform the production of goods and services. The capitalist economy made the technological revolution a continuous feature of our lives.

In many countries, workers' power and wages were enhanced through extension of the vote, prohibition of slavery and hiring children, and organization into trade unions and political parties. (Figure 2.18 (page 89) explains how this happened in Britain.) Their living standards rose.

But rising labour costs provided ongoing incentives for firms to adopt labour-saving innovations using non-human energy from fossil fuels—leading to an impoverishment of nature.

A degraded and threatened environment cannot be reversed by the same mechanism that created this affluence. In raising their wages, workers were their own advocates. Their success in improving their living standards—by gaining higher wages—made it profitable for owners of firms to adopt a pattern of technological change in which less labour was used relative to other inputs, including natural resources.

You could imagine that a similar process might raise the price of natural resources, leading to nature-saving technical change. But the biosphere does not have the vote. Soon-to-be-extinct animals cannot form unions or political organizations to protect their interests, and the profit incentives to save them are not clear.

New terms, new tools: Stocks and flows

To understand how the process of climate change could be contained, let's consider the underlying scientific process.

Burning fossil fuels for power generation and industrial use emits CO_2 into the atmosphere. Greenhouse gases such as CO_2 allow incoming sunlight to pass through the atmosphere, but trap reflected heat on the earth, leading to increases in atmospheric temperatures and changes in climate. Some CO_2 also gets absorbed into the oceans, increasing the acidity of the oceans and killing marine life.

stock A quantity measured at a point in time, such as a firm's stock of capital goods, or the amount of carbon dioxide in the atmosphere. Its units do not depend on time. *See also: flow.*

flow A quantity measured per unit of time, such as weekly income, or annual carbon emissions. *See also: stock.*

The amount of CO_2 in the atmosphere is called the **stock**, while the amount being added per year is called the **flow**. To better understand what the terms stock and flow mean, consider Figure 2.19. The stock of CO_2 is the amount in the bathtub.

A flow is a measure based on a time period, like the number of tons of CO_2 per year. CO_2 emissions are an inflow that adds to the amount of atmospheric greenhouse gases, while the natural decay of CO_2 and its absorption (for example, by forests) are outflows that reduce the amount.

A key fact of climate science is that global warming results from the stock. It's what's in the tub that matters. The flow matters only because it will alter the stock. Figure 2.20 (page 93) illustrates the movements in the stock of atmospheric CO_2 and annual temperatures.

The increase in the stock of atmospheric CO_2 is occurring because the outflows (natural decay, and absorption by forests and other carbon sinks) are far less than the new emissions that we add annually. Moreover, deforestation in the Amazon, Indonesia, and elsewhere is reducing the CO_2 outflows while also adding to CO_2 emissions. Forests are often replaced by agriculture, which produces further greenhouse gas emissions—including methane from livestock, and nitrous oxide from fertilizer overuse.

The natural decay of CO_2 is extraordinarily slow. Of the carbon dioxide that humans have put in the atmosphere since the mass burning of coal that started in the Industrial Revolution, two-thirds will still be there a hundred years from now. More than a third will still be 'in the tub' a thousand years from now. The natural processes that stabilized greenhouse gases in pre-industrial times have been entirely overwhelmed by human economic activity. And the imbalance is accelerating.

A future without fossil fuels

The GDP hockey sticks in Unit 1 tell a powerful story of the entry of country after country onto the path of continuously rising average living standards—and of the

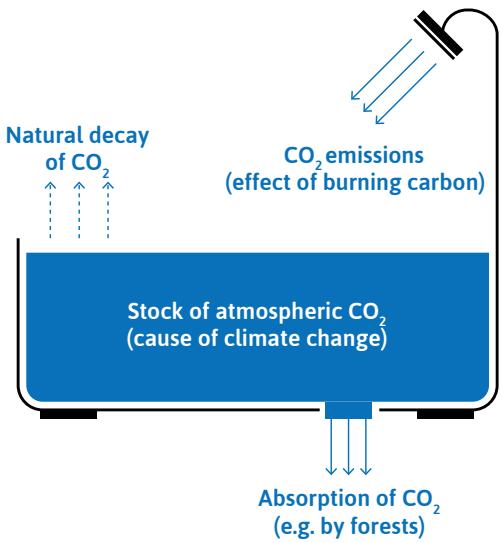

Figure 2.19 A bathtub model: the stock of atmospheric CO_2.

many countries that have not yet experienced the transition to broad-based growth. The production of energy is currently responsible for 87% of global greenhouse gas emissions. For the 85% of the global population who live below the level considered poor in a high-income country, is a fossil fuel-based transition to that standard of living in their future?

The evidence from climate science says that the growth in world production that would be required to raise incomes this much (estimated to be more than four times the size of today's total output) will have to be based on renewable energy combined with reduced energy input per unit of consumption.

How quickly this happens and at what cost depends critically on the policies that governments pursue; and these differ across countries. Figure 2.21 (page 94) shows the link between rising living standards and CO_2 emissions: countries where GDP per capita is higher tend to have higher CO_2 emissions as well. This is to be expected because greater income per capita is the result of a higher level of production of goods and services per capita, involving greater use of fossil fuels. The upward-sloping 'line of best fit' shows the average emissions per capita for each level of GDP per capita. Low emissions by low-income countries signal energy poverty, not green energy or energy conservation.

But even among countries with similar per capita income, some emit much more than others. Compare the high emissions in the US, Canada, and Australia with the

Visit Our World in Data (https://tinyco.re/7649094) to read more about the world's two energy problems.

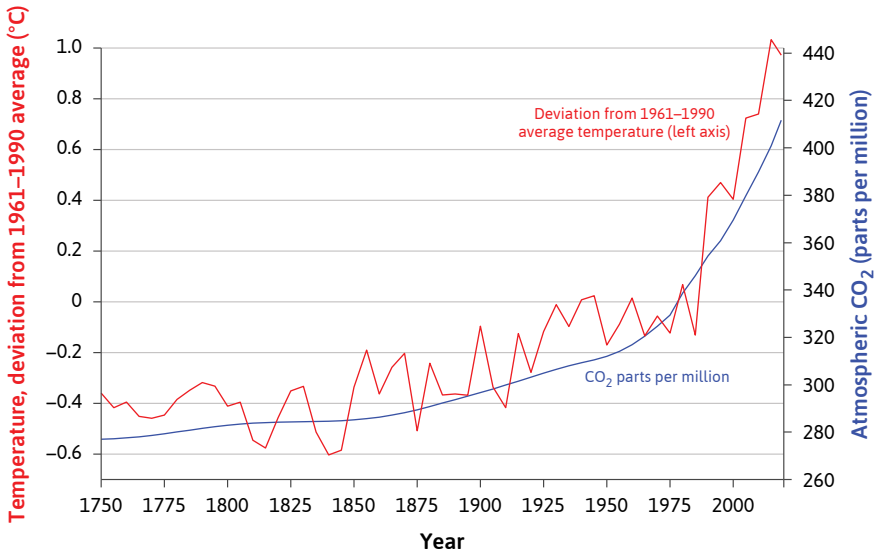

Figure 2.20 Global atmospheric concentration of carbon dioxide and global temperatures (1750–2019).

Pieter Tans, NOAA/GML, and Ralph Keeling, Scripps Institution of Oceanography. 2022. Trends in Atmospheric Carbon Dioxide (https://tinyco.re/8976788); D. Gilfillan, G. Marland, T. Boden, and R. Andres, R. 2021. Global, Regional, and National Fossil-Fuel CO2 Emissions (https://tinyco.re/4356621). Carbon Dioxide Information Analysis Center (CDIAC) Datasets. Accessed: September 2021.; Michael E. Mann, Zhihua Zhang, Malcolm K. Hughes, Raymond S. Bradley, Sonya K. Miller, Scott Rutherford, and Fenbiao Ni. 2008. 'Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia' (https://tinyco.re/1009800). *Proceedings of the National Academy of Sciences* 105 (36): pp. 13252–13257.; C. P. Morice, , J. J. Kennedy, N. A. Rayner, and P. D. Jones. 2012. Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: The HadCRUT4 dataset (https://tinyco.re/6765840). Journal of Geophysical Research 117. D08101, doi:10.1029/2011JD017187. Note: This data is the same as in Figures 1.2a and 1.2b. Temperature is average northern hemisphere temperature.

lower levels in France, Sweden, and Germany. Norway and Switzerland both have higher per capita incomes than the US but emit half as much CO_2.

This suggests that it is possible to organize production to offset, in part, the tendency for increased emissions as income rises. In low-emitting countries like France and Sweden, a substantial share of electricity is generated by non-fossil fuel sources (92% and 99% respectively) and petrol prices are much higher than in the countries with high emissions like the US and South Africa (above the line). For the poor countries on the left of the figure, their move to higher incomes needs to be a more nearly horizontal one rather than along the 'line of best fit'.

A transition to low-carbon electricity could occur simply by governments ordering it, but it would be more likely to happen—either by government order or by private decisions—if the energy from these sources is cheaper than from fossil fuels. Until well into the twenty-first century, electricity generated from renewables was far more expensive than from fossil fuels. Even in the absence of a carbon tax which will —as intended— raise the price of fossil fuel-based energy, prices have changed dramatically more recently. In most parts of the world, power from new renewable facilities is cheaper than from new fossil fuel ones.

The collapse in the price of renewable electricity generation since 1976 is illustrated vividly in Figure 2.22 by the data on the cost of photovoltaic cells for producing solar energy. This chart uses a different scale from other charts so far: it is a ratio (or equivalently, logarithmic) scale. Each step up the vertical axis corresponds to a doubling of the price, and each step along the horizontal axis multiplies the installed capacity by ten. The data points form close to a straight line: its slope tells us that a 10-fold increase in capacity roughly halves the cost.

Concentrating on the last ten years, Figure 2.23 compares the changes in the costs of generating electricity using renewables and fossil fuels. As we have discussed in this unit, it is the relative price of electricity generation over the lifetime of the power plant that affects decisions to switch to a new technology: the changes in ranking of wind, and especially solar (from the most expensive to the least) mean that by 2019, 72% of all new additions to capacity worldwide have been in renewables.

The World Bank. 2021. 'World Development indicators (https://tinyco.re/1998076)'.; EPI. 2018. 'Environmental Protection Index 2018 (https://tinyco.re/5473228)'. Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network. Note: Three small very high-income countries (Kuwait, Luxembourg, and Qatar) are not shown.

