Chapter

13

Biorenewable Policy

13.1 Introduction

The primary reason for the predominance of fossil fuels in the energy sector over the last century has been their low cost relative to biorenewables. Coal, natural gas, and petroleum have rarely been unable to compete economically against biomass, and declines in the market share of one fossil fuel have almost always been to the benefit of another. In terms of dollars per unit of energy, fossil fuels have been (and remain) among the least expensive feedstocks available to the energy sector. This has allowed them to become economically entrenched, especially within developed economies. During the twentieth century this dependence often resulted in the creation of government programs designed to encourage the exploitation of fossil fuel resources. While some biorenewable pathways historically gained traction during times of global crisis, such as biodiesel in the United States and cane ethanol in Brazil during the petroleum shortages caused by the World War II, fossil fuels quickly regained their former market share after the supply disruptions passed.

In the 1970s, one geological and two geopolitical supply shocks caused US policymakers to reconsider their country's reliance on petroleum as the primary transportation fuel feedstock. In 1956, a petroleum geologist for Shell Oil named M. King Hubbert forecasted a steady fall in the United States petroleum production beginning in the 1970s. US production did peak in 1970 at 9637 thousand barrels per day (bpd) and, with the exception of a brief increase in the 1980s, gradually fell thereafter to 5000 thousand bpd in 2008. Formerly "energy independent" in that its domestic petroleum production exceeded its petroleum imports; the UnitedStates was forced to compensate for this decline by sourcing more of its supply from foreign suppliers. In 1977, US petroleum imports surpassed domestic production for the first time of the post-war period and have continued to do so ever since.

The risks of relying on foreign petroleum to meet domestic demand became apparent to the United States in 1973 when the Organization of Petroleum Exporting Countries (OPEC) embargoed petroleum exports to the United States in

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response to the latter's support of Israel during the Yom Kippur War. The US price of imported petroleum tripled, and extensive supply shortages arose as the Nixon Administration began imposing price controls in an attempt to keep the prices down. Import prices did stabilize and even decline a bit after the embargo ended in 1974, although they remained well above their pre-embargo levels. A second shortage arose in 1979, however, following the Iranian Revolution. Iran, which had been one of the world's largest petroleum producers under the Shah, experienced a sharp decrease in production and the suspension of exports. The revolution was quickly followed by war between Iran and its neighbor Iraq, further disrupting production in the region. While other OPEC members attempted to alleviate the situation by increasing production, they were unable to prevent another doubling of US import prices, which reached a level not seen again for nearly three decades.

The twin price shocks of the 1970s spurred interest in the use of ethanol as a fuel, with 662 million liters produced in the United States in 1980. With the encouragement of the federal government, which created a fuel excise tax exemption for ethanol blends and a tariff on imported ethanol, US fuel ethanol production gradually increased to 3400 million liters in 1990 and 6200 million liters in 2000. Renewed energy security concerns following the 9/11 terrorist attacks in 2001 and the subsequent revelation that the majority of the hijackers were citizens of Saudi Arabia, one of the largest sources of US petroleum imports, caused fuel ethanol production to further increase by 1360 million liters in 2002 and 2500 million liters in 2003. In 2005, Congress passed the Energy Policy Act, which created a fuel ethanol mandate in the form of the Renewable Fuel Standard (RFS1), solidified favorable tax treatment for ethanol in the form of the Volumetric Ethanol Excise Tax Credit (VEETC), and incentivized the replacement of methyl tertiary-butyl ether (MTBE) as a fuel additive by ethanol in response to concerns over MTBE groundwater pollution. By 2008, fuel ethanol production was expanding at a rate of 10 000 million liters per year, an increase in volume that initially took 24 years to achieve. High petroleum prices and continued protectionist policies in the forms of mandates, tax credits, and tariffs made fuel ethanol production so profitable that, from 2010 to 2012, more than 50 million liters of fuel ethanol (virtually all of it from starch feedstock) was being produced in the United States annually.

