19 THE CENTRAL ROLE OF CARBON PRICES

Climate-change policy is a tale of two sciences. The natural sciences have done an admirable job of describing the geophysical aspects of climate change. The science behind global warming is well established. While the timing and regional effects of the changes are not known with certainty, natural scientists have persuasively shown that unchecked CO_2 emissions will have dangerous consequences.

But understanding the natural science of climate change is only the first step. Designing an effective strategy to control climate change will require the social sciences—the disciplines that study how nations can harness their economic and political systems to achieve their climate goals effectively. These questions are distinct from those addressed by the natural sciences. They involve not only estimating the economic impacts of climate change along with the costs of slowing climate change, as we have seen, but also designing policy tools that society can deploy to attain the desired emissions reductions.

I discuss these questions in the chapters that follow. The present chapter discusses the central role of pricing the CO_2 externality, or the design of "carbon prices." Chapter 20 discusses how governments actually go about setting carbon prices. And Chapter 21 examines how the goals of climate policy can be effectively and efficiently implemented among the community of nations. We confront here the politically charged issues of institutional design for a low-carbon world.

WHAT ARE CARBON PRICES?

Something crucial is missing from our survey. We have concluded that reducing concentrations of CO_2 and other greenhouse gases is the only reliable way to slow the freight train of global warming. We saw how much it costs to reduce emissions, and why all countries must participate if we are to keep the costs down and why it is important to shift power generation from coal to natural gas or low-carbon sources, to develop energy-efficient equipment, and to invent new low-carbon technologies. People who are serious about slowing climate change would probably agree with all these steps.

But this leaves individual choices out of the equation. What will persuade you and me and everyone else to undertake the necessary actions? How can we be induced to buy fuel-efficient cars? To vacation close to home rather than flying around the world? What incentives will lead firms to redesign their operations in ways that reduce carbon emissions while keeping their stockholders happy by maximizing profits? What will convince scientists and engineers and venture capitalists that a promising area for their talents is investing in new low-carbon processes and products?

These questions are likely to make your head spin. Fortunately, there is a simple answer. The history of economic interventions in the energy sector and elsewhere shows that the best approach is to use market mechanisms. And the single most important market mechanism that is missing today is a high price on CO_2 emissions, or what is called "carbon prices."

Carbon prices? On first hearing the idea of placing a price on carbon, and a high price at that, many people wonder whether this is some hare-brained fantasy. Actually, the idea is firmly based in economic theory and history. The main insight is that people must have economic incentives to change their activities in ways that lower emissions of CO_2 and other greenhouse gases. The best way to accomplish this is by putting a price on CO_2 emissions. This will in turn raise the relative prices of carbon-intensive goods and lower the relative prices of carbon-free goods, thereby bending down the trend of CO_2 emissions.

Let's begin with the economic analysis. Recall that carbon emissions are economic externalities—activities in which people consume things but do not pay the full social costs. When I turn on my air conditioner, I pay for the electricity. But I do not pay for the damage done by the CO_2 emissions because the price of CO_2 emissions in the United States is zero. If you look back at the list of carbon-producing household activities in Table 6, you will see that none of these includes a CO_2 price that reflects the social costs.

How can we fix this omission? This is one of the few areas where the economic answer is very simple. Governments must ensure that people do pay the full costs of their emissions. Everyone, everywhere, and for the indefinite future must face prices that reflect the social costs of their activities.

Putting this differently, putting a price on carbon represents a societal decision about the priority of reducing CO_2 emissions. The signal is similar to the one given by a high price of land. When land in central Manhattan sells for an astronomical price, that high price indicates that this is not an economical place for a golf course. A price tag on carbon emissions will provide a signal that emissions are harmful and should be reduced.

So much for the economic theory. What is a carbon price in practice? It is the price attached to the burning of fossil fuels (and similar activities). In other words, whenever a firm or person burns fossil fuels, and the CO_2 enters the atmosphere, the firm or person must pay an additional price that is proportional to the quantity of CO_2 emitted. In the examples that follow, I generally use a carbon price of $25 per metric ton of CO_2 so that readers can become familiar with this price. I suggest later that this is a reasonable target to aim for in near-term policies.