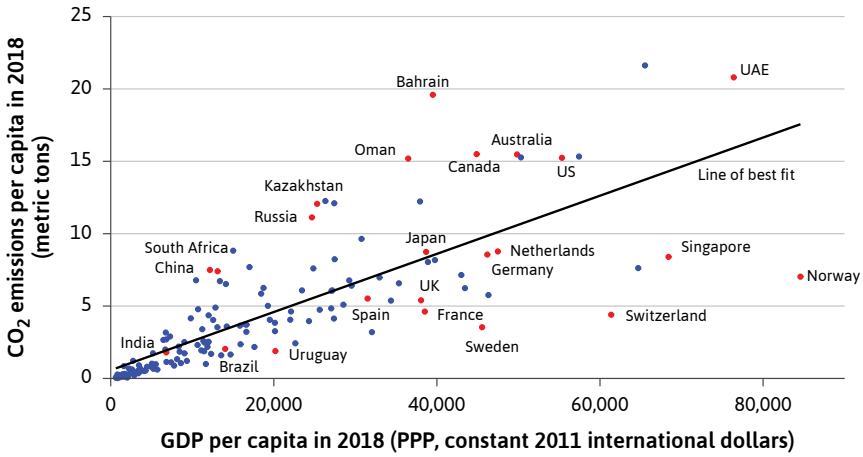

Figure 2.21 Carbon dioxide emissions are higher in richer countries.

The technological progress in renewables is a sign that a path to higher living standards without fossil fuels may be possible. But whether this is feasible on the scale required both to arrest climate change and make a serious dent in global poverty is doubtful.

What is not in doubt is the need to decouple growth from environmental destruction. The case of Sweden illustrates that this can happen. Figure 2.24 shows how GDP per capita has grown since 1995 alongside a decline in per capita energy use—whether measured by domestic energy use, or by a trade-adjusted measure that subtracts energy used to produce exports and adds energy used to produce imported goods.

K. Stadler, R. Wood, T. Bulavskaya, T., *et al.* 2018.'EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables (https://tinyco.re/1554321)'. *Journal of Industrial Ecology* 22 (3): pp. 502–515.

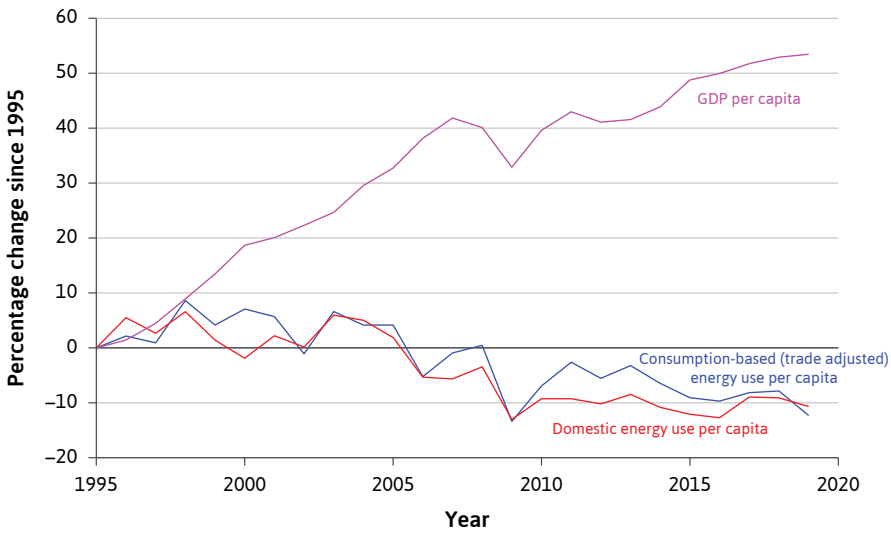

Figure 2.24 Changes in energy use and changes in GDP per capita in Sweden (1995–2019).

produced by enslaved workers in the British colonies of the Caribbean and North America. Therefore the first Industrial Revolution was a global phenomenon, supported by capitalism in Britain and Britain's colonies and slavery in the rest of the world.

- Over the past two centuries, cheap coal, oil, and other carbon-based resources along with rising wages provided ongoing incentives to increase the use of energy and economize on labour. The resulting build-up of CO_2 and other greenhouse gases caused dangerous increases in global temperatures.
- To address the dual challenges of climate change and the elimination of global poverty, changes in the incentives to use fossil fuels along with other public policies are necessary.

Concepts and models introduced and applied in Unit 2

- A model of economic decisions: **opportunity cost**, **economic cost**, **reservation option**, **economic rents**
- **Incentives**; **innovation rents** and **relative prices**
- A model of the gains from specialization and trade: **comparative advantage** and the **division of labour**
- **Production functions**, **factors of production**, **constant returns to scale**, **fixed-proportions technologies**, and the **average product** of labour
- A model of the choice between different two-factor technologies, using **isocost lines** to show how the choice depends on the relative prices of the factors
- The principles of economic modelling: simplification and ***ceteris paribus***, **equilibrium**, **endogenous** variables and **exogenous** changes, testing models against evidence

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Irrigated rice terrace fields in Yuanyang County, Yunnan Province, China.

UNIT 4

Strategic interactions and social dilemmas

When social dilemmas arise from self-interested behaviour, a combination of social norms, a regard for the wellbeing of others, and appropriate institutions may lead to more desirable social outcomes

4.1 Climate negotiations: Conflicts and common interests

> The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response.
>
> *The Stern Review on the Economics of Climate Change*, 2006

The Stern Review examined both scientific evidence and economic implications of climate change. Its conclusion, that the benefits of early action would outweigh the costs of neglecting the issue, was reinforced in 2014 by the United Nations Inter-governmental Panel on Climate Change (UN IPCC). Early action would mean a significant cut in greenhouse gas emissions, by reducing our consumption of energy-intensive goods, a switch to different energy technologies, reducing the impacts of agriculture and land-use change, and an improvement in the efficiency of current technologies.

These changes could not happen under what the Stern Review called 'business as usual', in which people, governments, and businesses were free to pursue their own

pleasures, politics, and profits, taking little account of their effects on others, including future generations.

But national governments disagree on which policies to adopt, and who should bear the costs. Countries' interests differ according to their stage of economic development, possession and use of natural resources, and vulnerability to the impacts of climate change. The 2015 Paris Agreement made progress: countries would adopt domestic mitigation measures to achieve 'nationally determined contributions' to emissions reduction, with the goal of limiting the temperature rise to 1.5°C by the end of the century and avoiding the worst impacts of climate change. But in October 2022, the UN warned (https://tinyco.re/3444340):

> We are still nowhere near the scale and pace of emission reductions required ... To keep this goal alive, national governments need to strengthen their climate action plans now and implement them in the next eight years.

This article (https://tinyco.re/8890909) describes the history of climate change negotiations over the last 30 years.

The problem of climate change is extreme, but far from unique. It is an example of a **social dilemma**. Social dilemmas occur when people do not take adequate account of the effects of their actions on others, whether these are positive or negative.

social dilemma A situation in which actions taken independently by individuals in pursuit of their own private objectives result in an outcome that is inferior to some other feasible outcome that could have occurred if people had acted together, rather than as individuals.

Social dilemmas occur frequently in our lives. Traffic jams happen when our choice of a way to get around—for example driving alone to work rather than taking public transport, or car-pooling—ignores the contribution we make to congestion. Similarly, overusing antibiotics for minor illnesses may help a sick person recover quickly, but creates antibiotic-resistant bacteria that have a much more harmful effect on many others.

The Tragedy of the Commons

In 1968, Garrett Hardin, a biologist, published an article about social dilemmas in the journal *Science*, called 'The Tragedy of the Commons'. He argued that resources like the earth's atmosphere, or fish stocks, that are not owned by anyone (sometimes called 'common property' or 'common-pool resources') are easily overexploited unless we control access in some way. The fishing industry as a whole would be better off not catching as much tuna, and consumers as a whole would be better off not eating too much of it. Humanity would be better off emitting less pollution, but if you as an individual decide to cut your consumption or your carbon footprint, you will hardly affect the global levels.

You can learn more about your carbon footprint and what you can do to reduce it here (https://tinyco.re/3329023).

Examples of Hardin's tragedies and other smaller-scale social dilemmas are all around us: if you live with room-mates or in a family, you know just how difficult it is to keep a clean kitchen or bathroom. When one person cleans, everyone benefits, but it is hard work: whoever cleans up bears this cost. The others are sometimes called **free-riders**. If as a student you have ever done a group assignment, you understand that the costs of effort (to study the problem, gather evidence, or write up the results) are individual, yet the benefits (a better grade, higher class standing, or simply the admiration of classmates) go to the whole group.

free rider, free riding, free ride Someone who benefits from the contributions of others to some cooperative project without contributing themselves is said to be free riding, or to be a free rider.

Resolving social dilemmas

We have been facing social dilemmas since prehistory.

More than 2,500 years ago, the Greek storyteller Aesop wrote about a social dilemma in his fable 'Belling the Cat'. A group of mice needs one of its members to place a bell around a cat's neck. Once the bell is on, the cat cannot catch and eat the other mice. But the outcome may not be so good for the mouse that takes the job.

altruism Altruism is a social preference: a person who is willing to bear a cost to benefit somebody else is said to be altruistic.

There are countless examples during wars or natural catastrophes in which individuals sacrifice their lives for others who are not family members, and may even be total strangers. These actions are termed **altruistic**.

Altruistic motivations can help to address social dilemmas—because our altruism means that we care about how our actions affect others—but for global challenges like climate change, altruism will not be sufficient: new government policies will have to be involved. Governments have successfully imposed quotas to prevent the overexploitation of stocks of cod in the North Atlantic. In the UK, the amount of waste that is dumped in landfills, rather than being recycled, has been dramatically reduced by a landfill tax (https://tinyco.re/8403762).

Local communities also create institutions to regulate behaviour. Community irrigation systems need people to work to maintain the canals that benefit the whole community. Individuals also need to use scarce water sparingly so that other crops will flourish, although this will lead to smaller crops for themselves. For centuries in Valencia, Spain, farming communities have used a set of customary rules to regulate communal tasks and to avoid using too much water. Since the middle ages, they have had an arbitration court called the *Tribunal de las Aguas* (https://tinyco.re/8410208) (Water Court) that resolves conflicts between farmers about the application of the rules. The ruling of the *tribunal* is not legally enforceable. Its power comes only from the respect of the community, yet its decisions are almost universally followed.