Two important lessons arose from the US experience with fuel ethanol between 1980 and 2012. The period demonstrated the ability of government policy to make biorenewables economically competitive with fossil fuels over long periods of time even when fossil fuel prices are low. Fuel ethanol's share of the US gasoline market increased from 1% in 2000 to more than 10% by 2011, with the largest annual increases occurring during a period characterized by both high energy prices and significant government support. Production increased so rapidly that the first US fuel ethanol mandate, implemented in 2006, was already obsolete by 2008. Second, the US experience also demonstrated the dangers of such rapid growth. Public concerns over the negative effects of using starch feedstocks for large-scale fuel ethanol production have resulted in the passing of legislation in many developed countries that impose restrictions on the industry's future growth and emphasize the production of other types of biofuels.

The following sections describe the major government programs that have affected biorenewable production in several countries since the 1970s and outline the types of programs that can be expected to impact biorenewable industries in the future.

13.2 Subsidies

Subsidies are one of the oldest forms of government industrial support, whether of biorenewables or otherwise. They are defined as financial assistance to producers and/or consumers to reduce the market prices of commodities. It is not uncommon for governments to subsidize commodities considered to be of great importance to their citizens; for example, Egypt's government spends billions of dollars each year on subsidies designed to keep the consumer price of diesel fuel much lower than the market price, and India heavily subsidizes imports of fertilizer for similar reasons. Subsidies can take a number of forms, although five of the most common are *income tax credits*, *direct payments*, *indirect payments*, *mandates*, and *loan guarantees*.

13.2.1 Income Tax Credits

Income tax credits are subsidies that reduce a taxpayer's income tax liability below the amount required by the statutory tax rate. The subsidy amount can be determined either by the amount of a taxpayer's expenditures (e.g., on R&D) or by the volume of its production of a particular commodity (e.g., of fuel ethanol). Income tax credits are also known as "non-refundable tax credits" in some jurisdictions. One example of a US income tax credit that was designed to promote biorenewables production is the Second Generation Biofuel Producer Tax Credit (SGBPTC), which grants qualifying producers of second-generation biofuels a credit of $1.01 against their income tax liabilities for every gallon of its cellulosic biofuel that is used as or to produce a motor vehicle fuel. In other words, a producer of 20 million gallons per year of qualifying biofuel receives a credit of $20.2 million against its income tax liability for the year, reducing its income tax liability by that amount. It is important to note that income tax credits may only be taken against the producer's income tax liability, which diminishes the subsidy's value to economically uncompetitive producers. A producer that does not achieve a profit will have an income tax liability of zero since income taxes are commonly imposed on profits, and the income tax credit will not affect a producer without any profits as a result. Income tax credits help competitive producers remain competitive but will not make an uncompetitive producer competitive. Producers of some types of second-generation biofuels have historically struggled to compete with fossil fuels, and the SGBPTC has had limited impact as a result.

13.2.2 Direct Payments

Direct payments differ from income tax credits in that, as the name suggests, they represent a direct monetary transfer from the government to the producer. Like income tax credits, however, the amount of this transfer can be based on either the producer's expenditures or production volume. Direct payments can also be based on participation in an encouraged behavior; in Brazil, for example, qualifying parents receive direct payments from the government for ensuring that their children attend school. Direct payments are more valuable to economically uncompetitive producers than income tax credits since they are not based on their income tax liabilities and, by extension, their profitability.

One of the largest US subsidies for biorenewables historically took the form of both a tax credit and a direct payment and was officially known as a "refundable tax credit" to reflect this hybrid structure. The now-defunct VEETC, popularly known as the "Blenders' Credit", provided ethanol producers with an income tax credit of \$0.45 for every gallon of anhydrous ethanol that was blended with gasoline to produce ethanol. (The exact amount of the subsidy varied over time and at one point reached \$0.54/gal) The VEETC differed from the SGBPTC in that it became a direct payment as soon as the value of the income tax credit exceeded the producer's income tax liability. As an example, assume that a fuel ethanol producer has a \$10 million income tax liability in a given year and 50 million gallons of anhydrous ethanol production for the same year. Assuming that all of the ethanol was blended with gasoline, then only the first 22 million gallons of production would count as an income tax credit against the producer's income tax liability. Whereas the SGBPTC would cease to apply at this point, the VEETC would become a direct transfer for the purposes of the remaining 28 million gallons, and the producer would receive a payment from the IRS of \$12.6 million (in addition to the \$10 million reduction in income tax liability).