Electricity generation provides an example for understanding the role of carbon pricing. Consider a household that consumes 10,000 kilowatt hours (kWh) of electricity each year at the current price of 10 cents per kWh, or $1,000 per year. If half the electricity is generated from coal and half from natural gas, the generation would produce 8 tons of CO_2 emissions. If the carbon price were $25 per ton of CO_2, this

would increase the annual cost of electricity generation by $200 and raise household electricity expenditures by 20 percent.

RAISING PRICES THROUGH TRADABLE PERMITS OR TAXES

How do governments actually put a price on CO_2 emissions? I discuss this at length in Chapter 20, but it should be introduced very early to highlight the idea. There are two ways to raise the price of carbon.

- The easiest way is simply to tax CO_2 emissions: a "carbon tax." It would require firms and people to pay a tax on their emissions much the same way as they do when buying gasoline.
- A second and more indirect method requires firms to have permits to emit CO_2, and to allow them to be bought and sold. This is called "cap and trade" because the quantity of emissions is capped, but the rights to emit can be traded for a price among firms.

While these two mechanisms sound different, they both accomplish the same economic goal of raising carbon prices. I discuss their similarities and differences in Chapter 20, but it is central to understand that these are the two ways, and in reality the only two ways, to put a market price on the externality of greenhouse-gas emissions.

There is one technical but important detail: Who actually pays the price? You might naturally say, "Look, I didn't burn the coal. In fact, I don't even know how or where my electricity is made. How can anyone calculate the right price?"

This is an astute observation. An important administrative issue in designing a carbon pricing system is deciding who writes the check. Consider the oil flowing out of the well, into the pipeline, to the refinery, then perhaps on a truck to the gas station, into the storage tank, through the gas pump, and then into your car. Who would pay for the CO_2 emissions? In principle, anyone along the chain of production might pay. However, the most economical system would probably have refineries pay the price rather than gas stations or consumers. For coal, since there are a few large users, perhaps power plants would write the check. Imports and exports would need to be included in the system as well.

Political scientists point out that the public acceptability of a price-raising regulation or tax may be affected by the point in the production chain at which it is levied. "The only good tax is an invisible tax," as the adage goes. For example, by law one-half of Social Security taxes are "paid" by firms, and most people don't count them as part of their own tax burden. Labor economists firmly believe that both parts of the Social Security taxes come out of wages (or, in technical language, are shifted to wages). Given these behavioral perceptions, or misperceptions, it might be advisable to place regulations or carbon taxes upstream from consumers so that they are less prominent and meet less public opposition.

From an economic point of view, however, it does not make any difference whether the producer, the refiner, or the gas station pays. The carbon price will be passed on to the consumer in the form of higher prices, and the impact on the price of gasoline or other goods does not depend upon who writes the check.

THE ECONOMIC FUNCTIONS OF PUTTING A PRICE ON CARBON EMISSIONS

Putting a price on the use of carbon serves the primary purpose of providing strong incentives to reduce carbon emissions. It does this through three mechanisms: by affecting consumers, producers, and innovators.

First, a carbon price will provide signals to consumers about what goods and services have high carbon content and should therefore be used more sparingly. Consumers will find that air travel becomes relatively more expensive than visiting local sights or taking the train, which will reduce air travel and therefore the emissions from air travel.

Second, it will provide signals to producers about which inputs use more carbon and which use less or none. It thereby induces firms to move to low-carbon technologies so as to lower their costs and increase their profits. One of the most important signals will come in electric power generation. The costs of generating electricity from coal will rise sharply; costs from natural gas will rise somewhat less; and those from nuclear power and renewable sources like wind will rise not at all. Of

all the adjustments, reducing CO_2 emissions from coal is probably the most important step for the United States.