Some present-day global environmental problems have also been tackled effectively. The Montreal Protocol (https://tinyco.re/8364376) has been remarkably successful. It is an international agreement to protect the ozone layer that protects us against harmful ultraviolet radiation, by phasing out chemicals like chlorofluorocarbons (CFCs) that deplete it.

In this unit, we will use the tools of game theory to model **social interactions**, in which the decisions of individuals affect other people as well as themselves. We will examine when and why social dilemmas arise, and how people can sometimes solve them—but not always (or not yet), as in the case of climate change.

social interactions Situations in which the actions taken by each person affect other people's outcomes as well as their own.

EXERCISE 4.1 Social dilemmas

Using the news headlines from last week:

1. Identify two social dilemmas that have been reported (try to use examples not discussed above).
2. For each, specify how it satisfies the definition of a social dilemma.

4.2 Social interactions: Game theory

On which side of the road should you drive? If you live in Japan, the UK, or Indonesia, you drive on the left. If you live in South Korea, France, or the US, you drive on the right. If you grew up in Sweden, you drove on the left until 5 p.m. on 3 September 1967, and at 5.01 p.m., you started driving on the right. The government sets a rule, and we follow it.

But suppose we just left the choice to drivers to select one side of the road or the other. If everyone else was already driving on the right, self-interest (avoiding a collision) would be a major motivating factor in leading people to drive on the right as well.

Devising policies to promote people's wellbeing requires an understanding of the difference between situations in which self-interest can promote general wellbeing, and cases in which it leads to undesirable results. To analyse this, we will introduce game theory, a way of modelling how people interact.

Social and strategic interactions

In some economic models there is just one decision-maker—like the model in Unit 3 (page 118) of a worker (Karim) deciding on his working hours. Karim faces a set of feasible options determined by his budget constraint, and chooses the best possible outcome for himself—which does not depend on what anyone else decides to do. He is not engaged in a social interaction.

Social interactions are situations in which there are two or more people, and the actions taken by each person affect both their own outcome and other people's outcomes. For example, one person's choice of how much to heat their home will affect everyone's experience of global climate change.

We use four terms:

- When people are engaged in a social interaction and are aware of the ways that their actions affect others, and vice versa, we call this a **strategic interaction**.
- A **strategy** is defined as an action (or action plan) that a person may choose while being aware of the mutual dependence of the outcomes on their own and others' actions.
- Models of strategic interactions are described as **games**.
- **Game theory** is a set of models of strategic interactions. It is widely used in economics and elsewhere in the social sciences.

strategic interaction A social interaction in which the participants are aware of the ways in which their actions affect others (and the ways in which the actions of others affect them).
strategy An action (or action plan) that a person may choose, while being aware that the outcomes for themselves and others depend on their own strategy and the strategies chosen by others.
game A model of strategic interaction that describes the players, the feasible strategies, the order of play, the information that the players have, and their payoffs. *See also: game theory.*
game theory A branch of mathematics that studies strategic interactions, meaning situations in which each actor knows that the benefits they receive depend on the actions taken by all. *See also: game.*

Read the article 'Game Theory in Economics and Beyond' (https://tinyco.re/1495676) to learn about how game theory is used in other disciplines, including political science, biology, philosophy, and computer science.

To understand how game theory can clarify strategic interactions, imagine two farmers, who we will call Anil and Bala. They face a problem: should they grow rice or cassava? We assume that they have the ability to grow both types of crop, but can only grow one type at a time.

Anil's land is equally suitable for growing rice and cassava. Bala's land is likewise good for producing rice, but less suitable for cassava. They both sell whatever crop they produce in a nearby village market. On market day, if they bring less rice to the market, the price will be higher. Likewise, the price of cassava depends on how much cassava they have grown.

The farmers choose what to grow independently, which means they do not meet together to discuss a course of action. This assumption may seem odd in a model of just two farmers, but understanding what happens when players act independently will give us insight into problems in which many people—billions, in the case of climate change—interact.

Figure 4.1 describes the farmers' interaction, which is what we call a game.

Anil's choices are the rows of the table and Bala's are the columns. We call Anil the 'row player' and Bala the 'column player'. When an interaction is represented in a table like Figure 4.1, each entry describes the outcome of a hypothetical situation. For example, the upper-left cell should be interpreted as:

> 'Suppose (for whatever reason) Anil planted rice and Bala planted rice, too. What would the outcome be?'

There are four possible hypothetical situations. Figure 4.1 describes what would happen in each case.

This is remarkable: if you care only about your own pay-off, contributing nothing at all is the dominant strategy. One possible explanation for the high initial contributions is that the participants in the experiment were altruistic. But the difficulty (or, in Hardin's words, the tragedy) is obvious. Everywhere, contributions decreased over time.

In some cities (Copenhagen, Bonn, and St. Gallen) this trend is very evident. In others (Muscat, Riyadh, or Athens) contributions are still high at the end of the experiment. Contributions to the common pool vary widely across societies.

Altruism is not the most plausible explanation of these results. Altruistic players would care about the pay-offs received by others in all periods independently of the actions of other players, maintaining their contributions over time to ensure benefits for all. But it appears that contributors decreased their level of cooperation if they observed that others were free-riding. They cared about how others behaved.

The role of social norms

People make decisions according to their own individual preferences—the likes, dislikes, attitudes, feelings, and beliefs that motivate them (including social preferences, such as altruism). But their preferences may be influenced by social norms.

A social norm is an understanding that is shared among most members of a community about how people should behave towards each other in particular circumstances. Giving gifts on birthdays to close family members and friends is a social norm in many communities, as are conventions that also apply among strangers, like 'waiting in line'.

In the situations modelled by public good games, many people are happy to contribute when they observe others contributing. This suggests that they are influenced by social norms: for example that people ought to contribute for the good of the group, or that outcomes should be fair.

reciprocity A preference to be kind to or to help others who are kind and helpful, and to withhold help and kindness from people who are not helpful or kind.

The most convincing reason for falling contributions in later rounds of the experiment is that players whose contributions were initially high were disappointed that others did not follow a social norm of **reciprocity** by raising their contributions in return. The disappointed players responded—according to the same norm—by lowering their own contributions.

If people care strongly about social norms, they may wish to punish those who violate them, even if the cost to themselves is high. In the experiment in Figure 4.14b, the only way to punish free-riders was to stop contributing. To test what would happen if players could punish each other directly, the experimenters introduced a punishment option. After observing the contributions of their group, individual players could punish other players by making them pay a $3 fine. The punisher remained anonymous, but had to pay $1 per player punished.

Figure 4.14c shows the effect. For the majority of players, including those in China, South Korea, northern Europe, and the English-speaking countries, contributions were higher when they had the opportunity to punish free-riders.

In some cities, the threat of punishment was sufficient to prevent contributions falling over time. But in Melbourne, where contributions fell rapidly to below $2 in the previous experiment, players were able to use punishment to raise the average from $8 initially to $16 before the end.

When people engage in a common project—whether pest control, irrigation, or reducing carbon emissions—everyone has something to gain if they cooperate, but also something to lose when others free-ride. This experiment illustrates how, even in large groups of people, repeated interactions, social norms, and social preferences

would they choose? Astrid obviously prefers that they both play Java while Bettina prefers that they both play C++. This is another example of a negotiation with a conflict of interest, although unlike the example in Section 4.10, they do not appear to have a 50-50 option. But the total pay-off from the project is higher if both choose C++. If they could agree that both would use C++, perhaps they could also agree to split the proceeds in a way that would make both of them content with the outcome.

In Exercise 4.15, you can compare the outcome of such a negotiation with what might happen under other conditions affecting their decisions.

EXERCISE 4.15 Conflict between Astrid and Bettina

What is the likely result of the game in Figure 4.22 (page 207) if:

1. Astrid can choose which language she will use first, and commit to it (just as the Proposer in the ultimatum game commits to an offer, before the Responder responds)?
2. the two can make an agreement, including which language they use, and how much cash can be transferred from one to the other?
3. they have been working together for many years, and in the past they used Java on joint projects?

EXERCISE 4.16 Conflict in business

In the 1990s, Microsoft battled Netscape over market share for their web browsers, called Internet Explorer and Navigator. In the 2000s, Google and Yahoo fought over which company's search engine would be more popular. In the entertainment industry, a battle called the 'format wars' played out between Blu-ray and HD-DVD.

Use one of these examples to analyse whether there are multiple equilibria and, if so, why one equilibrium might emerge in preference to the others.

4.14 Modelling the global climate change problem

Why has it proved so difficult for international negotiations to make progress in limiting climate change? The success of the Montreal Protocol in protecting the ozone layer contrasts with the relative failure to reduce emissions responsible for global warming. The reasons are partly scientific. The alternative technologies to CFCs were well developed and the benefits relative to costs for large industrial countries, such as the US, were much clearer than in the case of greenhouse gas emissions.

This article (https://tinyco.re/1482500) describes the disastrous floods in Pakistan in 2022.

Reducing carbon emissions requires much greater changes, across many industries and affecting all members of society. One of the obstacles at the United Nations' annual climate change negotiations has been disagreement over how to share the costs and benefits of limiting emissions between countries—and in recent years, the heavy costs some countries now face from the effects of past emissions elsewhere.

To explore the possible situations facing climate negotiators, we will model them as a game between two large countries, hypothetically labelled China and the US, each considered as if it were a single individual. First, we identify possible equilibria when each country behaves strategically; then we can think about how an agreed outcome might be achieved.

Figure 4.23a shows the outcomes of two alternative strategies: Restrict (taking measures to reduce emissions, for example by regulating or taxing the use of fossil fuels) and BAU (continuing with 'business as usual').

What we can expect to happen depends on the pay-offs in each outcome. The essential features of the problem can be captured using an ordinal scale from Best to Worst: it is the order of the pay-offs, not the size, that matters. Figure 4.23b shows two games, corresponding to different sets of hypothetical pay-offs.