The VEETC was ultimately allowed to expire at the end of 2011 by Congress after coming under public and media attack due to its size. Initially the VEETC made uncompetitive starch ethanol producers competitive by allowing them to reduce their fuel ethanol minimum fuel selling price (MFSP) below that of gasoline in the market. The direct transfer resulted in windfall profits to ethanol producers as gasoline prices doubled between 2005 and 2008 due to higher petroleum prices, however, as the producers continued to receive the same payment from the IRS for every gallon produced even as the market value of the ethanol increased. While the large profit margins to producers that resulted from this combination caused US fuel ethanol production to rapidly increase, the cost to US taxpayers grew at the same rate. By 2010, the US government estimated this cost to be in excess of $7 billion annually. In 2011, Congress, which by this time was focused on reducing government spending, chose to let the VEETC expire without renewal. Two similar refundable tax credits for biodiesel still exist, although their total cost is substantially lower than that of the VEETC due to the smaller scale of US biodiesel production.

13.2.3 Indirect Payments

Indirect payments are monetary transfers from one private entity to another that are required by the government. Whereas the cost burden of direct payments are distributed to taxpayers according to their tax liability, the cost burden of indirect payments falls upon a more limited group. An advantage of imposing the payment burden on a narrowly defined group is that the burden can be limited to only those entities that are affected by the industrial sector in question. Since imposing subsidy costs on taxpayers apportions them according to the taxpayer's income tax liability, under a program like the VEETC a wealthy individual relying on a bicycle for transportation carries a heavier burden of paying for the ethanol subsidy than a less wealthy individual driving a fuel-inefficient sports utility vehicle. The cost burden of indirect payments can instead be imposed on those entities with a strong connection to the subsidized product; for example, obligating petroleum refiners to pay for a biofuel subsidy results in the costs being passed down to transportation fuel consumers who have a stronger connection to the underlying purpose of the subsidy than a random taxpayer. For example, if a government's goal is to reduce its country's dependence on petroleum imports, then reducing the market price of domestic biofuels by increasing that of petroleum products imposes the costs of the program on petroleum consumers in proportion to their consumption.

One of the largest biorenewable indirect payment subsidies is a mechanism within the revised US Renewable Fuel Standard (RFS2) called the "Renewable Identification Number" (RIN). Part mandate and part indirect payment, the RFS2 mandates the consumption of specific volumes of biofuels by refiners (also known as "obligated blenders" since the refiners commonly blend the biofuels with petroleum-based fuels) on an annual basis through 2022. The RINs are attached to each gallon of biofuel following its production and identify the details of the underlying biofuel. The RINs are detached following the biofuel's blending with or use as transportation fuel by a refiner, at which point the refiner can submit them to the government to demonstrate its compliance with the mandate. To encourage the production of the biofuels, however, each RIN is also a tradable "compliance commodity." A refiner owning more RINs than are necessary to demonstrate its compliance with the RFS2 mandate for a given year can sell its excess to a refiner holding insufficient RINs, giving them a market value. Since the RINs are attached to the biofuel at the point of production, refiners must purchase both the gallon of biofuel and the attached RIN, with the biofuel producer receiving the market value of the biofuel (equal in amount to the corresponding petroleum-based fuel on an energy content basis) in addition to the market value of the RIN. RINs therefore can be categorized as an indirect payment from refiners to biofuel producers. RIN sales are still considered to be a government subsidy despite operating as a transaction between two private entities since the government requires their purchase by refiners; were they not required by the government, the total payment from the refiner to the producer for each gallon of biofuel would not exceed its market value.

RINs are also notable in that they are a *flexible subsidy* rather than a *static subsidy*. One of the primary criticisms of the VEETC program was that it was a static subsidy that made the same payments to highly profitable producers as it did to unprofitable producers, resulting in windfall profits for the former at the expense of US taxpayers. The core value of each RIN is a function of the underlying biofuel's production cost and its market value (the latter being equal to the market value of the corresponding fossil fuel on an energy basis). This core value increases when the biofuel's production costs increase (e.g., due to higher feedstock costs) and when its market value decreases (e.g., due to lower petroleum prices). The core value decreases when the biofuel's production costs decrease (e.g., due to technological breakthroughs or improved economies of scale) and when its market value increases.