A high carbon price will get the attention of electricity generators. Indeed, many companies already build the possibility of high carbon prices into their long-term plans, even though the current price in the United States is zero. For example, a survey of twenty-one electric utilities in 2012 in the United States found that sixteen had built a positive CO_2 price into their planning, with the average price for 2020 being slightly below $25 per ton of CO_2.[1]

A third and more subtle effect is that carbon prices will give market incentives for inventors and innovators to develop and introduce low-carbon products and processes to replace current technologies. Suppose you are the executive in charge of research and development (R&D) at a large company like GE, which had an R&D budget of $5 billion in 2012. You make equipment for generating electricity from different sources—coal, nuclear energy, and wind. Most generating facilities will last for decades. If carbon prices are going to be zero or very low, then coal-burning plants will continue to be an important source of profits, and you will continue to do substantial R&D for coal technologies.

On the other hand, if you expect carbon prices to rise sharply, few conventional coal stations will be built, and zero-carbon technologies like wind and nuclear power will be the areas on which to place your bets. In other areas where consumer or producer demand is sensitive to carbon prices—air travel, consumer appliances, and automobiles being good examples—companies with big R&D budgets will be sensitive to the signals given by carbon prices and redirect their investments accordingly. I discuss the economics of innovation at length in Chapter 23.

CARBON PRICING AND ENVIRONMENTAL ETHICS

People often wonder why economists recommend such a complicated approach as carbon pricing. Why not just tell people to stop using so much CO_2, or shut down coal production? Perhaps we should all have bumper stickers: "Just say no to carbon."

I return to regulatory and other alternatives below. But the interesting point is that carbon pricing actually simplifies life. Decisions about emissions reductions are complicated, diverse, and pervasive. One of the beautiful aspects of using carbon prices rather than other mechanisms is that it simplifies the complex carbon-related decisions. It does this by reducing the amount of information that is required to undertake the different tasks.

Suppose you take environmental ethics seriously. You desire to reduce your carbon footprint—the amount of carbon emissions your activities produce. How might you go about adapting your daily life to include carbon-related decisions?

Here is a story that describes the way carbon prices simplify decisions. Perhaps you and your brother live in Denver and want to visit your father in Albuquerque. Should you drive or fly? You consult an online carbon calculator and find that flying produces 350 kilograms of CO_2 while driving your Toyota produces 400 kilograms. So flying is better from a pure carbon footprint viewpoint.

But then you remember that you have to get to and from the airport, so you need to calculate the carbon emissions for those activities. You also wonder whether the calculator takes into account whether the flight is full or not. You further consider whether these calculators include only the carbon in the gasoline and jet fuel but have excluded the CO_2 released in the production of the tires, aluminum, steel, cushions, and everything else that goes into making the air travel possible, not to mention the carbon costs of flying the crew in from Los Angeles.

Maybe you should just forget the trip and stay home. You would save carbon, but you would then have an unhappy father to deal with. You might well decide that all these carbon calculations are too complicated and try to find some other way to be a responsible citizen of the world.[2]

This is where the advantages of a carbon price as an aid to decision making become so clear. If a price were charged on all carbon emissions, the costs would already be included in the price of the gasoline for the car trip, in the ticket and taxi fares for the air travel, and in the costs of all the alternative activities. Once the carbon price is universally

applied, the market price of all activities using carbon would rise by the carbon price times the carbon content of fuels they used. We would not know how much of the price is due to the carbon content, but we would not need to care. We could make our decisions confident that we are paying for the social cost of the carbon we use.

To summarize: You can see why economists emphasize the many advantages of using carbon prices to reduce carbon emissions. They provide strong incentives to reduce emissions; they do so in an even-handed way; they affect all aspects of the economy from production to innovation; and they economize on the information that people need to make efficient decisions.

SETTING THE RIGHT CARBON PRICE

Economics teaches us that unregulated markets will not put the correct price on externalities like CO_2—because they are external to the marketplace. So how should the price be determined? Economists have used two approaches to estimating the appropriate carbon price. The first is to estimate the damages from climate change with a concept called the "social cost of carbon." The second is to estimate the required price of carbon that would attain different environmental objectives using integrated assessment models.

Begin with the social cost of carbon. This concept represents the economic damage caused by an additional ton of CO_2 emissions (or, more succinctly, carbon) or its equivalent.[3] Estimates of the social cost of carbon are a critical ingredient in climate-change policy. They provide policymakers a target to aim for in setting a carbon tax, or in setting the level of emissions reductions in a cap-and-trade system, or in international negotiations on minimum carbon prices.