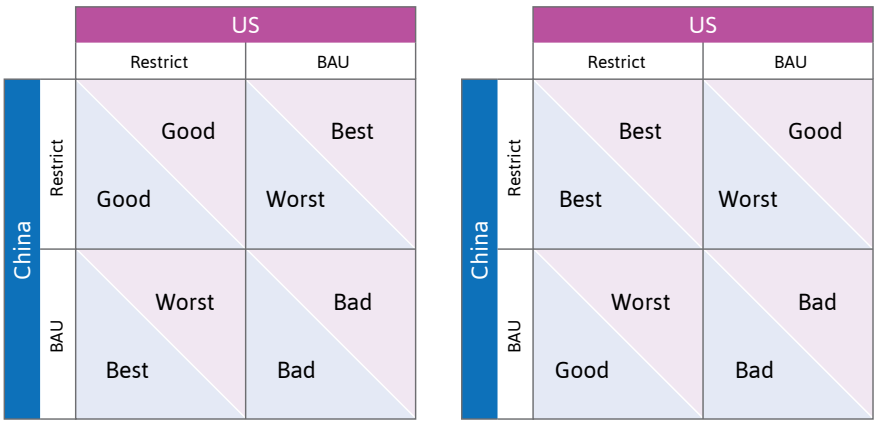

Figure 4.23b Two different climate policy games.

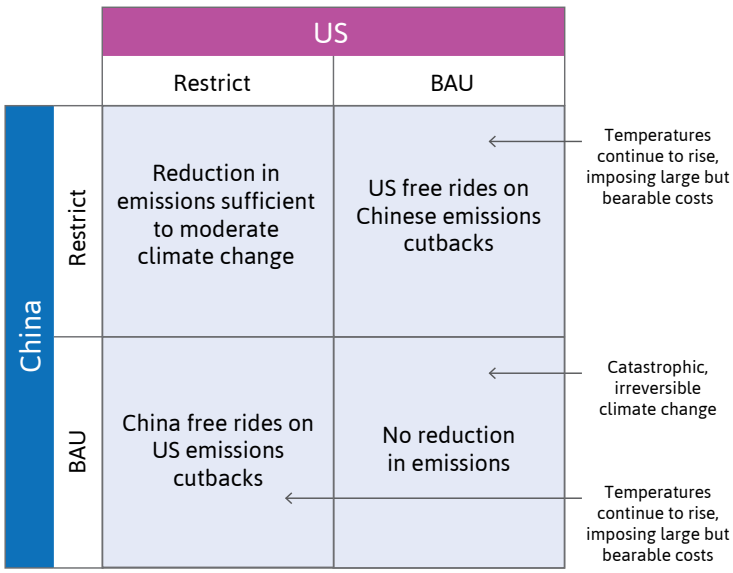

Figure 4.23a Outcomes of climate change policies.

If you work out the best responses and find the Nash equilibria in each case, you will realise that these two games are similar to cases we have already analysed. The left-hand one is a prisoners' dilemma, in which BAU is a dominant strategy for each country, leading to a Bad outcome for both. The game on the right is a coordination game, similar to the rice–cassava game in Figure 4.21 (page 206), except that the players would like to coordinate on the same strategy, rather than the opposite one. There are two Nash equilibria: one is the Best outcome, in which both countries restrict emissions. But the Bad outcome in which neither do so is also an equilibrium, and if each country expects the other to choose BAU following their past behaviour, we can predict that they may be stuck in the (BAU, BAU) equilibrium.

In each case, negotiation may be able to improve the outcome. Exercise 4.17 will help you work out which of these two games better represents the problem facing China and the US, and the implications for negotiations between them.

EXERCISE 4.17 Nash equilibria and climate change

Consider the two games presented in Figure 4.23b (page 209).

1. Consider the pay-offs when one country plays Restrict while the other plays BAU. Why might a country view restricting when the other country plays BAU as the worst possible outcome?
2. In the prisoners' dilemma version (left panel), each country thinks the best possible outcome is that they play BAU while the other country plays Restrict. But in the coordination version (right panel), each country thinks the best possible outcome is that both play Restrict. Explain why they may hold these views and what that could indicate about their preferences, in either case.
3. In both games, the outcome would be better for both countries if they could negotiate a binding treaty to restrict emissions. Use the concepts you have learned in this unit to explain why it might be difficult to achieve such a treaty.
4. Choose one of the games shown (prisoners' dilemma or coordination game) and describe the changes in preferences or in some other aspect of the problem that would convert that game to one in which (like the invisible hand game) both countries choosing Restrict is a dominant strategy equilibrium.

Figure 4.23c presents a third model. It also shows the players' best responses, and hypothetical numerical pay-offs indicating the value of each possible outcome to the citizens of each country. The worst outcome for both countries is that both persist with BAU, thereby running a significant risk of human (and many other species') extinction. The best for each is to continue with BAU and let the other one Restrict. The only way to moderate climate change significantly is for both to Restrict.

This is another coordination game with two equilibria, but now (as in Astrid and Bettina's coding game) there is a conflict of interest between the players. This game is what is termed a **hawk–dove game**: players can act like an aggressive and selfish Hawk, or a peaceful and sharing Dove. In the climate change version, Doves Restrict and Hawks continue with BAU. The conflict of interest is that each country does better if it plays Hawk while the other plays Dove.

It captures a situation that is different from the previous two. Both countries have incentives to avoid catastrophic climate change. But they strongly prefer that the other should bear the costs of reducing emissions: each would like to wait to determine if the other will move first.

The hawk–dove game is sometimes called the chicken game: in the 1984 film, *Footloose* (https://tinyco.re/7566753), two high-school students challenge each other by driving tractors towards each other, to see which one will 'chicken out' first.

hawk–dove game A coordination game in which the players want to coordinate on the opposite action from their opponent, and in each of the Nash equilibria, (Hawk, Dove) and (Dove, Hawk), the Hawk obtains the higher pay-off; but both players choosing Hawk is the worst outcome for both.

The Pareto-efficient allocation in which both countries restrict emissions also has the highest joint pay-offs. We can think of this as the best outcome for the world as a whole. But it is not an equilibrium.

Applying the hawk–dove game to climate policy

How do you think the hawk–dove game would be played in reality? Can the conflict of interest be resolved?

If one country could commit itself to BAU so that the other was certain that it would not consider any other strategy, then the other would play Restrict to avoid catastrophe. But this is true for both countries.

Negotiations are bound to be difficult, since each country would prefer the other to take the lead on restricting carbon emissions. The real climate negotiations are of course more complex—virtually all countries in the world are involved. Pay-offs may be different for these varied players. For example, in 2021 China produced 31% of the world's total carbon emissions, the US was second with 44% of China's level, followed by India. On a per-capita basis, China produced 55% of the emissions that the US did, and India produced 13% of US emissions.

Using public policy to change the game

How could the global social dilemma of climate change policy, as represented in this game, be solved?

Could the governments of the world simply prohibit or severely limit emissions that contribute to the problem of climate change? This would amount to changing the game by altering available strategies by making BAU illegal. But who would enforce this law? There is no world government that could take a government that violated the law to court (and lock up its head of state!).

If the climate change social dilemma is to be addressed, Restrict must be in the interests of each of the parties. Consider the bottom-left corner (China plays BAU, US plays Restrict) equilibrium. If the pay-offs to China for playing Restrict were higher,

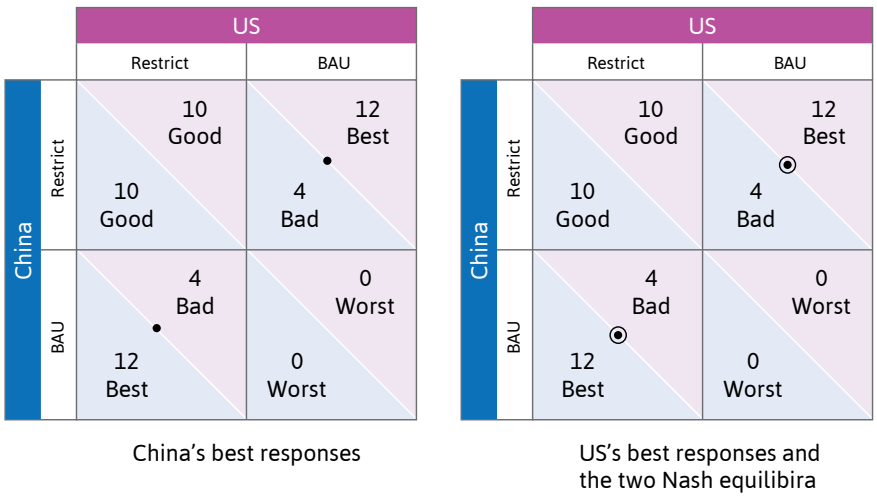

Figure 4.23c Best responses in a climate change game with a conflict of interest.

when that is what the US is doing, then (Restrict, Restrict) might become an equilibrium.

Indeed, in the eyes of many climate change scientists and concerned citizens, the aim of global environmental policy is to change the game so that (Restrict, Restrict) becomes a Nash equilibrium. A number of mechanisms, aided by policy, could accomplish this:

- *Sustainable consumer lifestyles:* As a result of their concern for the wellbeing of future generations, people could come to prefer lifestyles that use fewer goods and services of the kind that result in environmental degradation. This would make the Restrict policy less costly and the BAU strategy less desirable.
- *Governments could stimulate innovation and the diffusion of cleaner technologies:* They might do this by, for example, raising the price of goods and services that result in carbon and other emissions, which would discourage their use. In the process, the use of cleaner technologies would become cheaper, lowering the cost of Restrict. For example, renewable energy has become much cheaper. In some regions, it is now the cheapest energy option, which means Restrict is no longer more expensive than BAU. Self-interested behaviour will result in lower carbon emissions.
- *A change in norms:* Citizens, non-governmental organizations (NGOs), and governments can promote a norm of climate protection and sanction or shame countries that do nothing to limit climate change. This would also reduce the attractiveness of BAU.
- *Countries can share the costs of Restrict more evenly:* This is possible if, for example, a country for whom Restrict is prohibitively expensive instead helps another country where it is less expensive to Restrict. An example would be paying countries in the Amazon basin to conserve the rainforest.

After initial setbacks, China and the US issued a joint declaration at the 2021 (https://tinyco.re/1480111) climate summit in Glasgow, committing to work together towards the goals of the Paris Agreement.