Flexible subsidies have two advantages over static subsidies. First, they ensure that producers do not generate windfall profits from the subsidy alone; RIN values are designed to fall to zero either when the biofuel's market price exceeds its production cost, thus ensuring a profit to the producer, or when the mandated volume for a given year is met. Second, flexible subsidies provide biofuel producers with an incentive to reduce their production costs over time. While the RFS2 RINs ensure that all qualifying producers initially receive enough value from the RINs to ensure profitable production, this incentive gradually decreases in value as production increases relative to the volumetric mandate. When production exceeds the mandate for a given year, the RIN core value decreases to the amount necessary to ensure the profitability of those producers with the lowest production costs. It is too low to ensure the profitability of producers with higher production costs, forcing them to either reduce their costs or cease production.

The drought that struck the US Midwest during the summer of 2012 provided a stark example of the flexible subsidy mechanism in practice. As mentioned earlier, US starch ethanol production exceeded the volumes mandated by the RFS1 and the RFS2 between 2006 and 2012. RIN values for the starch ethanol category of the RFS2 remained below \$0.04/RIN through the end of 2012 even as corn prices reached historical highs due to the drought. Even though starch ethanol producers were experiencing a drastic increase in production costs even as petroleum prices remained stable, RIN values remained close to zero since starch ethanol production exceeded the mandate, indicating that the RINs were not necessary at that point in time. In the second half of 2012 many starch ethanol producers responded to low feedstock yields by closing their facilities, causing starch ethanol production to fall below the mandated level for 2013. The starch ethanol RINs worked as designed and began to rapidly increase in value in January 2013 and quickly reached $1/RIN, a 2400% increase in value in a matter of weeks. All of this occurred without any changes to the 2007 legislation that created the RFS2 and the RINs, demonstrating the ability of flexible subsidies to automatically and effectively respond to changes in market conditions.

Another form of indirect payment is the *tariff*, which is a tax that is only levied on imports of a particular commodity or product or those from a particular foreign source. By protecting domestic production from foreign competition, tariffs permit the domestic producers in the same industry to attain greater market prices for their products. So while tariffs differ from other indirect payments in that they are not an explicit transaction from one private entity to another, the tariff beneficiary does derive higher income at the expense of both the foreign producer (via lost revenues) and the domestic consumers (via higher market values). Once common throughout the world, tariffs have declined in use due to the expansion of World Trade Organization (WTO) membership and that entity's restrictions on their use. An exception is made for tariffs on agricultural products, however, and until 2011 the United States was able to impose a substantial tariff on imports of ethanol despite its membership in the WTO. The United States continues to impose a tariff on sugarcane imports, which increases the attractiveness of corn starch as an ethanol feedstock by increasing the market price of another popular ethanol feedstock.

13.2.4 Mandates

In the biorenewables sector, mandates are government programs requiring the domestic production and/or consumption of a particular commodity or product by specific entities. (In theory consumption mandates cause their corresponding production, although the opposite is not always true.) Several countries have employed them as a means of creating markets for biorenewables by requiring their consumption, often by industries with heavy fossil fuel use such as petroleum refiners. While the early US starch ethanol industry benefited from various forms of tax credits that allowed it to compete with petroleum-derived gasoline, a major fuel ethanol market was created when the US government began requiring the blending of fuel oxygenates with gasoline by refiners to reduce certain tailpipe emissions. MTBE was initially used but eventually phased out following concerns that it was leaking from storage tanks and polluting groundwater, at which point starch ethanol was left as the primary remaining oxygenate on the market.

