7 Market-based Economic Instruments

The underlying goal of policymaking is to ensure improvements in the well-being of all its citizens. In the context of energy or climate-related issues, the goal of policy design is largely to address some of the problems that we illustrated in Chapter 1, and determined by the market failures, including behavioural anomalies that we described in Chapter 2.

In this chapter, we first provide an overview of energy and climate policy goals, a discussion that we introduced in Chapter 2 and continue upon in this chapter, and then we will present and discuss the most important policy measures using a microeconomics-based approach. As we will discuss in more detail, these two categories of policies (energy and climate) share one goal, namely the protection of the environment, and thus many policy instruments can be classified into both categories. This is why we think that it is important to discuss these two policy categories in tandem. Moreover, in most countries, energy and climate policies are defined by different laws. This can create coordination problems in defining the policy instruments because while they may share a common goal, they are not always discussed and implemented at the same time in the political decision process.

We discuss the relevance of these policies and categorise policy instruments based on whether they operate through the market mechanism, that is, whether they are market-based instruments or non-market-based instruments. While this distinction need not be watertight, market-based instruments incentivise economic agents to adopt efficient behaviour, whereas non-market-based instruments tend to operate by obliging agents to follow some behaviour or adopt some standards. Market-based instruments (what they are, how they work, and their strengths and limitations) will then be discussed in detail in this chapter, whereas non-market-based instruments will be the subject of Chapter 8.

7.1 Energy and Climate Policy: Goals and Instruments

7.1.1 The Purpose of Energy and Climate Policy

States intervene in the energy and climate realms using policy instruments to address market failures including behavioural anomalies that may prevent economies from reaching welfare-maximising (or equitable) outcomes. In doing so, the general objective of energy and climate policy instruments is to improve the well-being of society and promote sustainable development.

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As already introduced in Figure 2.4 in Chapter 2, Figure 7.1 illustrates the specific goals of policymakers when designing energy and climate policies. Energy policies seek to meet three objectives: ensuring the security of energy supply, warranting economically efficient and affordable energy supply, and last, addressing ecological and environmental concerns, in broad terms. The last objective involves ensuring that the energy supply is ecological and thus likely to minimise local (e.g., air pollution or waste generation) and global (e.g., greenhouse gas (GHG) emissions) environmental damages, an objective that is also shared by climate policy. The current emphasis is on transitioning societies from positive tons of GHG emissions (such as CO_2) to zero net emissions, a goal that is best captured by the Paris Agreement signed in 2015. Climate policy is also designed to meet another goal, namely to make sure that adaptation strategies are implemented to minimise climate damage during the transition to a sustainable energy system. Therefore, ultimately, climate and energy policies only share one policy goal.

To achieve the three energy policy goals, a policymaker can potentially employ several kinds of strategies, as Figure 7.2 illustrates. For example, diversifying the group of countries from whom energy is imported, as well as the promotion of domestic renewable energy sources can be strategies towards achieving energy security. Policymakers who are interested in making energy more affordable might consider adopting policies that introduce reforms in energy-sector markets to improve economic efficiency, and therefore decrease prices, or to introduce subsidies. Of course, the introduction of subsidies (e.g., subsidies for gasoline), as we will discuss later on, can have a negative impact on economic efficiency, while having a positive effect on equity. Note that in some institutions, the goal of providing affordable energy is listed under the goal of security of supply, and not considered under the goal of economic and affordable supply, as we do. Ensuring the ecological supply of energy can be achieved through the

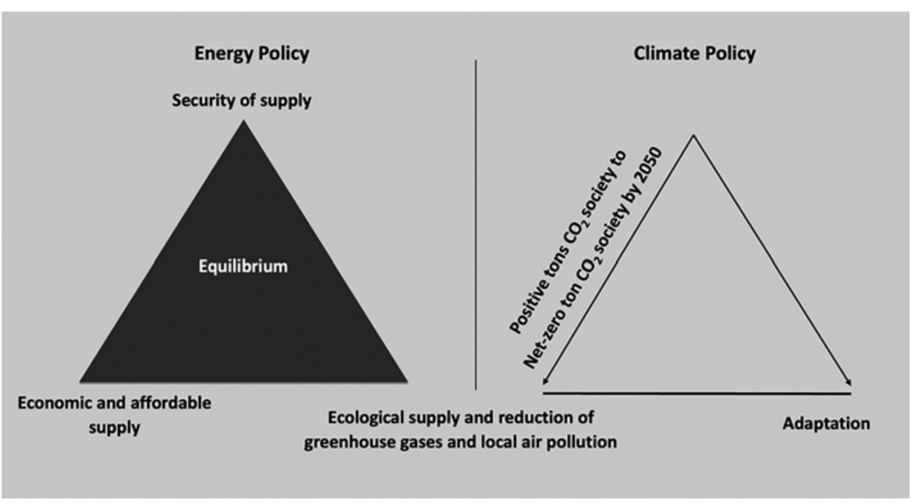

Figure 7.1 Goals of energy policy and climate policy

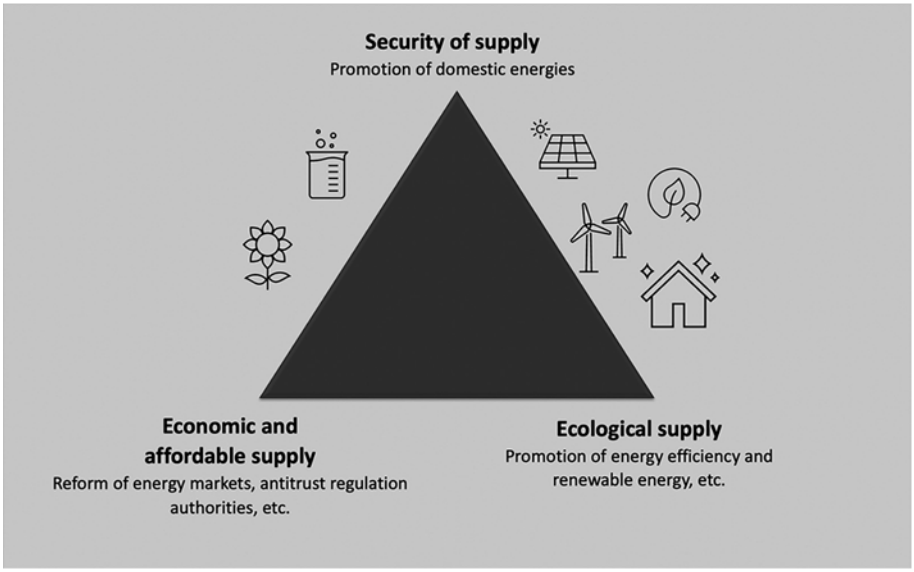

Figure 7.2 Strategies of energy policy

promotion of energy efficiency in consumption, as well as through the increased use of renewable energy sources.

Another important difference that arises between energy policy and climate policy is that energy policy is mostly designed to cater to national interests and, therefore, to maximise the well-being of citizens of a country, but it also has positive spillovers in mitigating global warming. For instance, energy policy involves implementing measures to reduce fossil fuel consumption to improve the security of supply and to reduce local air pollution, so it also has an effect on GHG emissions, and therefore on the sustainable management of a global resource, that is, the atmosphere.

Climate policy, on the other hand, is mainly oriented to mitigate the negative effects of global warming, and thereby it also has a positive effect on the national climate of countries, and therefore on the well-being of their citizens. However, it also indirectly contributes to reaching some of the goals of energy policy. For instance, climate policy instruments have the positive side effects of reducing local air pollution and increasing the security of energy supply because of the reduction in energy consumption. Climate policy will only fulfil its potential benefits if all countries cooperate at the international level in mitigating damages. To summarise, energy policy tends to be more domestic in scope, whereas climate policy tends to be more global (except adaptation-based strategies that are locally oriented).