Following the 2015 Paris Agreement (https://tinyco.re/8890909), almost all countries submitted individual plans for cutting emissions. Although there is no way that the agreement could be enforced, and these plans are not yet consistent with the goal of limiting the global temperature rise to 1.5°C, it is widely considered as a basis for further international cooperation. The Paris Agreement should:

- allow countries to better understand the costs of restricting emissions
- encourage economic players to innovate in order to further lower the costs
- strengthen norms that reduce the attractiveness of BAU
- establish a base of trust to share some of the costs of Restrict and negotiate more ambitiously in the future.

EXERCISE 4.18 Summary of games in this unit

Use the categories in the table shown to classify each game presented in this unit. In the final column, write down one or two key features that help you identify a game that belongs to that category.

- crop selection game (Figure 4.2b (page 165))
- Adam and Bella's afternoon (Question 4.2)
- pest control game (Figure 4.4b (page 170))
- Thelma and Louise (Figure 4.5 (page 171))
- Dimitrios and Ameera, the forex traders (Question 4.3)
- driving on the left or right side of the road (Section 4.13)
- programming languages (Figure 4.22 (page 207))
- climate change (hawk–dove game) (Figure 4.23c (page 211))
- irrigation game (Figure 4.9 (page 178))
- splitting $100 (Figure 4.16 (page 198))

Type of game	Categories	Examples	Key features
Simultaneous two-player games	Invisible hand games		
	Prisoners' dilemmas		
	Coordination games—without conflict of interest		
	Coordination games—with conflict of interest		
Games with more than two players	Public good games		
Sequential two-player games	Ultimatum game		

4.15 Summary

- Addressing the challenge of climate change requires understanding conflicting as well as common interests.
- Game theory is a way of modelling economic interactions in which people behave strategically, because each person knows that the outcome depends not only on their own actions, but also on what others do.
- The outcome of an interaction is a Nash equilibrium if none of those involved could do better by choosing some different action.
- There may be an outcome that is not a Nash equilibrium, but in which everyone would be better off than at a Nash equilibrium. In this case, the Nash equilibrium is not Pareto efficient.

EXERCISE 4.18 Summary of games in this unit

Use the categories in the table shown to classify each game presented in this unit. In the final column, write down one or two key features that help you identify a game that belongs to that category.

- crop selection game (Figure 4.2b (page 165))
- Adam and Bella's afternoon (Question 4.2)
- pest control game (Figure 4.4b (page 170))
- Thelma and Louise (Figure 4.5 (page 171))
- Dimitrios and Ameera, the forex traders (Question 4.3)
- driving on the left or right side of the road (Section 4.13)
- programming languages (Figure 4.22 (page 207))
- climate change (hawk–dove game) (Figure 4.23c (page 211))
- irrigation game (Figure 4.9 (page 178))
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Type of game	Categories	Examples	Key features
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4.15 Summary

- Addressing the challenge of climate change requires understanding conflicting as well as common interests.
- Game theory is a way of modelling economic interactions in which people behave strategically, because each person knows that the outcome depends not only on their own actions, but also on what others do.
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- There may be an outcome that is not a Nash equilibrium, but in which everyone would be better off than at a Nash equilibrium. In this case, the Nash equilibrium is not Pareto efficient.

- When individuals pursue higher pay-offs for themselves, the result can be worse for everyone (as in a prisoners' dilemma game). But there are conditions in which self-interest results in the best outcome for each (as in an invisible hand game).
- Experimental games with pay-offs in money often demonstrate that people care about the pay-offs that others get. In other words, their preferences are social rather than purely self-interested.
- By taking account of both self-interested and social preferences, game theory can explain what we observe in experiments and in the world.
- People care about fairness; in ultimatum game experiments, they are often willing to get no pay-offs at all rather than to accept what they think is an unfair division of the pie.
- Opportunities to punish free-riders in the public good game, or competition in the ultimatum game, are examples of changes in the rules of the game that alter people's behaviour.
- Game theory—including the hawk–dove game—provides alternative ways of representing the challenge of climate change, and means of addressing it.

Concepts and models introduced and applied in Unit 4

- **Social interactions**; social dilemmas
- **Game theory**: **strategic interaction**, **game**, players, actions, pay-offs, **strategies**
- **Best response**, **Nash equilibrium**, **dominant strategy**, **dominant strategy equilibrium**
- **Simultaneous games** and **sequential games** with two or more players
- Types of game: **invisible hand game**, **prisoners' dilemma**, **coordination game** (such as the **hawk–dove game**), **public good game**, ultimatum game
- Criteria for evaluating an **allocation**: **Pareto criterion**, **Pareto efficiency**, **fairness**
- Self-interested preferences; **social norms**; **social preferences** such as **altruism**, **inequality aversion**, and **reciprocity**.

4.16 References

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effect of both changes is to lower the Gini coefficient. By this measure, inequality in our hypothetical village has been cut in half.

The fact that, in West Bengal, both productivity and equality increased, highlights why this programme was considered to be such a success story.

EXERCISE 5.9 Land reform and inequality

Figure 5.29 shows how Operation Barga reduced economic inequality between farmers and landowners. However, since tenancy rights could only be passed down to sons in the family, Operation Barga also affected gender inequality within households. Use Sections 1 and 2 of this article (https://tinyco.re/0905981) to answer the following questions. (The article mentions some technical statistical terms, but they are not required to understand the main findings.)

1. How did the authors measure gender inequality within households? Briefly summarize how Operation Barga affected this measure of gender inequality.
2. Which types of households were most affected by the land tenure reforms, and why?

EXERCISE 5.10 An increase in inequality

Suppose that instead of the sharecroppers gaining enough political power to reduce the crop share they had to give to the landowner (which is what actually happened in West Bengal), the opposite had occurred, and the landowners had gained the right to claim three-quarters of the crop.

1. Assume that the landowner implemented this share, and that the sharecroppers, now receiving just a quarter of the crop, would correspondingly work only a quarter as hard as the landowner. What would the resulting Gini coefficient be?
2. Explain why the landowner would not implement this new share (that he gets three-quarters of the crop).

5.14 Application: Conflicts of interest and bargaining over wages, pollution, and jobs

Bruno and Angela have conflicting interests over hours of work and the distribution of grain. We can apply a similar model to cases of conflicting interests about the environment. Conflicts arise because environmental quality is never the same for everyone. When greenhouse gases or pollutants degrade an environment, some people suffer more than others, depending on their location and income, while some benefit from the economic activity that causes the damage.

external effect, externality
An external effect occurs when a person's action confers a benefit or imposes a cost on others and this cost or benefit is not taken into account by the individual taking the action. External effects are also called externalities.

For example, in 2008 and 2009, two oil spills in the Niger delta of Nigeria destroyed fisheries. The spills resulted from the oil extraction activities of the Anglo-Dutch company, Royal Dutch Shell. Lawyers for the Ogoni people, who suffered these **external effects**, brought a lawsuit against the Nigerian subsidiary of Shell in the British courts. In 2015, Shell settled out of court and paid £3,525 per person (https://tinyco.re/1087343), of which £2,200 was paid to each individual, and the rest to support community public goods. This award amounted to more than most Ogoni people would earn in a year. Lawyers representing the community helped to set up bank accounts for the 15,600 beneficiaries.

A study of 15 beach markets along 225 km of the northern Kerala coast found that, once the fishermen used mobile phones, differences in daily prices among the beach markets were cut to a quarter of their previous levels. No boats jettisoned their catches. Reduced waste and the elimination of the dealers' bargaining power raised the profits of fishermen by 8% at the same time as consumer prices fell by 4%.

We know that one of the conditions for competitive equilibrium is that buyers and sellers are aware of the prices at which others are trading. Mobile phones allowed the fishermen to get more information about prices, and become very effective rent-seekers. Their rent-seeking activities changed how Kerala's fish markets worked: they came close to implementing the Law of One Price, to the benefit of fishermen and consumers (but not of the fish dealers who had acted as intermediaries).

QUESTION 8.12 Choose the correct answer(s)

Figure 8.22 (page 430) shows how bargaining power affected prices in Kerala beach markets on 14 January 1997. Based on this information, what can we conclude?

- ☐ The higher the excess supply, the lower the price of fish.
- ☐ The price of fish in all markets with excess demand is 9.3.
- ☐ The data satisfies the Law of One Price.
- ☐ The data demonstrates that buyers have bargaining power when there is excess supply.

8.12 The effect of a tax

Governments levy taxes in different ways and for different reasons. They use taxes on income or wealth both to raise revenue to finance public expenditure, and to redistribute resources and reduce inequality. Particular goods may be taxed to raise revenue, or with the aim of changing decisions to buy them. Many countries now tax cigarettes to discourage smoking, but long before the harmful effects on health were known, tobacco taxes were used to raise revenue. Carbon taxes are an important tool for tackling climate change; in this case, the aim is unambiguously to reduce greenhouse gas emissions.

Tobacco was one of the first consumer goods to be taxed in North America in the eighteenth century. In 1951, the US federal cigarette excise tax was increased from 7 cents to 8 cents per pack to help finance the Korean War.

We can use the supply and demand model to assess the impact of a tax on prices, quantities, and government revenue.

Using taxes to raise revenue: The case of salt

For centuries, salt has been used as a preservative, allowing food to be stored, transported, and traded. The ancient Chinese advocated taxing salt to raise revenue, because people needed it, however high the price. Salt taxes were used by ruling elites in ancient India, by the French monarchy and Tsarist Russia, and by the British in India.

Figure 8.23 illustrates how a salt tax might work. Initially the market equilibrium is at point A. Suppose that a sales tax of 30% is imposed on the price of salt, to be paid by the suppliers. The marginal cost of supplying each unit of salt increases by the amount of the tax, so the supply curve shifts: the price is 30% higher at each quantity.

tax incidence The effect of a tax on the surplus of buyers, sellers, or both.

The new equilibrium is at point B, where a lower quantity is traded. Although the consumer price has risen, note that it is not 30% higher than before, because consumers respond to the price increase by buying less salt, and when less salt is

- *Tax revenue:* A tax equal to $(P_1 - P_0)$ is paid to the government on each of the Q_1 units of salt sold (the green-shaded area).
- *Total surplus (including tax revenue) is lower*: The tax causes a deadweight loss equal to the area of the white triangle, which is $1/2 \times (Q^* - Q_1) \times (P_1 - P_0)$.