The US biofuel mandate was expanded by the RFS1 in 2005 and the RFS2 in 2007, although the underlying mechanism of both is the same: refiners are required to blend predetermined volumes of biofuel with petroleum-based transportation fuels. The success of the RFS1, which just applied to starch ethanol, resulted in an increase in both the total mandated biofuel volume and the number of different biofuel categories in the RFS2. The latter mandate actually caps the starch ethanol mandate at 57 BLY while requiring the additional production of 79 BLY of so-called "advanced biofuels" by 2022. The advanced biofuels mandate is further subdivided into "cellulosic biofuel" and "biomass-based diesel" mandates, the former comprising any biofuel derived from lignocellulosic biomass and the latter consisting of biodiesel and renewable diesel produced from lipids. The cellulosic biofuel mandate is the largest of the four, reaching 61 BLY of consumption by 2022. As described in the previous section, the RFS2 mandates are combined with indirect subsidies to have the combined effect of incentivizing production and ensuring consumption.

Mandates as represented by renewable fuel standards only impact transportation fuel markets, which are responsible for just a fraction of energy market economic value and GHG emissions. A second common type of mandate is the *renewable portfolio standard* (RPS), which mandates the production of electricity from renewable sources, including biomass. Many countries and a majority of US states have individual RPS mechanisms in place. A key component of an RPS is the requirement that electricity generators in the covered state or country source a minimum percentage of their total generation from renewable sources such as hydropower, solar power, wind power, and biomass. Many RPSs are similar to the RFS2 in that a compliance certificate is associated with renewable production, passing from the renewable energy generator to the obligated party, which uses it to demonstrate its annual compliance with the mandate. Alternatively, established electricity generators can generate their own renewable electricity, eliminating the need to find a separate qualified generator.

RPSs resemble RFSs in that they are primarily market-driven mechanisms. While obligated parties are required to either purchase or generate renewable electricity for public consumption, competition allows them to choose between multiple suppliers, permitting the presence of price competition. In many countries and US states the percentage of total electricity that must be produced from renewable sources is relatively low (10–20%) in the program's early years and gradually increases over a decade or more, preventing the price shocks that can occur from a rapid and substantial transition to new and untested generation pathways. Because of the gradual natures of many RPSs, however, it will be at least a decade before their success (or failure) can be determined.

A final type of mandate that has been employed in many countries is the *feed-in tariff* (FIT). FITs differ from RFSs and RPSs in that they guarantee a price (rather than just a purchaser) for renewable electricity over periods ranging from 10 to 20 years. In Europe, for example, many countries determine the costs of production for different renewable electricity pathways and then obligate traditional electricity generators to purchase the renewable electricity at these rates, which often exceed market electricity rates. By guaranteeing long-term future revenues for renewable electricity generators, FITs are designed to eliminate much of the uncertainty and risk from renewable electricity generation, increasing the probability that generators are able to acquire the financing necessary to construct new capacity. To prevent windfall profits, some versions of FITs include “tariff degression” or the gradual reduction of mandated tariff rates over time. Tariff degression is motivated by expected cost reductions as new renewable electricity pathways take advantage of economies of scale and increased efficiencies resulting from capacity growth.

Many European countries employing FITs have experienced substantial increases in renewable electricity generation as a percentage of total electricity generation since 2000. In some cases the FITs have been too successful, however. Spain suspended its FIT program in 2012 after new solar capacity exceeded original projections by more than 500%, imposing a substantial cost on the country’s electric utilities during a time of widespread economic crisis in the European Union (EU). While the implementation of FITs can cause large increases in renewable electricity generation capacity, Spain’s experience illustrates the importance of accurately estimating the minimum tariff rates necessary for each pathway to be economically feasible. Underestimating the rates results in little to no growth in capacity, while overestimating the rates imposes excessive costs on traditional electricity generators and causes regulatory uncertainty to occur as governments attempt to correct their tariff calculations.

13.3 Emission Controls

13.3.1 Carbon Prices

GHG emissions are considered to be a *negative externality* or a form of economic activity causing a negative effect that is not reflected as a cost borne by the party responsible for the activity. Air pollutants such as soot and other particulate emissions are a common example of a negative externality, as the costs of the negative human health effects caused by these emissions are carried by the general public rather than those responsible for the pollution. While GHG emissions are not as immediately visible as soot and smog, many countries legally treat them as pollutants due to concerns that excessive emissions will cause severe global climate change in the future, the costs of which will be borne by people and entities in negatively affected areas rather than by those responsible for the emissions. One method of removing negative externalities is via the imposition of a price by the government on the responsible activity. A *carbon price* imposes a monetary value on GHG emissions, generally on a mass basis (e.g., dollars per metric ton of CO_2-equivalent emissions). Under a carbon price system, emitters are required to pay the government a monetary amount based on their GHG emissions over a period of time. Carbon prices discourage emissions by ensuring that the costs of emitting are reflected in a monetary form.