From a policymaker's point of view, given that energy policy is more directly oriented towards maximising national welfare, it can find higher favourability from the citizens, compared to climate policy.

The success of climate policy initiatives at a national level would then need to be reliant on the implementation of clearly defined international agreements that elaborate on mitigation goals and instruments. Moreover, it also depends on providing financial support to developing countries that are facing the brunt of climate change, and that, as discussed in Chapter 1, did not contribute as much to creating the problem in the first place. Thus, if we recognise this, then from an equity point of view, it is important that industrialised countries not only implement domestic energy and climate policy to reduce their own GHG emissions but also help developing countries in mitigating and adapting to climate change. There are several approaches to do this; one approach is to directly transfer financial resources to developing countries, and the other approach is to realign development cooperation policy and aid, for instance by promoting investment in new sustainable technologies for mitigation and adaptation, or a combination of the two. In this manner, the financial burden of climate policies is shared, and the commitment to achieve sustainable development can be strengthened.

7.1.2 Types of Energy and Climate Policy Instruments

There are two main groups of measures to address energy and climate issues: public measures that are designed and implemented by the state, and private measures that are implemented by non-state entities such as firms or associations. Public measures, also called policy instruments, can further be divided into market-based and non-market-based policy instruments, while private instruments can either be voluntarily implemented by firms or by civil society (Figure 7.3).

7.1.2.1 Public Energy and Climate Policy Instruments

The distinction between market-based and non-market-based instruments is not always unambiguous. One approach is to consider all measures that improve the functioning of the market, including monetary-oriented measures such as taxes and subsidies, as well as information campaigns and nudges that enable economic agents to take better decisions, as market-oriented instruments. The other approach is to count only monetary measures as market-oriented instruments and to consider the other non-monetary measures that improve the functioning of markets as non-market-oriented instruments. In this text, we opt for the former approach. This implies that market-based approaches will comprise monetary policy measures as well as other measures to improve the functioning of markets (such as informational policies and nudges).

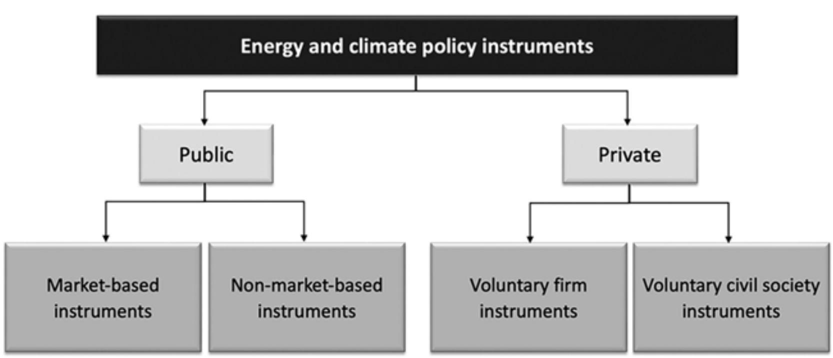

Figure 7.3 Types of energy and climate policy instruments

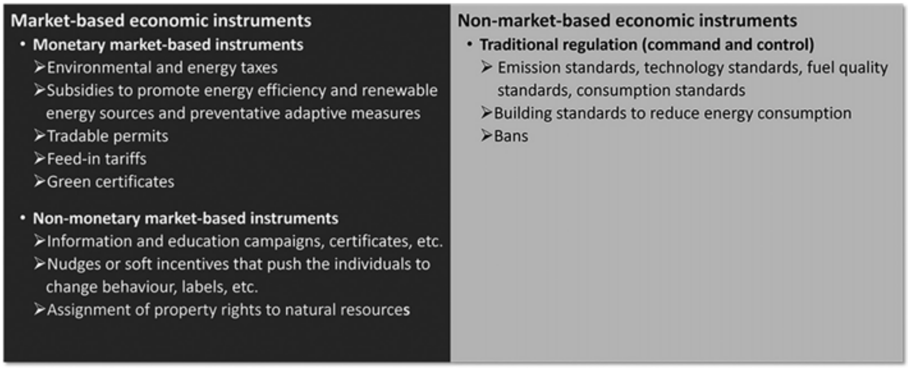

Figure 7.4 Public energy and climate policy instruments

Figure 7.4 includes some examples of public energy and climate policy instruments. Typical market-based economic instruments are environmental and energy taxes, subsidies, tradable permits, feed-in-tariff (FiT), and environmental or 'green' certificates. Non-market-based instruments include traditional regulatory policy instruments (such as standards and direct control measures) and voluntary agreements or negotiated approaches between industries and the government (to reduce fossil fuel consumption). Policies to promote educational or information dissemination programmes, as well as nudges, namely interventions that steer individuals to change behaviour, facilitate effective functioning of markets, and thus can be conceived of as market-based instruments as well. An example of an information-based policy is an energy-efficiency label on durable goods (such as appliances or vehicles) to make consumers aware of their energy performance.

The last non-monetary market-based instrument is the assignment of property rights for the use of natural resources. This instrument can be used to address the market failures of negative externalities and common resources. For instance, if a firm pollutes a lake, and therefore produces a negative externality for the population dependent on it, assigning the property rights to the lake among the population would eliminate the problem. In this case, the firm may, on the one hand, invest in technologies to reduce pollution and, on the other hand, transfer money to the affected population and acquire the rights to pollute. It is important to keep in mind that the practical implementation of this instrument is challenging and cumbersome because it involves reaching an agreement among different parties at the local as well as global levels, on who has the right to the resource. In this chapter, we will not emphasise this policy approach.

The energy and climate policy instruments described in Figure 7.4 can be implemented at different institutional levels:

- Local (i.e., at the level of municipalities, districts, states, cities, etc.)
- National
- International (i.e., at the level of the European Union, the United Nations (UN), etc.)

Figure 7.5 Private energy and climate policy instruments

The UN system encourages international agreements to promote sustainable development as well as sustainable energy consumption, and to address climate change. Agreements can be either legally binding or non-binding. A binding contract represents a legally enforceable voluntary commitment by states to take specific actions, whereas a non-binding agreement does not entail legal obligations. A strong legally binding agreement is, in practice, very difficult to negotiate across heterogeneous parties, such as countries. International treaties generally contain a mix of binding and non-binding elements, such as clauses using obligation-related language (e.g., shall) and passages meant to convey a guiding principle (e.g., should).

7.1.2.2 Private Energy and Climate Measures

Some energy and climate policy instruments can also be voluntarily promoted and implemented by private agents, such as firms and civil society groups, as shown in Figure 7.5. Firms, for example, can incorporate notions of corporate social responsibility (CSR) into their business as well as production processes. Alternatively, producers can also contribute towards sustainable development through the adoption of eco-labelling and eco-certification practices, and financial institutions can complement these activities by offering sustainable investment funds such as ESG (environmental, social, and governance-related) funds. Civil society programmes, on the other hand, can guide socially responsible behaviour through the launch of campaigns and initiatives, either through consumer associations or cooperatives.