Provided that the revenue is used to benefit society, we can think of total surplus as a measure in monetary terms of the gains generated by trade in the market for salt for society as a whole. Compared to the situation before the tax, some of the surplus has been transferred from consumers and producers to the government, but also the total surplus is lower: there is a deadweight loss. If the revenue is spent on goods and services that enhance the wellbeing of the population, we might nevertheless conclude that this benefit to society outweighs the loss to consumers and producers, even though it reduces the surplus in the particular market that is taxed.

To raise as much revenue as possible, and reduce deadweight loss, the government would prefer to tax a good with low elasticity of demand, so that the fall in quantity is quite small. But this also means that the incidence of the tax falls heavily on consumers. The notorious salt tax imposed by the French monarchy was much resented by the people, and helped to precipitate the French Revolution. In 1930, the artificially high price of salt in British colonial India provoked one of the defining moments of the Indian independence movement: Mahatma Gandhi's salt march (https://tinyco.re/6239641) to acquire salt from the Indian ocean. Similarly, in what came to be called the Boston Tea Party, in 1773 American colonists objecting to a British colonial tax on tea dumped a cargo of tea into the Boston harbour.

In many modern economies, institutions for tax collection are well established, with democratic consent. If citizens believe taxes are implemented fairly and used to benefit society, they are accepted as a necessary part of social and economic policy.

In contrast, if the government's objective is to reduce the consumption of a good that is considered harmful—like tobacco or carbon—the tax will be more effective if demand is elastic so that quantity falls substantially. We discuss some examples in Unit 10 (page 506).

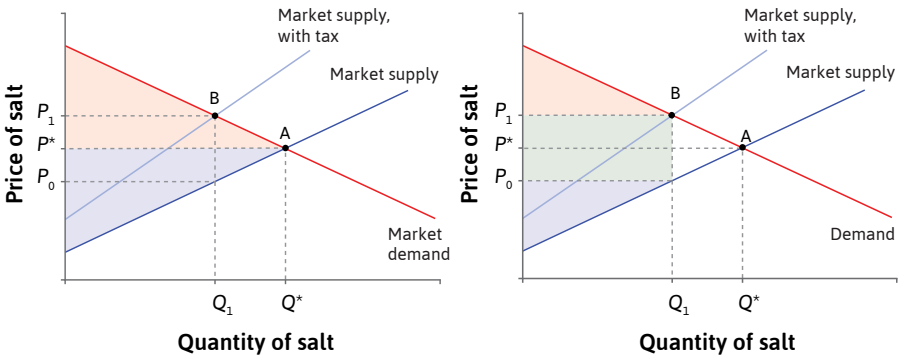

Figure 8.24 When the tax is imposed, the surplus from the salt market is:
total surplus = consumer surplus + producer surplus + government revenue

income In general, income refers to any flow of resources (goods, or money) that an individual (or other economic actor) receives over time. It is the amount received per period. It could include labour earnings, profits, rent from property, or interest on assets. Your income is the maximum amount that you could consume per period and leave your wealth unchanged.

Income either adds to wealth (in which case it is termed saving) or is used for consumption spending.

Some wealth takes physical forms, such as a car or office equipment. The value of physical wealth tends to decline, either due to use or simply the passage of time. This reduction in the value of a stock of wealth over time is called **depreciation**. Using the bathtub analogy, depreciation is the amount of evaporation of the water. In economics, an example of depreciation is the fall in the value of a car with mileage and with age. Like income, depreciation is a flow (for example, you could measure it in dollars per year for a car or computer), but a negative one.

In order to take account of depreciation, economists distinguish between income (which is net of depreciation) and gross income. The flow of income into the bathtub is gross income.

A person's wealth will affect the opportunities they have for borrowing and investing. This is the reason why we focus on wealth (and wealth inequalities) in this unit rather than income and income inequalities.

Consumption and saving

In this unit, we simplify by not considering taxes as a deduction from one's income, or transfers from the government as an addition.

Water also flows out of the tub. The flow through the drain is called consumption, and it reduces wealth just as income increases it. Consumption refers to household spending on goods and services.

An individual (or household) saves when consumption is less than net income, so wealth increases. Wealth is the accumulation of past and current **savings**. Saving can take a number of forms, for example, putting money into bank deposits, or buying financial assets, such as **shares** (also known as stocks) in a company, or **bonds** issued by a government or a company in the financial markets. The choice about where and how to save depends on the relative returns that you can earn and on how easy it is to turn the savings back into money for consumption. Purchases of shares or bonds are often done on behalf of the individual by another organisation, most often the company that runs their personal pension fund who will have more expertise on what to buy and when. The decisions about how much money to save in each saving option will depend on what the expected return is, which will depend on the riskiness of the asset. Returns in asset markets are generally higher for assets that are considered higher-risk. Contributions to a personal pension fund are an example of the use of savings to buy financial assets.

flow A quantity measured per unit of time, such as weekly income, or annual carbon emissions. *See also: stock.*

stock A quantity measured at a point in time, such as a firm's stock of capital goods, or the amount of carbon dioxide in the atmosphere. Its units do not depend on time. *See also: flow.*

When a government's spending is greater than its tax revenue, it borrows by issuing bonds. A **government bond** is generally considered to be a safe asset because it is a promise from the government to pay some *fixed amount* to the holder of the bond on a given schedule over a fixed period of time, and because it is assumed that the government will not default on the payments.

When companies plan to spend more than their revenue (for example, on the purchase of machinery and equipment), they have a number of choices. They can borrow from banks (bank loans), borrow from the public by selling company bonds, or sell part of the company (shares). A company is more likely to default on its payments to bondholders than is the government. This higher risk of default means that it is generally more expensive for firms to borrow than it is for the government. The return that a bondholder searches for will be higher to compensate for the higher risk relative to government bonds—in other words, company bonds are riskier than government bonds.

depreciation The loss in value of a form of wealth that occurs either through use (wear and tear) or the passage of time (obsolescence).

Read Extension 9.2 (https://tinyco.re/3283026) for more details on the characteristics of bonds and shares.

Shares are literally a share in the ownership of a company. The holder owns some fraction of the company's buildings, equipment, intellectual property, and other

QUESTION 9.6 Choose the correct answer(s)

Figure 9.6 (page 459) depicts Julia's choice of consumptions in periods 1 and 2. She has no income in period 1 (now) and an income of $100 in period 2 (later). The current interest rate is 10%. Based on this information, read the following statements and select the correct option(s).

- ☐ At F, the interest rate exceeds Julia's discount rate (degree of impatience).
- ☐ At E, Julia is on the highest possible indifference curve, given her feasible set.
- ☐ E is Julia's choice, as she is able to completely smooth out her consumption over the two periods and consume the same amount.
- ☐ G is not a feasible choice for Julia.

Building block

It will be helpful to review income and substitution effects from Section 3.7 (page 127) before completing Exercise 9.3.

EXERCISE 9.3 Income and substitution effects

Use Figure 9.6 (page 459) to show that the difference in current consumption at the lower and higher interest rate (at E and G), namely $23, is composed of an income effect and a substitution effect.

Why do the income and substitution effects work in the same direction in this example?

9.5 Application: Discounting, external effects, and the future of the planet

Discount rates are central to the discussion in economics of how best to address climate change and other environmental damages. But what is discounted is not the value placed by a citizen on their consumption later (as opposed to consumption now) but instead the value we place on the consumption of people living in the future compared to our own generation.

Our economic activity today will affect how climate changes in the distant future, so we are creating consequences that others will bear. This is an extreme form of external effects that we study throughout the book. It is extreme not only in its potential consequences, but also in that those who will suffer the consequences are future generations. But the future generations that will bear the consequences of our decisions are unrepresented in the policymaking process today. The only way the wellbeing of these unrepresented generations will be taken into account at the environmental bargaining tables is the fact that most people care about, and would like to behave ethically toward, others, as we discussed in Unit 4 (page 181).

These social preferences underlie the debates among economists about how much we should value the future benefits and costs of the climate change decisions that we make today.

In the model developed in this unit, we know that the actor (say, Julia) is best off when she chooses the combination of consumption now and later where the MRS = MRT; that is, where her subjective discount rate is equal to the rate of interest.

In considering alternative environmental policies addressed to climate change, how much we value the wellbeing of future generations is commonly measured by an interest rate; that is, by applying the same MRS = MRT approach. This raises the question of what interest rate should be used to discount future generations' costs or benefits. Economists disagree about how this discounting process should be done.

WHEN ECONOMISTS DISAGREE

The discounting dilemma: How should we account for future costs and benefits?

When considering policies, economists seek to compare the benefits and costs of alternative approaches, often in cases where some people bear the costs and others enjoy the benefits. Doing this presents especially great challenges when the policy problem is climate change. The reason is that costs will be borne by the present generation but most of the benefits of a successful policy to limit CO_2 emissions, for example, will be enjoyed by people in the future, many of whom are not yet alive.

Put yourself in the shoes of an impartial policymaker and ask yourself: Are there any reasons why, in summing up the benefits and costs of such a policy, I should value the benefits expected to be received by future generations any less than the benefits and costs that will be borne by people today? Two reasons come to mind:

- *Technological progress and diminishing marginal utility*: People in the future may have lesser unmet needs than we do today. For example, as a result of continuing improvements in technology, they may be richer (either in goods or free time) than we are today, so it might seem fair that we should not value the benefits they will receive from our policies as highly as we value the costs that we will bear as a result.
- *Extinction of the human species*: There is a small possibility that future generations will not exist because humanity becomes extinct.

These are good reasons why we might discount the benefits received by future generations. Neither of these reasons for discounting is related to intrinsic impatience.

This was the approach adopted in the 2006 *Stern Review on the Economics of Climate Change* (read the executive summary on the UK National Archives website (https://tinyco.re/6397444)). Nicholas Stern, an economist, selected a discount rate to take account of the likelihood that people in the future would be richer. Based on an estimate of future productivity increases, Stern discounted the benefits to future generations by 1.3% per annum. To this he added a 0.1% per annum discount rate to account for the risk that in any future year there might no longer be surviving generations. Based on this assessment, Stern advocated an urgent and fundamental shift in the policies of governments and businesses to ensure substantial investments to limit CO_2 emissions today in order to protect the environment of the future.

Several economists, including William Nordhaus, criticized the *Stern Review* for its low discount rate (https://tinyco.re/9892599). Nordhaus wrote that Stern's choice of discount rate 'magnifies impacts in the distant future'. He concluded that, with a higher discount rate, 'the Review's dramatic results [Stern's policy conclusions above] disappear'.