Another application is in rule making where countries do not have comprehensive policies covering all greenhouse gases. In this context, regulators might use the social cost of carbon in a calculation of social costs and benefits of policies involving energy or climate-affecting decisions. For example, the U.S. government has used the social cost of carbon in setting regulations or subsidies for installation of low-carbon energy sources, for efficiency standards in buildings, for fuel efficiency

standards for motor vehicles (discussed shortly), and for setting emissions standards for new power plants.

There are currently many estimates of the social cost of carbon. A U.S. government report provided a best estimate of about $25 per ton of CO_2 for 2015.[4] This is consistent with numbers that come from models, as I show next, so I use this as the target price in the discussion that follows.

A second approach used to determine an appropriate carbon price is to employ integrated assessment models. For example, we might estimate what trajectory of CO_2 prices would be required to attain a given temperature objective. Figure 33 shows an example, where for these calculations I have chosen a temperature limit of 2½°C.[5] This target is consistent with Chapter 18's discussion of cost-benefit analysis.

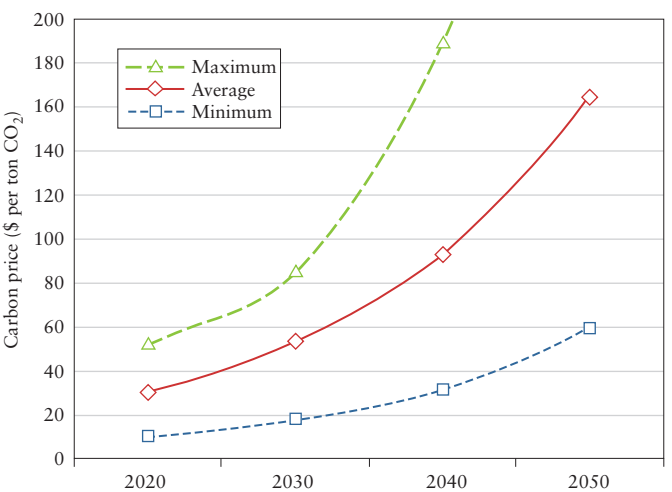

Figure 33. Illustrative carbon prices needed for a 2½°C temperature limit. This figure shows target price paths for CO_2 that would lead to a maximum temperature rise of around 2½°C. These results are from a group of thirteen models and show the central tendency as well as maximum and minimum required carbon prices across models. The path assumes full participation and efficient policies.

Figure 33 shows the trajectory of carbon prices over the next half century under the idealized situation of universal participation and efficient implementation.[6] It would start at about $25 per ton in 2015. The required carbon price rises rapidly over time, at around 5 percent per year in real or inflation-corrected terms, reaching $53 per ton of CO_2 in 2030 and $93 per ton of CO_2 in 2040. The sharp price rise is needed to choke off the rapid projected growth in CO_2 emissions that is assumed in most economic models.

The figure also shows the range of estimates of different models. You can see the substantial uncertainty across different models about just what carbon price would be required to contain global warming at the 2½°C limit. The large range reflects intrinsic uncertainties about future economic growth, energy technologies, and climate models.

IMPACT OF CARBON PRICES ON ENERGY PRICES

To understand how a carbon tax would affect daily life, Table 8 shows the impact of a $25 per ton carbon price on representative energy products at the wholesale level.[7] The increases are determined by the CO_2 content per dollar of cost. Coal is the most heavily affected, while petroleum shows the smallest impact because it has high value per unit of CO_2 emissions.

Table 8. Impact of a $25 per ton carbon tax on wholesale energy prices. This table shows the impact on the wholesale prices of major energy products. The effect on coal will be substantial because it is so carbon intensive. Petroleum has the smallest increase because it has high value per unit of CO_2 emissions.