7.1.3 Market Failures and Policy Instruments

Policy instruments are meant to address market failures, including behavioural anomalies, and thus promote sustainable development. Tables 7.1 and 7.2 provide an overview of some policy instruments for addressing several common market failures related to the energy sector. The policy instruments mentioned in these figures will be discussed in this chapter, as well as in Chapter 8. For instance, if positive externalities can arise from learning-by-doing, as is the case in the research and development (R&D) of energy-sector technologies, R&D subsidies and tax credits might be helpful. Likewise, several policy instruments (such as taxes, permits, and standards) can be utilised to address negative externalities that may arise from air pollution.

Similarly, each behavioural anomaly related to energy consumption might also be counteracted using suitable policy instruments. As discussed in Chapter 2, behavioural anomalies represent systematic deviations of behaviour from assumptions of the rationally self-interested model, namely *homo economicus*. Some of these anomalies that

Table 7.1 Classical market failures and possible policy instruments

Type of market failure	Damage / benefit	Main instruments
Negative externalities: • Local air pollution and global GHG emissions • Public goods and common resources	• Harmful to health • Property damages • Environmental damages • Insufficient provision of public goods • Tragedy of the commons • Insufficient investment in adaptation infrastructure	• Environmental taxes • Tradeable pollution permits • Standards • Subsidies for the provision of public good
Fossil fuel import dependence	• Harm to national energy and economic security	• Energy import tax • Subsidies for Indigenous energy production
Positive externalities: • Learning-by-doing spillovers • R&D spillovers • First adopters of new technologies	• Insufficient investments in R&D, energy efficiency ('energy-efficiency gap') and renewable energy technologies	• Subsidies for R&D • Subsidies for adopters • Tax credits • Standards
Consumers' lack of information: • Asymmetric information • Principal–agent problems	• Insufficient investments in energy-efficiency ('energy-efficiency gap'), in renewable energy technologies and in adaptation strategies	• Information campaigns • Subsidy for consultancies/audit • Nudges (public information campaigns) • Labelling • Standards

Table 7.2 Market failures in the form of behavioural anomalies

Type of behavioural anomaly	Damage / benefit	Main instruments
Bounded rationality	• Insufficient investments in energy efficiency ('energy-efficiency gap'), in renewable energy technologies, and in adaptation technologies • Imperfect decisions related to consumption and investment choices	• Standards • Default options • Nudges in form of information • Social norms • Educational programmes • Information campaigns
Bounded willpower (weakness of will, impulsiveness, and myopia)	• Insufficient investments in energy efficiency ('energy-efficiency gap'), in renewable energy technologies, and in adaptation technologies	• Standards • Default option • Subsidies • Tax credits • Rebates • Loans

have been found to be relevant to the energy or climate realms are described in Table 7.2. An example of a behavioural anomaly is the limited use of information by agents, which might arise because of the limited attention paid to energy consumption, or the limited salience of this information. It could also arise due to incorrect prior beliefs about a product, or about which pieces of information are relevant in making energy consumption decisions. This may result in agents making imperfect consumption decisions, and this can be countered through standards or information campaigns.

In Tables 7.1 and 7.2, we listed the policy instruments that the government can use to address market failures. In this discussion, we are implicitly assuming that the choice, design, and implementation of the policy measure are completely oriented to address effectively the market failure and, therefore, to increase the welfare of the society. However, as discussed in the public choice theory, in some situations, government intervention may not correct market failures. The reasons for the ineffectiveness of government intervention mentioned in the public choice theory are several. For instance, the presence of special interest groups that try to influence policy decisions in their favour rather than towards the broader society interest, lack of alignment between the goals of part of the policymakers and society, or the presence of inefficient government agencies. Further, in some cases, the corruption of the bureaucrats responsible for implementing interventions can also determine the ineffectiveness of policy measures. For this reason, policymakers should promote analysis of the effectiveness of a policy measure to identify the presence of potential problems and correct them. More generally, as we will discuss in more detail in Chapter 9, the choice of a policy instrument should be based on several criteria, such as economic efficiency, the effectiveness of the instrument, its impact on equity, etc.

7.2 Monetary Market-based Instruments

7.2.1 Pollution Taxes, Product Taxes, and Energy Taxes

The next subsection explains the uses of environmental and energy taxes, which are among the important policy instruments to address energy and climate issues.

7.2.1.1 Types of Environmental and Energy Taxes

There are different types of taxes that can be used to internalise the negative externalities due to energy use that arise from environmental damage or climate change. A product tax is levied on the output of polluting firms, while a pollution tax is imposed directly on the pollution/emissions of firms. An energy tax is one that is imposed not on the output, but on the energy inputs used by firms and households in the production of goods and energy services. Figure 7.6 provides brief descriptions of these three taxes.

From an economic point of view, the pollution tax is the most efficient type of tax to address negative externalities that are generated by burning fossil fuels. The level of a pollution tax is set equal to the MEC of local and global pollution, which results in an efficient solution to tackle negative externalities, as the problem is addressed directly, unlike with the use of a product tax. Pollution taxes provide firms with incentives to

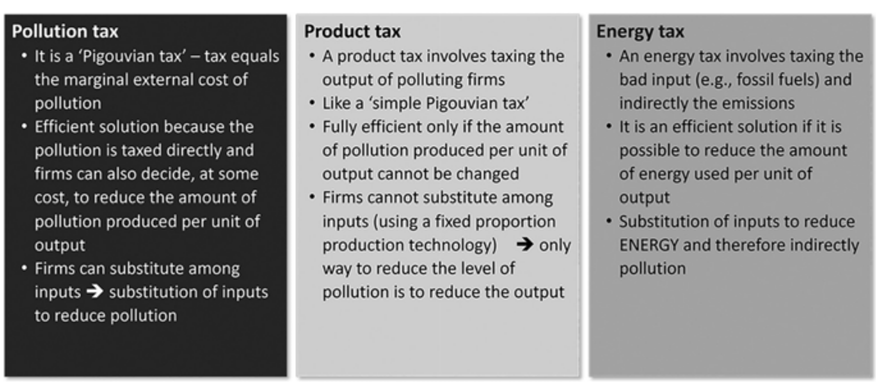

Figure 7.6 Types of environmental taxes

replace polluting inputs and technologies with more environmentally friendly alternatives, and therein reduce their tax costs. However, this is not the case with all types of taxes.

The product tax is less efficient, as the level of taxation is not directly tied to the level of pollution. Accordingly, the only way for a firm to decrease its burden from a product tax is to reduce its output, and no appropriate incentives exist for them to substitute old technologies with new, more efficient ones that produce the same output but cause less pollution. Product taxes, however, can be efficient in the case where the pollution produced per unit of output cannot be changed. As an example, consider fixed-proportion production technologies, where firms are forced to use inputs in pre-determined proportions, due to a lack of substitutability between inputs (such as energy and capital).

Last, the energy tax, especially an energy tax on fossil fuels, is another relevant form of environmental taxation, and it is a useful policy instrument to reduce pollution if it can be concluded that there is a constant ratio between the use of fossil fuels (or energy) and the level of pollution. In this case, the level of the energy tax is determined by the level of pollution, and the instrument offers firms the possibility to substitute away from using fossil fuel-intensive inputs. Adoption of energy taxes might, therefore, lead to the use of more sustainable inputs (substitution of energy with capital) and technologies, and in that sense, it is like a pollution tax.