Nordhaus advocated the use of a discount rate of 4.3%, which gave vastly different implications. Discounting at this rate means that a $100 benefit occurring 100 years from now is worth only $1.48 today, while under Stern's 1.4% rate it would be worth $24.90. This means a policymaker using Nordhaus's discount rate would approve of a project that would save future generations $100 in environ-

mental damages only if it cost less than $1.48 today. A policymaker using Stern's 1.4% would approve the project only if it cost less than $24.90.

Not surprisingly, then, Nordhaus's recommendations for climate change abatement were far less extensive and less costly than those that Stern proposed. For example, Nordhaus proposed a carbon price of $35 per ton in 2015 to deter the use of fossil fuels, whereas Stern recommended a price of $360.

Why did the two economists differ so much? They agreed on the need to discount for the likelihood that future generations would be better off. But Nordhaus had an additional reason to discount future benefits: intrinsic impatience.

Reasoning as we did in Julia's choice of consumption now or later, Nordhaus used estimates based on *market* interest rates (the slope of the feasible set) as measures of how people today value their own future versus present consumption. Using this method, he came up with a discount rate of 3% to measure the way people discount future benefits and costs that they themselves may experience. Nordhaus included this in his discount rate, which is why Nordhaus's discount rate (4.3%) is so much higher than Stern's (1.4%).

Critics of Nordhaus pointed out that a psychological fact like our own impatience—how much more we value *our own* consumption now versus later—is not a reason to discount the needs and aspirations of *other people* in future generations.

Stern's approach counts all generations as equally worthy of our concern for their wellbeing. Nordhaus, in contrast, takes the current generation's point of view and counts future generations as less worthy of our concern than the current generation, much in the way that, for reasons of intrinsic impatience, we typically value current consumption more highly than our own future consumption.

Is the debate resolved? The discounting question ultimately requires adjudicating between the competing claims of different individuals at different points of time. This involves questions of ethics on which economists will continue to disagree.

EXERCISE 9.5 Negative discount rates

Some economists (https://tinyco.re/1970112) have suggested that the discount rate for future environmental benefits and costs should be negative, meaning that we value benefits and costs experienced by future generations more than those experienced by the current generation.

Use your diagram and the arguments presented in the following articles to explain why this suggestion might make sense:

- Marc Fleurbaey and Stephane Zuber 2013. Climate Policies Deserve a Negative Discount Rate (https://tinyco.re/7865544). *Chicago Journal of International Law* 13 (2), Article 14.
- M. Kahn *et al*. 2019. Long-term macroeconomic effects of climate change: A cross-country analysis (https://tinyco.re/4677821). IMF Working Paper.

QUESTION 9.7 Choose the correct answer(s)

The following table shows the present values of a $1 payment in the future, discounted at different rates. For example, $1 paid in 10 years' time is worth $0.82 today when discounted at 2% annually.

Discount rate (%)	Years in the future				
	0	1	10	50	100
0.0%	$1.00	$1.00	$1.00	$1.00	$1.00
1.0%	$1.00	$0.99	$0.90	$0.61	$0.37
2.0%	$1.00	$0.98	$0.82	$0.37	$0.14
5.0%	$1.00	$0.95	$0.61	$0.09	$0.01

Based on this information, read the following statements and select the correct option(s).

- ☐ The difference in the discounting effect among alternative discount rates is larger as the time to payment increases.
- ☐ Doubling the time to payment leads to halving of the present value.
- ☐ Doubling the discount rate leads to halving of the present value.
- ☐ If a project is expected to give benefits of $1,000 10 years from now, but costs $800 today, policymakers using any discount rate shown in the table above would recommend approving the project.

9.6 Lending and storing: Moving consumption to the future

Now think about Marco, an individual otherwise identical to Julia, but facing a very different situation. Marco has wealth of $100, but does not (yet) anticipate receiving any income later.

By identical, we mean that Marco's preferences between consumption now and later are the same as Julia's. For example, in Figure 9.5 (page 457) we showed a hypo-

received reports on contamination in Guadeloupe a few years later, but waited until 1990 to ban the substance, and were pressured by banana plantation owners to give them a special exemption until 1993.

Twenty years later, fishermen protesting against the slow pace of French government assistance in addressing the fallout from the contamination demonstrated in the streets of Fort de France (the largest town in Martinique) and barricaded the port. Looking back, Franck Nétri, a Gaudeloupean fisherman, worried: 'I've been eating pesticide for 30 years. But what will happen to my grandchildren?'

He was right to worry. In 2012, the fraction of Martiniquean men suffering from prostate cancer was the highest in the world and almost twice that of the second-highest country, and the mortality rate was well over four times the world average. Neurological damage in children, including retarded cognitive development, has also been documented.

Social and private costs and benefits

external effect, externality An external effect occurs when a person's action confers a benefit or imposes a cost on others and this cost or benefit is not taken into account by the individual taking the action. External effects are also called externalities.

The devastating damage to health and livelihoods caused by chlordecone is an example of the **external effects** of some economic decisions. When the owners of banana plantations decided to use it, they considered the private costs and benefits: the cost to themselves of buying the pesticide, and the benefit of increased banana productivity and revenue. For them, it was a profitable choice. But they did not take into account the effects on other people: the external costs imposed on the local population. The social costs of producing more bananas using chlordecone—that is, the private and external costs added together—were much higher than the social benefits of additional banana production.

Pareto efficient, Pareto efficiency An allocation is Pareto efficient if there is no feasible alternative allocation in which at least one person would be better off, and nobody worse off.

When people make decisions without taking into account the full social costs and benefits of their actions, the allocation of resources is not **Pareto efficient**: that is, there are allocations that would be better for everyone involved. Then the questions we need to address are: Why have these preferred allocations not been achieved? Are there institutions or policies that could make everyone better off? Or at least, those that society would prefer to the status quo?

Unit 4 (page 159) examines some other social dilemmas in which external effects arise:

- Neighbouring farmers, Anil and Bala, choose their pest control method without taking into account the negative effects of a pesticide, or the positive effects of beneficial insects, on each other.
- Farmers relying on shared irrigation facilities have incentives to free-ride on each other, rather than contributing to the costs of maintaining the facilities, if they only take into account the private costs and benefits of contributing.
- People throughout the world make decisions resulting in carbon dioxide emissions without considering how their decisions contribute to climate damage.

In each case, the social costs or benefits of people's decisions differ from the private costs or benefits—that is, the cost or benefit experienced by each individual decision-maker themselves.

Markets and market failure

In this unit, we will discuss many more examples, and potential solutions. In cases where small numbers of decision-makers are involved, there may be institutions that could facilitate bargaining to a mutually acceptable solution. Communities may be

able to influence individual behaviour by establishing social norms so that people take more account of the effects of their actions on others, as Elinor Ostrom demonstrated.

In other cases, we search for the source of the problem in the market system, and consider whether institutional reforms or governmental intervention could address it.

The logic of Adam Smith's famous claim, that the businessman in pursuit of his own interest is 'led by an invisible hand' to promote the interests of society, is the basis of the economic model of a perfectly competitive market (Unit 8 (page 424)). Friedrich Hayek explained how, in the market system, prices send messages about the real scarcity of goods and services, motivating people to produce, consume, invest, and innovate in ways that make the best use of an economy's productive potential.

If the market for a good is perfectly competitive, and affects no one other than the buyers and sellers, the allocation of the good is Pareto efficient (as explained in Section 8.5 (page 400)). In that case, market prices send the right messages to decision-makers about the costs of supplying the good and the benefits of consuming it. But if others are affected, prices will send the wrong messages: for example, the price of fossil fuels typically reflects the suppliers' costs of extracting and distributing them, but not the costs of global warming which affect all of us.

When the market system results in a Pareto-inefficient allocation—a misallocation of resources—we describe this as a **market failure**. Markets fail when prices don't send the right messages, and also in some cases because markets do not exist: some goods that matter to people—like clean air or uncongested roads—cannot be bought and sold.

Unit 7 (page 360) describes an example of a price sending the wrong message: the producer of a differentiated good sets a price above the marginal cost of production. The allocation of the good is not Pareto efficient, since some consumers who would be willing to pay more than its marginal cost do not obtain it. Although this seems very different from the pesticide case, market failure occurs because the producer does not consider the external effect on these consumers.

Smith himself explained that markets do not always work well. In areas such as education and the legal system, government policies were needed to promote social wellbeing. He was also clear that some things should not be bought and sold in markets. Most people today find the buying and selling of human organs to be wrong, and the same goes for buying and selling votes, or life-saving medical care.

market failure If the allocation resulting from market interactions is not Pareto efficient, we describe the situation as a market failure. The term may be used loosely to refer to any interaction resulting in a Pareto-inefficient allocation, whether or not a specific market is concerned.

Diagnosis and treatment

In studying the misallocation of resources, we will think of the issues as a doctor would. We diagnose the problem, and attempt to devise an appropriate treatment. In the case of chlordecone, the banana plantation owners ignore the danger they cause to the fishermen's livelihood and health. Why does this happen? There are often several different ways of thinking about external effects, that may suggest possible treatments.

We could find instances where prices send the wrong messages. For example, the price of using the pesticide is too low, in that it doesn't reflect the costs imposed on the fisheries. So the plantations use too much pesticide and produce too many bananas. Would regulating or taxing their activities be an effective treatment?

Another approach is to think about property rights: if the fishermen had a right to fish in clean water, the plantation owners would have to find an alternative pesticide,

Negative production externalities

Chlordecone and PFOA are specific examples of a widespread problem, where firms' production decisions have negative external effects on the environment, and hence on the wellbeing or livelihoods of the local population—or globally, in the case of carbon emissions. Two more examples are the oil spills by Royal Dutch Shell in the Niger Delta, and lead poisoning in Idaho caused by the Bunker Hill Company (Section 5.14 (page 266)). Other negative externalities of firms' activities include:

- *Noise*: People living near major international airports may experience intrusive levels of noise that can damage physical and mental health.
- *Inadequate safety measures:* The Rana Plaza building in Dhaka, Bangladesh, collapsed in 2013, killing more than 1,100 garment workers in factories supplying apparel to global brands at low prices.
- *Deforestation for logging and commercial agriculture* destroys the resources and livelihoods of local communities and causes wildfires; it has huge impacts globally on biodiversity loss and climate change.

missing market When there is no market within which a potentially beneficial exchange or trade could occur, because of asymmetric or non-verifiable information, we say that the market for the good is missing.