Carbon prices commonly are part of a larger *cap-and-trade* scheme. These schemes impose a cap, or ceiling, on emissions. Emitters exceeding this cap in any given year are required to purchase *carbon allowances* equal to the amount of their excess emissions. The value of the carbon allowances is determined by the carbon price. Allowances are purchased from or distributed by the government and those entities whose GHG emissions fall short of the cap can sell a number of allowances equal to the shortfall to those entities whose emissions exceed the cap. This second mechanism is the "trade" aspect of cap and trade. Over time the emissions cap is reduced, further incentivizing emission reductions by reducing the number of available carbon allowances and thus raising the carbon price, making the emissions more costly.

Cap-and-trade schemes provide multiple benefits to biorenewable pathways. Emissions caps are generally based on lifecycle emissions, allowing pathways employing sustainable biomass feedstocks to discount their smokestack or tailpipe emissions by the amount of GHGs absorbed during biomass growth (also known as biogenic carbon). Many biorenewable facilities emit a fraction of the amount of GHGs as a similarly sized fossil fuel facility on a lifecycle basis as a result. Biorenewable facilities falling under the cap thus have a greater number of carbon allowances to sell to other emitters, representing an additional source of income when the allowances are freely distributed by the government and a financial advantage relative to fossil fuel users when they are not. When the carbon price is high enough, this difference in required allowances can make biorenewable pathways economically competitive with fossil fuel pathways. Biorenewable pathways can benefit even when biorenewable facilities are not directly involved in the scheme, since the carbon price increases the production costs of fossil fuel pathways relative to biorenewable pathways, increasing the attractiveness of biorenewable investment and consumption.

An alternative method of allowing biorenewable pathways to participate in a cap-and-trade scheme is via *carbon offsets*. Biorenewable pathways not covered by the emissions cap can receive offset credits from the government for engaging in activities resulting in net carbon mitigation or sequestration, such as afforestation/reforestation, anaerobic digestion, or the production of biochar for use as a soil amendment agent. These offset credits take on a value equal to the carbon price and can be sold to GHG emitters exceeding the emissions cap, thus taking on a function that is very similar to the carbon allowances. The primary difference between allowances and offset credits is that the former are sold by entities that are covered by the cap, while the offset credits are sold by entities not otherwise included in the scheme. The offset mechanism has been employed by the European Union's Emissions Trading Scheme (ETS) as a means of reducing the atmospheric GHG concentration while providing an additional source of income for entities in underdeveloped countries, although its initial implementation was rife with abuse and fraud. When properly designed, however, offset credits represent a means of reducing the costs of a cap-and-trade program while also reducing net global GHG emissions.

Cap-and-trade schemes are often characterized as a market-based approach to environmental regulation since the carbon price is determined in part by trading between emitters and holders of excess allowances and offset credits. While trading does affect the carbon price, the way in which the cap-and-trade scheme is designed by the government does so as well. GHG emissions, particularly those from large emitters, are closely correlated with a country's economic health; emissions tend to increase during periods of economic growth and decrease during recessions. The government is responsible for establishing the initial emissions cap level and determining the rate at which it is reduced over time. Establishing either an initial cap that is too low or a reduction rate that is too fast can cause carbon prices to be very high, effectively reducing both GHG emissions and economic growth. Alternatively, establishing either an initial cap that is too high or a reduction rate that is too slow can result in carbon prices that are so low as to be ineffective, as emitters find the purchase of allowances and offsets to be much less expensive than actual emission reductions.