From an economic point of view, the best type of tax to address market failures such as negative externalities is a pollution tax, followed by an energy tax, and last, a product tax. Even though this has been theoretically shown, note that from an energy policy point of view, the energy tax has several advantages. The introduction of an energy tax on all energy sources will reduce levels of energy consumption and, therefore, will decrease pollution (if the energy supply is dependent on fossil fuels), as well as increase the security of supply. This positive effect on the security of supply is due to the fact that by reducing energy consumption, indirectly one is also likely to reduce the imports of energy, and this augments energy supply security. Of course, a pollution tax will also tend to reduce the energy consumption up to the extent that economic agents do not use filters, scrubbers, or sequestration technologies that enable reducing pollution while continuing to burn fossil fuels. An energy tax can also be introduced only on imports to encourage the development of indigenous production and thus also strengthen the security of domestic supply. Another advantage of an energy tax with respect to the pollution tax is that it is more salient to consumers: for example, a gasoline tax is likely to be noticed by consumers whenever they refill, and it is also more easy to implement compared to a pollution tax.

Note that generally, with the introduction of environmental and energy taxes, we will observe two behavioural changes. On the one hand, economic agents will reduce consumption due to the price increase. On the other hand, these taxes can promote a change in investment behaviour, such as encouraging economic agents to make investments in energy efficiency or pollution abatement technologies.

Generally, the revenues from collecting these taxes can be used by the state in the following ways: to fund R&D in new technologies, provide subsidies for the adoption of energy-efficient or renewable technologies, or a per capita redistribution of revenue based on income, etc. For instance, in Switzerland, the government introduced a CO_2 tax on heating oil and natural gas in 2008, and the revenues are used both for R&D funding and for promoting measures for enhancing energy efficiency, as well as redistributing to the people on a per capita basis.

We will now discuss each of these types of taxes in more detail.

7.2.1.2 Product Tax

As discussed previously, a product tax is added to the price of pollution-generating output to correct negative externalities. The tax, therefore, follows the polluter-pays principle. The graph in Figure 7.7 depicts a case in which a product tax is imposed on a market for a product derived from livestock, such as meat. We choose this as an example, because as mentioned in Chapter 1, the agricultural sector (including the management of livestock) is responsible for a large share of the emissions of GHGs, particularly methane. The price level is shown on the vertical axis and the quantity on the horizontal axis. The demand function for meat is represented by the marginal private benefit (MPB) function, which in this case is considered equal to the marginal social benefit (MSB), and it slopes downwards, as consumers will demand less meat as prices increase. The upward-sloping marginal private cost (MPC) curve represents the supply and captures the increase in the quantity of meat supplied by producers, as prices increase. However, each additional kilogram of meat produced also has an external cost (in terms of emissions), due to feed production and processing, as well as enteric fermentation. This is captured by the upward-sloping marginal external cost (MEC) curve. Of course, we could also imagine a MEC curve that is constant, but also in this case, the analysis will follow. The marginal social costs (MSCs) of meat production, thus, equal the sum of the MPC and MEC, at each quantity.

If the external costs (i.e., negative externalities) are not considered in the output decision, the competitive equilibrium quantity of meat will be given by the intersection of the MPC and the MPB curves, namely at Q_C. At this quantity, Q_C, however,

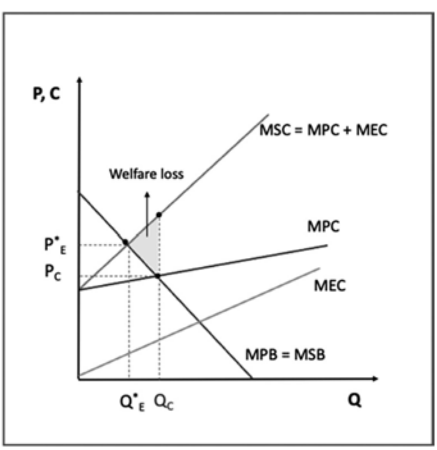

Figure 7.7 Welfare loss without considering externalities of meat production

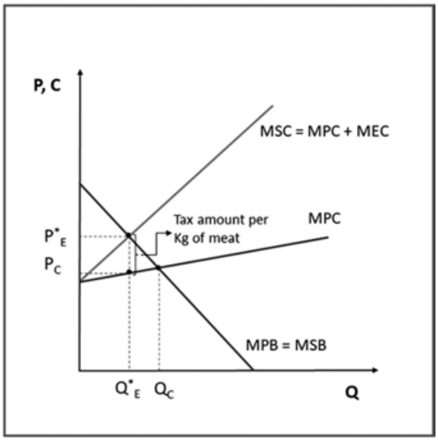

Figure 7.8 Product tax on meat produced

the MSC from the consumption of meat is higher than the consumers' marginal willingness to pay (which is given by the MPB and MSB curves). Therefore, a welfare loss manifests from output level Q_C, shown by the shaded triangle, due to the overconsumption of meat. To reach the socially optimal equilibrium Q_E^*, that is, where the MSB curve intersects the MSC curve, a tax per kilogram of meat, namely a product tax, can be levied.

Figure 7.8 illustrates the introduction of a product tax. Both axes in this graph remain the same as before. The product tax is in our example the tax charged per kilogram of meat that is produced, and it is set equal to the difference between the MSC and MPC at the desired quantity, that is, it should be set equal to the marginal environmental cost MEC. For example, to achieve the optimal equilibrium represented by the point (P_E^*, Q_E^*), the tax should be set equal to the amount shown in the diagram. The imposition of this tax will ensure that the equilibrium quantity is determined by the intersection of the MSB and MSC curves because firms will respond to this tax by reducing their output such that their supply curve will align with the MSC curve.

Generally, the use of a product tax can create two problems. First, it is difficult to identify the value of the MEC at output level Q_E^*. Second, the use of a product tax in a situation in which firms can substitute inputs and therefore invest in abatement technologies to reduce the use of fossil fuels is not efficient because it doesn't provide incentives to reduce pollution. Therefore, with a product tax, the only way to reduce pollution is by reducing the output. In general, this is an unrealistic assumption. However, in a situation characterised by a fixed-proportion production function, implying that no input substitution is possible, a product tax is efficient. Input substitution is, in most circumstances, possible. For example, a producer of meat could reduce the level of emissions, by improving energy efficiency, feed quality as well as cattle diets, or by using improved management practices such as rotational grazing. However, even in case the producer can reduce the pollution by investing in new production processes, with a product tax imposed per unit of meat produced, the producer will continue to pay the same amount of taxes, even though it has reduced the amount of emissions per unit produced. Therefore, even with the possibility to substitute inputs, there is no significant incentive to reduce emissions.

7.2.1.3 Pollution Tax

In the case of a pollution tax based on emission levels, the tax is imposed directly on the pollution instead of being imposed on the output produced by the firm. This is more efficient, as the output is not directly affected, and the polluting firm's response is not restricted to an output reduction. Producers can reduce pollution by changing the combination of inputs used, through investments in abatement technologies or in energy efficiency, for example. The cost of reducing the amount of pollution produced (through these investments) is called an abatement cost. Alternatively, firms might choose to continue to pollute in response to the tax and decide to pay the tax instead of investing in abatement equipment. The decision regarding which costs will be taken on, and how much taxes are paid, depends on the marginal abatement cost (MAC) curve; the MAC is defined as the incremental increase in abatement costs due to incremental increases in abatement levels. At the firm level, these MACs are increasing in the levels of abatement, and are graphically represented by an upward-sloping curve in the space with abatement (A) on the horizontal axis and cost (C) on the vertical axis as depicted in Figure 7.9.