Item	Unit	Without carbon price	With carbon price	Change (%)
Prices (2005 $):				
Petroleum	$ per million btu	17.2	19.1	11
Coal	$ per million btu	1.8	4.1	134
Natural gas	$ per million btu	4.5	5.8	30
Electricity (industrial)	cents per kWh	6.9	9.0	31

What is the impact of carbon prices on overall expenditures of the statistically average American family? Table 9 shows some examples for a carbon price of $25 per ton.[8] The prices of carbon-intensive goods rise sharply, while those of carbon-light goods rise much less. The largest increase would come in electricity prices, because so much electricity generation in the United States comes from CO_2-intensive coal. A typical year's motor fuels would cost 8 percent more. The percentage increase for an airline ticket would be slightly less. The prices of phone or banking services would rise hardly at all because they use so little CO_2. The cost of all consumption for the average U.S. household, from abacuses to zwieback, would rise slightly less than 1 percent.

Table 9 shows one of the important ways that putting a price on emissions can slow global warming. The prices of carbon-intensive goods go up relative to those of low-carbon goods. This will lead to behavioral responses in which consumers will buy more of the low-carbon and less of the high-carbon items. The higher the carbon price, the more CO_2 emissions will be reduced. This "law of downward-sloping demand"—meaning that quantity demanded goes down as price goes up—is one of the universally confirmed findings in all of economics.

Table 9. Impacts of a $25 per ton CO_2 price.

Example	Tons of CO_2	Increase in spending due to $25 CO_2 price	Increase in spending (%)
Year's electricity use	9.34	$233.40	19.45
Year's driving	4.68	$116.90	7.79
Economy class transcontinental flight	0.67	$16.80	5.61
One year's household communication services	0.01	$0.36	0.04
One year's household financial services	0.02	$0.41	0.04
One year's household consumption	29.48	$737.00	0.92

CARBON TAXES AND THE FISCAL PICTURE

Table 10 shows the aggregates for the U.S. economy based on the prices used in Figure 33. For these calculations, I assume that CO_2 prices are raised by carbon taxes (but it could also be done by auctioning emissions allowances). The carbon tax analyzed here would start at \$25 per ton of CO_2 in 2015, assuming that the economy has attained full employment at that time. It would raise substantial revenues, on the order of 1 percent of GDP. Over the period to 2030, the tax would cause U.S. emissions to stabilize at about the 2000 level. Models indicate that this path of carbon prices, if met with parallel policies in all other countries, would limit the global temperature increase to around 2½°C.

We generally think of energy and climate policy in isolation from overall economic policy, but there is an important fiscal interaction. Most major countries need to curb growing government debts, and a carbon tax can make a major contribution to that effort.

I will illustrate this point for the United States. The Congressional Budget Office in 2012 estimated that the federal debt–GDP ratio will rise from 36 percent in 2007 to 76 percent of GDP in 2013.[9] The debt ratio is increasing rapidly as a result of the collapse of revenues in the current extended downturn, as well as the economic stimulus programs. The long-term outlook is for a rapidly rising debt ratio unless major fiscal corrections are taken.

Table 10. Economic impacts of proposed carbon tax, United States, 2010–2030.

Year	Tax rate (2005 \$/ton CO_2)	Emissions (billion tons CO_2)	Revenues (2005 billion \$)	Revenues (% of GDP)
2010	0	6.3	0	0.00
2015	25	5.9	147	0.96
2020	30	5.5	168	0.97
2025	42	5.4	225	1.14
2030	53	5.2	277	1.25

A carbon tax is the closest thing to an ideal tax that can be imagined. It is the only tax under consideration that will increase economic efficiency because it reduces the output of an undesirable activity (emitting CO_2). It goes a long way toward implementing the U.S. goals for climate-change policy and meeting international obligations that the United States has undertaken. It will have substantial public health benefits because it will reduce harmful emissions, particularly those associated with burning coal. A carbon tax can buttress or replace many inefficient regulatory initiatives and will thereby provide yet further improvements in economic efficiency.

As Table 10 shows, the recommended carbon tax would yield $168 billion of revenues in 2020, equal to about 1 percent of GDP. Because the tax rate would rise sharply, the revenues would also increase substantially over time. Implementing a carbon tax can be a compromise for fiscal conservatives and environmental activists as a way to reduce growing fiscal deficits, slow global warming, and do both of these in a market-friendly manner.