The EU experienced both of these effects in implementing its ETS, first establishing a cap that was too high and then failing to reduce it quickly enough. The latter problem was compounded by the financial crisis and subsequent deep recession that afflicted the Eurozone beginning in 2008, which caused both economic growth and GHG emissions to fall far below pre-crisis projections. The ETS cap levels in the recession years were based on an expectation of economic growth, however, resulting in an oversupply of carbon allowances. The carbon price fell to very low levels in 2012 and 2013 due to this excessive supply, removing the incentive to reduce emissions via expensive equipment upgrades and adoption of economically uncompetitive renewable pathways. While the market influences the carbon price under a cap-and-trade scheme, it can only do so effectively when the government is able to accurately determine the allowance supply that will encourage the transition from fossil fuel pathways to low-carbon pathways such as biorenewables without stifling economic growth.

13.3.2 Carbon Taxes

Taxes, particularly those on income, are an integral source of government funding in developed countries. Taxes also have the effect of discouraging the activities on which they are levied by making them more expensive. Many governments levy taxes on commodities considered to be harmful to human health, such as alcohol and tobacco, in order to discourage their consumption by making them less affordable. These so-called *Pigovian taxes* are intended to correct inefficient market outcomes by preventing the occurrence of an activity the government wishes to discourage via the imposition of high costs on it as well as provide government funding for remedial measures to counter the negative effects of the activity when it does occur (e.g., rehabilitation centers for abusers of alcohol). A *carbon tax* is an example of a Pigovian tax that is applied to carbon emissions. It is similar to a cap-and-trade scheme in that it imposes a monetary cost on the act of emitting GHGs, thereby discouraging the activity. The basic mechanism of a carbon tax can be the same as a cap-and-trade scheme in that both impose a predetermined monetary value on a particular amount of GHG emissions, either in total or above an established cap. The cost of emitting can be avoided under both systems via methods such as equipment upgrades and the adoption of renewable pathways. Despite this similarity, however, several notable differences exist between the two systems.

Carbon taxes are less flexible than cap-and-trade schemes in that they do not include a market mechanism that influences the cost of emitting. This cost is instead determined by the government prior to implementation in the form of the tax rate and must be adjusted until the optimum rate is identified. As discussed in the previous section, this is not entirely different than cap-and-trade systems in practice, as the latter require the government to determine the carbon allowance supply that is most likely to result in the optimum carbon price and update it in response to changed economic conditions. Cap-and-trade schemes do provide more flexibility on a short-term basis, however, since they allow emitters to adjust their behavior in response to changes in the availability of carbon allowances and offsets. Carbon taxes also permit less flexibility than cap-and-trade schemes in that they do not allow emitters who fall short of the cap and entities engaged in carbon mitigation and sequestration activities to directly profit via the sale of allowances and offsets to those exceeding the cap. The most that emitters can do to reduce their carbon tax burden is by reducing their net emissions. This can indirectly benefit the economic feasibility of biorenewable pathways by making them more attractive relative to fossil fuel pathways, but it does not reward net sequestration activities. While a carbon tax could impose a “negative” tax on mitigation and sequestration activities equal to the carbon tax, this would be more accurately described as a subsidy. Furthermore, this subsidy would be primarily paid by income taxpayers rather than emitters and, while the cost could be offset by the proceeds of the carbon tax, additional effort would be needed to ensure that the two remained equal.

The relative short-term inflexibility of carbon taxes notwithstanding, they are sometimes criticized for supposedly being more flexible than cap-and-trade schemes in that they do not impose a hard cap on emissions. Emissions under a cap-and-trade scheme are ultimately limited to the total availability of carbon allowances and offset credits. Under a carbon tax, emitters are only limited by their ability to pay the respective tax on all emissions, an ability that can be quite substantial for wealthy individuals and multinational corporations. In reality, however, rational actors will only ignore a carbon tax when the benefits of doing so outweigh the costs, in which case the government can raise it to the level necessary to discourage emissions. It is unrealistic to assume that a wealthy entity would spend a fortune under a carbon tax program to emit GHGs simply for the sake of increasing the atmospheric GHG concentration. Furthermore, a government could impose a hard cap on emissions as part of a carbon tax, with the tax applying to emissions under this hard cap but above a lower soft cap.

Further Reading

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