To understand how an emissions-based tax works, consider a simple example of an economy with a coal power plant that produces a constant quantity of electricity. This scenario is shown in Figure 7.10. The maximum level of abatement that can be achieved in this society is given by the level A_{E0}, that is, this is the amount of abatement needed to reach zero emissions from the coal power plant for a given level of output (for instance, using a carbon capture and sequestration (CCS) technology). However, from society's point of view, the optimal amount of abatement is reached at A_{E^*}, and not necessarily at A_{E0}. The reason for this is that the reduction in the level of pollution to zero is too costly relative to the benefits of this reduction. The level

Figure 7.9 Marginal abatement cost

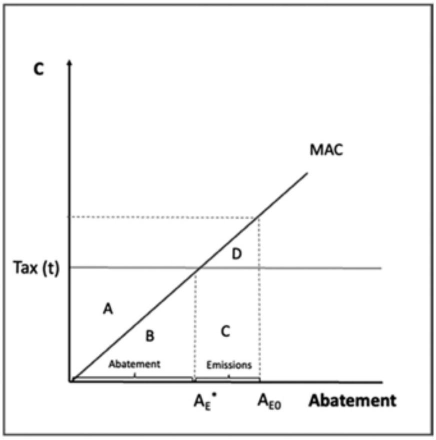

Figure 7.10 Emission tax

of optimal abatement is determined at the aggregate level (as we will discuss next) and reflects a situation where the MACs of all polluters are equal to the MSB from reducing pollution.

Now, consider the introduction of a pollution tax, set at the level 't' shown in the graph. In the situation that the firm decides to undertake zero abatement after the introduction of the tax, it would need to pay the full tax burden to the state, and this is given by the sum of areas A, B, and C in Figure 7.10, that is, the areas under the tax curve, up to the level of total emissions released by the firm (which is the horizontal quantity A_{E0}, in the zero abatement case). However, the more likely scenario is that the firm abates some pollution, right up to the point where each additional unit of abatement just starts to become more expensive than paying the tax, that is, the firm will choose to abate at the level A_{E^*}. In this case, the total abatement cost is given by the area under the MAC up to the level of abatement (area B in the graph), and the total tax burden is given by the area under the tax curve, corresponding to the total emissions (area C). Thus, it becomes clear why it is in the firm's interest to invest in abatement, as total costs are lower (total costs = $B + C$) than if the firm were to choose to not abate at all (total costs = $A + B + C$). Consequently, the firm abates this portion of its emissions (until A_{E^*}), but not more. This is due to the fact that for an additional unit of abatement to the right of this point A_{E^*}, the cost of abatement (the area $C + D$) is higher than the tax cost (C), so this portion of pollution will not be abated by the firm.

In Figure 7.11, we now explain how the optimal level abatement A_{E^*} is determined at the aggregate level. As shown, we can plot price or cost on the vertical axis and abatement levels on the horizontal axis. The curve MAC_{AGG} is the aggregate MAC function, and it is obtained by horizontally summing the firm's individual MAC curves. This is the curve which captures the abatement costs of all firms in society, which are increasing in levels of abatement. The downward-sloping MSB_{AGG} curve is the aggregate marginal benefits function, and it represents society's demand for environmental quality. It is measured as the value of damages or costs associated with

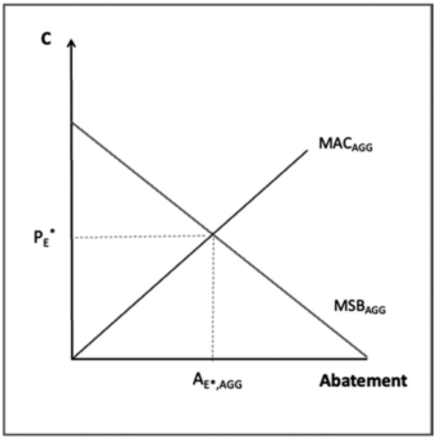

Figure 7.11 Emission tax at the aggregate level

pollution, and this can be expected to decline as levels of abatement increase. When abatement is low and emissions/pollution levels are high, society's marginal benefit from a unit reduction in pollution is high, but it decreases with increased abatement. The optimal level of abatement at the aggregate level is thus reached at $A_{E^*,AGG}$, where the curves for the two functions (MAC_{AGG} and MSB_{AGG}) intersect, and this represents the allocative efficient equilibrium for the economy.

Assuming that all firms have the same MAC curves, then the optimal level of abatement illustrated in Figure 7.11 can be reached by equal abatement, defined by $A_{E^*,AGG}$ divided by the number of firms (n), that is, $A_{E^*} = A_{E^*,AGG}/n$. This is the approach to derive the value of A_{E^*} that we plotted in Figure 7.10.

The model can also be extended to include more than one firm with different abatement costs. Consider the simplest case of two firms. In Figure 7.12, two distinct MAC curves for the two individual firms, MAC_1 and MAC_2, are shown. The primary vertical axis represents the costs and benefits for Firm 1, corresponding to the origin point a. Thus, MAC_1 represents increasing MACs for Firm 1, as total abatement levels (with respect to origin a) increase. Likewise, MAC_2 is drawn with respect to the origin for Firm 2, which is denoted by point b, and the secondary vertical axis denotes the costs and benefits for Firm 2.

Now assume that the total emissions by these two firms are 20 units of pollution. If the government finds, after doing a cost–benefit analysis, that the environment can assimilate no more than 10 units of pollution, a total abatement of 10 units would be needed in the economy. These 10 units are shown in the graph as the distance between a and b, that is, the total emissions required to be abated. Assume once more that output levels shall not be changed to reduce emissions. If the state wants to achieve minimum costs of abatement for the 10 pollution units, it should not ask the firms to each abate 5 units. Instead, the most efficient solution is the introduction of a tax set at level t, where MAC_1 and MAC_2 intersect.

Firm 1, with a relatively flatter MAC curve, experiences smaller increases in abatement costs than Firm 2, for each additional unit of abatement. Its total abatement cost,

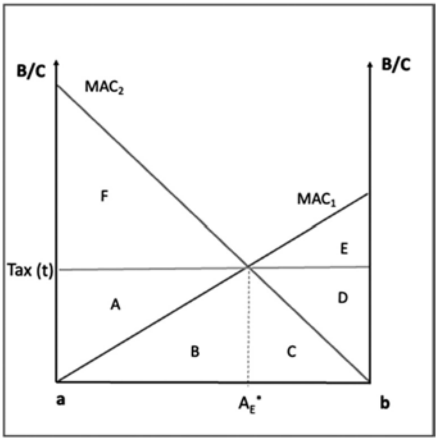

Figure 7.12 Equilibrium abatement with an emission tax

if it were to abate the maximum of 10 units in the absence of a tax, would be the sum of areas B, C, D, and E, or the area under MAC_1. This is lower than the total abatement cost of Firm 2 (which is $F + A + B + C$, or the area under MAC_2). Therefore, societal costs are minimised if Firm 1 abates more than Firm 2. The optimal tax level to achieve this goal is set at the price level given by the intersection point of the two MAC curves (A_{E^*}).

The principle that helps us to identify the appropriate tax level is known as the equi-marginal principle, which states that at an allocative efficient equilibrium, MACs must be equalised across all firms. At this tax rate, the total abatement cost of Firm 1 is given by area B, whereas it pays area $C + D$ as tax. Likewise, the total abatement cost of Firm 2 is given by area C, while the tax revenue obtained from it is given by $A + B$. Thus, total tax revenue in this simple economy is $A + B + C + D$, while the total abatement costs are $B + C$. The total costs to society, in this case, are lower than if the firms would have abated 5 units each with no tax introduced.