When firms make decisions without accounting for the full social cost, one interpretation is that there are **missing markets** for some of the inputs, so they are treated as if their price was zero. There is no market for a quiet neighbourhood or biodiversity, so airports and loggers do not have to pay to use up these resources. In turn, the price of the product (flights, or tropical hardwood) is too low; it is based only on the inputs that are paid for. Or we might interpret the problems in terms of property rights: the garment workers did not have an enforceable right to be safe at work.

To understand some of the reasons why **markets fail**, it is helpful to remember the institutions that are needed for them to work well. As explained in Section 1.8 (page 25), **private property** is a key requirement for a market system. You would hesitate to pay for something unless you believed that others would acknowledge (and if necessary, protect) your right to keep it. Governments provide systems of laws and law enforcement that guarantee property rights and enforce **contracts**. As demonstrated in the previous section, these institutions matter for private bargaining, too.

The absence of markets and property rights can often be traced to an **asymmetric information** problem: information about something that matters to someone other than the decision-maker—such as how much noise is produced, or which species have been endangered—cannot be observed, or is not **verifiable** by a court.

market failure If the allocation resulting from market interactions is not Pareto efficient, we describe the situation as a market failure. The term may be used loosely to refer to any interaction resulting in a Pareto-inefficient allocation, whether or not a specific market is concerned.

private property Something is private property if the person possessing it has the right to exclude others from it, to benefit from the use of it, and to exchange it with others.

contract A legal document or understanding that specifies a set of actions that parties to the contract must undertake.

Negative consumption externalities

The misallocation of resources is not limited to firms polluting the environment. Likewise, our consumption decisions have serious external effects.

Since the discovery of penicillin in 1928, the development of antibiotics has brought huge benefits to humanity. Diseases that were once fatal are now treated easily with medicines that are cheap to produce. But if we use them in the wrong dosage, or for non-bacterial conditions, or fail to complete the full course because we feel better, bacteria become resistant to them. 'Superbugs' emerge. The World Health Organization has recently warned that we are heading for a 'post-antibiotic era': 'Unless we take significant actions to … change how we produce, prescribe and use antibiotics, the world will lose more and more of these global public health goods and the implications will be devastating.'

If antibiotics are allocated by the market, as in India where they are easily available over the counter in pharmacies, the market price does not capture the full social costs

External benefits cause misallocation too

Some decisions have positive external effects: the social benefit is higher than the private benefit (or the private cost is higher than the social cost).

- If Kim, the farmer in Section 4.6 (page 177), contributes to the cost of an irrigation project, all the other farmers in the community will benefit.
- When a firm invests in R&D, the benefits can often be exploited by other firms who can adopt the new production methods or improve their own products in the same way.
- If a firm trains a worker who later quits for a better job, the skills of the trained worker go with them: the new firm obtains at least some of the benefits of the training.
- When someone is vaccinated against an infectious disease, they receive a benefit for themselves, but also benefit people who might otherwise have caught the disease from them.
- If an employee exerts a high level of effort, the net private benefit (job satisfaction, for example) may be small, but the employer benefits from higher productivity.
- A country that invests in reducing carbon emissions lowers the risks of climate change for other countries.

Why are external benefits a problem? Although they are indeed beneficial if they are conferred, misallocation of resources happens because decision-makers choose *not* to confer an uncompensated benefit. Kim would not receive payment for a public-spirited contribution to the irrigation project; the firm that paid for the training cannot collect compensation from the new employer. Just as people who don't face the true costs of production or consumption decisions are likely to produce or consume too much, those whose actions have external benefits will do too little. The equilibrium of the irrigation game is that each farmer chooses not to contribute, unless they are motivated by social preferences or social norms. Likewise, firms may train too few workers, or do too little R&D, relative to the social good.

Just as for negative externalities, it is typically infeasible to use the legal system to compensate people for the beneficial effects they have on others. For example, to pay the owner of a beautiful garden for the pleasure this confers on passers-by, a court would have to know how much it was worth to each one.

Establishing property rights can address some problems: for example, a system of patents gives firms the right to exploit the results of their own R&D for a period of time. The law of copyright enables authors to receive an income from their writing, by giving them a right to determine how and where it is published. But by creating a monopoly in the use of the copyrighted material (as intended), copyrights, patents, and other intellectual property rights limit competition, which is also necessary for efficient market outcomes.

In other cases, economic instruments can help. The Pigouvian remedy would be a subsidy to ensure that the decision-maker takes the **external benefit** into account. Subsidies or tax incentives can encourage firms to provide worker training; in some countries, these have been financed using a levy scheme, so that the firms that choose not to train have to pay for the training provided by others. But such systems are much more difficult to implement than a plastic bag tax, because of the need to ensure that the training provided is of a type and quality that will benefit other firms as well as the provider.

external benefit, positive externality, external economy A positive external effect: that is, a positive effect of an economic decision on other people, that is not taken into account by the decision-maker. It may be described as an external benefit, a positive externality, or an external economy. *See also: external effect.*

EXERCISE 10.6 Incomplete contracts

Choose three of the following examples discussed in this section: noise pollution, inadequate safety measures, deforestation, antibiotic resistance, worker training, and climate change. For each example chosen, answer the following questions:

1. Explain why the external effects are not (and possibly cannot be) covered by a complete contract.
2. What critical piece(s) of information required for a complete contract are asymmetric or non-verifiable?

EXERCISE 10.7 Property rights and contracts in Madagascar

Marcel Fafchamps and Bart Minten studied grain markets in Madagascar in 1997, where the legal institutions for enforcing property rights and contracts were weak. Despite this, they found that theft and breach of contract were rare. The grain traders avoided theft by keeping their stocks very low and, if necessary, sleeping in the grain stores. They refrained from employing additional workers for fear of employee-related theft. When transporting their goods, they paid protection money and travelled in convoy. Most transactions took a simple 'cash and carry' form. Trust was established through repeated interaction with the same traders.

1. Do these findings suggest that strong legal institutions are not necessary for markets to work?
2. Consider some market transactions in which you have been involved. Could these markets work in the absence of a legal framework, and how would they be different if they did?
3. Suggest some examples in which repeated interaction helps to facilitate market transactions.
4. Why might repeated interaction be important even when a legal framework is present?

10.6 Public goods, non-rivalry, and excludability: A model of radio broadcasting

Some of our examples of decisions that have external benefits can also be described as public goods. These are cases where, if one individual incurs a cost to provide the good, many others can benefit too. If one farmer contributes to the cost of an irrigation scheme, or one country takes measures to reduce carbon emissions, all farmers or all countries benefit. The irrigation scheme is a public good for the community where it is located. Reductions in atmospheric CO_2 are a global public good.

The distinction between public goods and positive externalities is not always clear-cut, and both terms are sometimes used loosely. But for example, we wouldn't describe a beautiful private garden as a public good, because the owner (who incurs the costs of maintaining it) benefits much more than individual passers-by. We generally reserve the term public good for cases where, for each individual, the private costs of producing it would be high and the private benefits low, so that no individual has an incentive to provide the good. If they did, everyone else would simply **free-ride** on their generosity.

free rider, free riding, free ride Someone who benefits from the contributions of others to some cooperative project without contributing themselves is said to be free riding, or to be a free rider.

- national defence
- clean air
- knowledge
- street lighting
- community irrigation system
- crime prevention
- radio broadcasting.

excludable public good, club good A good that is non-rival (can be supplied to more users at no additional cost) but excludable (it is possible to prevent people from using it) may be called an excludable public good, or a club good.

All of these goods share the characteristic of non-rivalry, the primary characteristic of public goods. Knowledge isn't used up if one person makes use of it; a street light helps you find your way just as effectively if someone else passed by earlier; all law-abiding members of the community benefit if crime is low in their neighbourhood.

Economists often define public goods as goods that are both non-rival and non-excludable. We prefer to think of non-rivalry as the primary characteristic. So we describe non-rival goods for which exclusion is feasible as **excludable public goods**, as we did in the previous section. This term is frequently used and well understood, whatever formal definition of public goods is used.

CORE Econ's *The Economy* is a public good. Exclusion is possible, but we prefer to make the ebook available free to students and teachers.

Excludability is a characteristic that can be changed, either as a result of the development of technologies for exclusion, as in the case of broadcasting, or by introducing legal restrictions. Some countries finance broadcasting by requiring users to pay for a television licence, with monitoring and legal enforcement. More importantly, whether or not excludability is possible, the value of the good to consumers is the same, and the economic problem remains: private providers will not supply a non-rival good at the Pareto-efficient level, and depending on costs—both of the good itself, and the exclusion technology—may not supply it at all.

copyright Ownership rights over the use and distribution of an original work.

Other examples of excludable public goods are the information in a **copyrighted** book, or a film shown in an uncrowded cinema: it costs no more if an additional viewer is there, but the owner can nonetheless require a payment to see the film. The same goes for a toll bridge, or a quiet road on which toll gates have been erected. Drivers can be excluded (unless they pay the toll) even though the marginal cost of an additional traveller is zero.

artificially scarce A good is artificially scarce if it is non-rival (can be supplied to more users at no additional cost) but some users are excluded from using it, either directly or because the price is greater than their willingness to pay. *See also: excludable public good.*

excludable public good, club good A good that is non-rival (can be supplied to more users at no additional cost) but excludable (it is possible to prevent people from using it) may be called an excludable public good, or a club good.

Excludable public goods are sometimes called **artificially scarce**, or **club goods**. They can function a bit like joining a private club: adding one more member costs the golf club nothing (at least, if the golf course is not crowded) but the club will still charge a membership fee. But some don't seem much like clubs: a copyrighted book or a toll bridge, for example, are also 'club goods'.

Public bads

'Goods' in economics are things that people want to use or consume. But there are also 'bads': things that people don't want, and might be willing to pay to not have, such as household refuse, or unpleasant-smelling drains. These are private bads. Analogously, we can define public bads: air pollution, for example, is a bad that affects many people simultaneously. It is non-rival in the sense that one person suffering its effects does not reduce the suffering of the others. Atmospheric CO_2 is a global public bad.

The characteristic analogous to excludability in the case of public bads is whether people can be protected from suffering their effects. We might describe an epidemic disease such as polio as a public bad, which became 'excludable' as a result of the development of a vaccine.