So far, the discussion about the introduction of a pollution tax has concentrated on the abatement strategy and costs to the firms determined by the introduction of the tax, assuming that the level of production remains the same. It is likely, that the introduction of a pollution tax, as we illustrated in Figure 7.10, leads to an increase in the production costs for firms, because of investment in abatement, as well as the payment of the tax. Note that this increase may also be neutralised if the investment in new abatement and production technology gives the firm the possibility to produce the same amount of output at the same cost, or at a lower cost. In case of an increase of the production cost due to the pollution tax and abatement costs, we can expect a shift of the supply function on the market of the good produced by the firms to the left. This shift will then increase the price, similar to the effect of the product tax, and reduce the demand and supply of the good. On the other hand, if the increase in cost is mitigated by investment in new and less polluting technology, the supply function need not shift, and the output will remain at the same level.

For instance, in the case of meat consumption, if the producers are able to adopt better management practices, implement improved diets for cattle, etc. without incurring significant costs, then the MECs represented in Figure 7.7 will have a lower slope, and the MPC function will remain the same. In case of an increase in costs, the MPC function will shift upwards.

7.2.1.4 Energy Tax

Some countries have introduced a tax on fossil fuels, that is, a so-called energy tax, based on the assumption that there is a roughly proportional relationship between the quantity of the fuel used and the corresponding emission levels. The tax is imposed on each unit of polluting fuel (fossil fuels) used, with the tax rates varying according to the type of fuel. Fuels that pollute more per unit used are taxed higher; this implies higher tax rates for coal and oil, with lower rates for natural gas and uranium. Non-polluting renewable energies are either taxed at very low tax rates or tend to benefit from tax exemptions.

An energy tax is thus a type of policy that incentivises economic agents to reduce energy demand by consuming less due to behavioural changes, and by investing in more energy-efficient technologies. In the latter case, the energy tax incentvises the economic agents to change the combination of inputs and adopt new energy-efficient technologies. In this regard, the economic analysis of the effects of an energy tax is similar to that of a pollution tax. However, an energy tax, as discussed previously, by inducing a reduction of energy consumption, will promote the security of supply. Furthermore, some countries have introduced an energy tax on gasoline and diesel to finance the construction and maintenance of highways and roads. This last type of energy tax is not a direct energy policy instrument, because it is not oriented to any energy policy goal. However, such a tax can indirectly help in reaching these goals.

In Figure 7.13, we will present how an energy tax can promote investment in energy efficiency that implies a substitution of energy with capital. The figure shows the mechanisms driving the adoption of energy-efficient technologies for an economic agent. We can use this to think about investment in energy-efficient cars energy-efficient cars (EECs), buildings, or in heating systems.

The graph plots the level of energy efficiency (EE) (and equivalently, the decline in energy consumption) on the x-axis and the costs and benefits of investing in energy efficiency on the y-axis. The two downward-sloping lines represent the MPB and the MSB curves. The MPB curve represents the private benefits from the reduction in energy consumption (which also implies a reduction in private energy expenditures) obtained by increasing the level of energy efficiency by using more efficient technologies. This curve represents the demand function for the level of energy efficiency. The MSB additionally considers the presence of a positive externality in improving energy efficiency levels, thus is represented as the sum of the MPB and marginal external benefits (MEB). The positive externality of investing in energy efficiency takes into account the reduction in air pollution and the resulting improvement in energy supply security. In this graph, we also plot the upward-sloping marginal energy reduction cost (MERC) curve. The MERC curve indicates the increasing marginal costs of improving

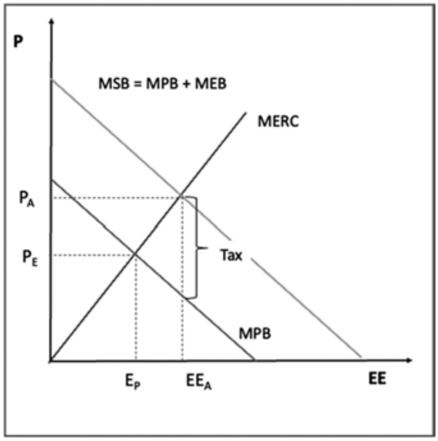

Figure 7.13 Introduction of an energy tax on the market for energy-efficient technologies

energy efficiency and reducing energy consumption. If no positive externalities are considered, the private optimum is reached at the level of energy efficiency denoted by E_P. However, since there are positive externalities associated with any type of energy efficiency improvements, economic efficiency is reached at EE_A where the MSB curve intersects the $MERC$ curve.

To reach an efficient level of energy efficiency, the state could introduce an energy tax that will shift the MPB curve to the right, as the benefits from adopting energy-saving behaviour increase due to the imposition of this tax. A unit reduction of energy implies lower energy expenditures as well as lower tax expenditures.

Of course, the introduction of an energy tax will also have an impact on the market for the energy source that is taxed and not only on the market for energy-efficient technologies. In this case, an energy tax that the producer will pay will shift the market supply function upwards and to the left. Therefore, the equilibrium price on the market for the energy source, for instance, heating oil, will increase and the quantity will decrease, as we described earlier for the product tax.

7.2.1.5 Benefits and Challenges of Environmental and Energy Taxes as Policy Instruments

Economists tend to favour environmental and energy taxes over other instruments, as they tend to promote economic efficiency more than other instruments. Some benefits of these types of taxes are:

- They maintain the freedom of economic agents to allocate their resources as they wish.
- The overall cost of achieving pollution and energy use reduction is minimised.
- Polluters pay for the damages incurred or the negative externalities (polluter-pays principle).
- Incentives for the development and adoption of less polluting and less energy-consuming products and technologies are created.

While many governments have adopted environmental and energy taxes as policy instruments, there are some challenges with the use of taxation to address market failures:

- It is difficult to know the MAC of pollution, the MERC, and the MSB of reducing pollution or energy use for economic agents.
- In the presence of MSBs that are heterogeneous across economic agents and regions, the introduction of a uniform tax can lead to economic inefficiency.
- Implementing taxes based on environmental performance (for example, the pollution quantity) needs to introduce a system to monitor the emissions and enforce the regulation, both of which can be difficult and costly, especially in developing countries. This is not relevant in the case of the energy tax, because it is more straightforward to measure energy consumption.
- Political pressure by large firms as well as general public dissatisfaction with paying taxes may dissuade policymakers from adopting taxes as instruments, and lead to a lack of will to implement taxation policies.
- Due to their distributional implications, taxes are generally less acceptable than other policy instruments. An additional challenge is related to deciding how to use the tax revenue. There are several possibilities to recycle this revenue, such as financing direct transfers to reduce other taxes, promoting innovation in green technologies, as well as compensating people affected by the externality.

7.2.1.6 Environmental Tax Reform

Environmental taxes may be introduced in an economy through a reform of the tax system. Consequently, several countries around the world have implemented the so-called environmental tax reform (ETR). The European Environment Agency defines an ETR as a 'Reform of the national tax system where there is a shift of the burden of taxes from conventional taxes such as labour to environmentally damaging activities, such as resource use or pollution' [98]. In practice, this means that taxation is shifted from goods such as labour (e.g., by a reduction in income taxes or in social security contributions) or capital (e.g., by a reduction in corporate taxes) to bads (e.g., implementing taxes on fossil fuels, air pollution, etc.). These reforms are said to be revenue-neutral, that is, governments do not retain any of the tax revenue earned from taxing the bads. In addition to reducing income taxes and social security contributions, as discussed previously, governments might use additional revenue to compensate affected groups and introduce incentives for achieving both environmental improvements and technological change. This reform can also be partial, that is, only some bad resources such as specific fossil fuels may be taxed. For instance, a government could decide to introduce a reform that foresees the introduction of a CO_2 tax on gasoline with redistribution of the revenues.

The benefits that can materialise out of such reforms can take different forms. The double-dividend hypothesis suggests that environmental tax reform can produce:

- A first dividend: an improvement in environmental quality, due to lower emissions

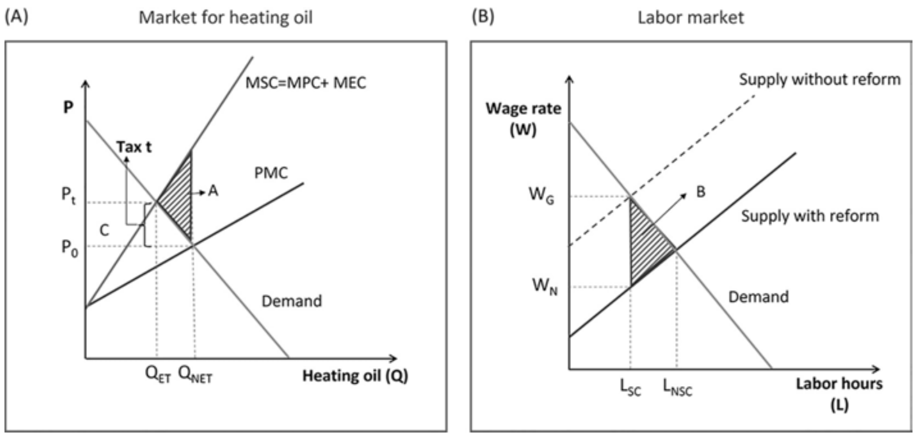

Figure 7.14 Environmental tax reform

- A second dividend: an increase in overall economic efficiency through the reduction of distortionary taxes such as income taxes that may manipulate labour and savings decisions

Figure 7.14A and B illustrate the notion of the double-dividend hypothesis associated with environmental tax reforms, using a simple example. Figure 7.14A, the market for a polluting good (for example, heating oil) is shown with output levels on the x-axis and price levels on the y-axis. On this graph, we also see the marginal private cost curve (MPC) and the marginal social cost curve (MSC) that are obtained by adding the MEC to the MPC. Figure 7.14B represents the labour market with total hours worked on the x-axis and wages on the y-axis. On this graph, we observe the individual labour supply function, as well as the demand of the firms for labour. The dotted labour supply curve that is shifted up takes into account the social security contributions that employees have to pay. The payment of social security creates a deadweight loss represented by area B.

If an environmental tax 't' is introduced in the market for heating oil, the optimal output-price combination, from a societal point of view, is reached (P_t, Q_{ET}). By implementing the tax, the policymaker effectively eliminates the dead-weight loss associated with the negative externalities (shown in the figure by triangle A) and achieves a reduction in heating oil use from Q_{NET} (the quantity without any environmental tax) to Q_{ET} (the quantity with an environmental tax). This also represents the first dividend of environmental tax reform.

The introduction of an environmental tax generates revenue (shown by rectangular area C in Figure 7.14A), which then allows the government to reduce individual social security contributions in the labour market (represented by the difference between W_G (the gross wage) and W_N (the net wage) in the diagram). Therefore, employees have the incentive to increase labour supply from L_{SC} (their labour supply when they had to pay social security contributions) to L_{NSC} (the labour supply without having to pay for these social security contributions). The lowering of these contributions on labour implies that the dead-weight loss area B in Figure 7.14B will also be eliminated, as workers increase their labour supply to L_{NSC}. This constitutes the second dividend of environmental tax reform. Thus, both sources of dividends can be effective in improving economic efficiency in the energy transition.

Environmental taxation and the double dividend hypothesis in CGE modelling literature: a critical review

Within the economics literature, there is a general consensus that environmental tax reform results in an improvement in environmental quality, whereas evidence on the second dividend is slightly weaker. Gonzalez (2018) [99] provided a meta-analysis of some economic studies that have tested the double-dividend hypothesis, and argued that while almost all the studies in the sample found that environmental taxation improved environmental conditions, an augmentation of economic efficiency was only observed in about 55 per cent of the cases, whereas it was not observed in the remaining 45 per cent. Thus, while there is some evidence to suggest that the double-dividend hypothesis may materialise under some conditions, it still remains ambiguous whether there are economic efficiency improvements in response to environmental taxation.

On the distributional impact of a carbon tax in developing countries: the case of Indonesia

Yusuf and Resosudarmo (2015) [100] analysed the distributional impact of a carbon tax imposed on energy sources such as kerosene, natural gas, coal, gasoline, and automotive diesel oil using a computable general equilibrium model. The authors conducted the analysis for highly disaggregated groups of households in Indonesia. They found that the carbon tax in Indonesia was likely to be a progressive instrument because the allocation of resources and structural changes arising from the carbon tax favoured low-income and rural households. This progressivity arises due to the fact that currently, households living in rural areas and belonging to the agricultural sector are less likely to consume gasoline, diesel, kerosene, etc., due to underinvestment in durables. This underinvestment also explains the low sensitivity of these households to price variations. The progressive impact of the carbon tax was also shown by the expansion of the service and agriculture sectors and the contraction of the manufacturing sector, which is highly energy-intensive.

7.2.2 Subsidies

Another pivotal instrument used to address both energy and climate-related issues is subsidies. Section 7.3 will provide an overview of how subsidies can be used in the framework of energy and climate policy. In general, such subsidies are implemented to encourage the adoption of energy-efficient technologies, to promote the use of renewable energy, or public financing of investment in adaptation to climate change that has a local public good character (public financing would be equivalent to a 100 per cent subsidy). Subsidies can also be used to make energy more affordable. Some examples of subsidies are:

- Subsidies to buy energy-efficient electrical appliances or cars
- Subsidies to build energy-efficient houses
- Subsidies to renovate houses with the installation of energy-efficient technologies
- R&D subsidies to promote innovation in new environmentally friendly and energy-saving technologies, for example, in renewable energy technologies
- Subsidies to promote the adoption of solar panels and wind turbines, etc.
- Subsidies to finance adaptation measures that have a local public good character, such as storm surge walls to prevent flooding, green shading of areas in urban localities, etc.

Such subsidies, by effectively reducing costs and prices, can lead to higher levels of adoption of energy-efficient technologies, renewable energies, or supply of local public goods that would otherwise be underconsumed or underprovided in a free market economy. Governments can also introduce subsidies to make energy consumption more affordable, especially for low-income households, which is a goal of energy policy.

7.2.2.1 The Justification for Using Subsidies

From an economic point of view, the introduction of subsidies can be justified as a means to improve economic efficiency in one of three cases. First, subsidies are justifiable in the presence of positive externalities linked to the adoption of new sustainable technologies (that can help with air pollution reduction, or in increasing the security of energy supply) as well as of potential positive spillovers of knowledge from first adopters of this sustainable technology to later adopters. Second, the presence of behavioural anomalies such as bounded rationality and bounded willpower related to the use of energy-efficient technologies or renewable energy might also warrant the use of this policy instrument. The third justification for using subsidies is related to climate policy objectives and, more specifically, to promote investment in adaptation measures. These measures tend to have the characteristics of local public goods. For instance, consider dikes to reduce the risk of flooding. In this case, a subsidy could promote the construction of such projects.

As previously mentioned, governments can also introduce subsidies to make energy consumption more affordable, that is, they can use this instrument for equity-related reasons, and not necessarily as a means to improve economic efficiency. For instance, due to the substantial increase in energy prices in Europe in 2022, mainly due to the war between Russia and Ukraine, several European governments decided to subsidise gasoline and diesel (by reducing the taxes on these fuels that were previously collected to finance the maintenance of the road systems or to fund other public expenditures). From an economic point of view, this approach may be inefficient for two reasons. First, the price will no longer equal the marginal cost and this is a source of economic inefficiency. Second, given that all households that own a vehicle receive a discount on gasoline and diesel prices, irrespective of their income or wealth, this creates an inequitable outcome. A better solution could be to introduce a direct subsidy to make energy consumption more affordable only for households that belong to the low-income classes.

7.2.2.2 How Subsidies Work: An Illustration

Figure 7.15 represents the market for investment in energy-efficiency technologies, and is similar to Figure 7.13. In this case, we represent the market for efficient cars with the quantity of EECs plotted on the horizontal axis and the price plotted on the vertical axis. This market is illustrated with the help of the MERC function, an MPB function, and an MSB function which reflect the benefits from the society's point of view. In this context, MEB is the marginal external benefits function. The external benefit is arising mainly because of the reduction in pollution due to the higher level of energy efficiency of EECs, the sharing of experience in using new and relatively unknown technology, and an improvement in the security of supply. In the absence of a subsidy for EECs, equilibrium is denoted by the combination (P_E, E_P). In this case, consumers are underpurchasing EECs because the optimal number of cars from the society's point of view (that considers the external benefits) is higher than E_P.

Now, consider the situation in which a policymaker decides to implement a subsidy to increase the adoption of EECs. The introduction of this subsidy has the intended effect, as shown in the figure, of moving the equilibrium point to (P_A, EE_A), also known as the allocative efficient equilibrium, by shifting the private demand curve to the MSB curve. If the subsidy is set to equal the MEB (as is the case at EE_A), an efficient equilibrium from the society's point of view is achieved, and this level of subsidy is called a Pigouvian subsidy. Thus, the introduction of a subsidy results in the internalisation of the positive externalities. Unfortunately, it is often difficult to measure the benefits to society from the use of a good (the MEB, as illustrated in Figure 7.15), which is a necessary first step to determine the optimal level of the subsidy.

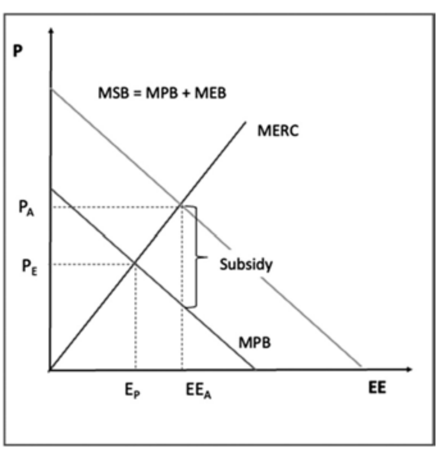

Figure 7.15 Introduction of a subsidy

The impact of policy awareness: evidence from Vehicle choices response to fiscal incentives

Switzerland is a federal state, with twenty-six provinces called cantons. These cantons are relatively independent in terms of the energy policies they implement. Some cantons have developed policies to promote the use of EECs and have introduced a so-called 'bonus-malus' system for the annual vehicle registration tax. This system consists of an adjustment of the annual registration tax, depending on the environmental impact (or fuel efficiency) of the car that is calculated using a specific metric. Owners of relatively inefficient cars need to pay a higher tax (a malus), whereas owners of relatively efficient vehicles receive a subsidy or bonus on this tax, that is, they need to pay a lower tax. In some cantons, thresholds on CO_2 emissions of cars are used to determine whether a vehicle is eligible for a bonus. In other cantons, vehicles that have received a high-efficiency rating, based on the energy label, receive a bonus.

Energy labels for vehicles typically provide energy-efficiency ratings for different models, that vary from A (most efficient) to G (least efficient) based on the fuel consumption of the cars. The bonus-malus system is an example of a policy instrument to enhance the adoption of EECs, and it works by providing a rebate on the owed registration taxes for relatively more EEC models. Naturally, its effectiveness as a policy tool depends at least partially on the level of awareness of economic agents about the policy and what it entails. A study by Cerruti et al. (2023) [101] has shown that consumer awareness of the existence of the bonus-malus system is relatively low. Accordingly, the effectiveness of such policies may often be hampered. Therefore, the authors of the study conclude that communication, as well as education on the presence of the bonus-malus system, is important to ensure its success, as economic agents may otherwise be oblivious to these benefits while making their investment decisions.

7.2.2.3 Subsidies to Promote the Adoption of Renewable Energy

As we discussed in Chapter 1, the promotion of the production of electricity using renewable energy sources (such as solar and wind) is an important pillar of the energy transition. In this context, several countries have introduced a subsidy policy to encourage investment in these renewable sources. In this subsection, we briefly present two types of subsidies, that is, initial grants and the FiT, which are used to promote the installation of solar photovoltaic (PV) panels.

- Initial subsidies/investment grants can be provided to producers of renewable energy, which may depend on the capacity of the renewable installation. This type of subsidy is particularly useful for households or firms that are more responsive to the upfront costs, rather than the lifetime costs, of technologies.
- A FiT is another form of subsidy which ensures that renewable energy producers receive a fixed price for the extra electricity that they produce (over and above the energy used for self-consumption) and feedback to the grid (which is known as a net FiT), or a fixed tariff that is paid for the total amount of electricity generated

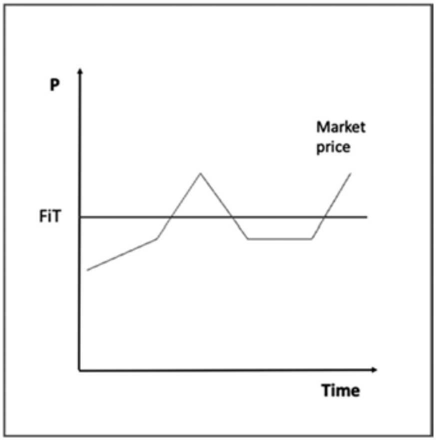

Figure 7.16 Fixed price feed-in-tariff

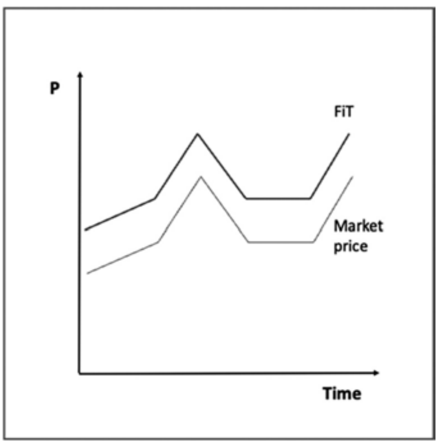

Figure 7.17 Non-variable premium price feed-in-tariff

and sent to the grid if they are obliged to sell all of it to the local distributor (gross FiT).

There are three main types of FiTs, that are illustrated in Figures 7.16 to 7.18:

1. Fixed-price FiT – the total FiT payment is fixed and remains independent of the market price as shown in the first graph (normally, it is also guaranteed for a long time, even up to 15–20 years, depending on the life-cycle of the technology). In this graph, we present time on the horizontal axis and prices on the vertical axis. The fixed tariff is set at the level shown (FiT). On the same graph, we also plot the market price, which on average is lower than the FiT. For example, the German government implemented a fixed price FiT in 2000 that guaranteed energy producers a payment per kilowatt hour for all quantities of electricity generated from renewable energy for a fixed period (generally 20–25 years). Other countries, such as Canada and France, and developing countries such as Ghana, have also implemented this system.

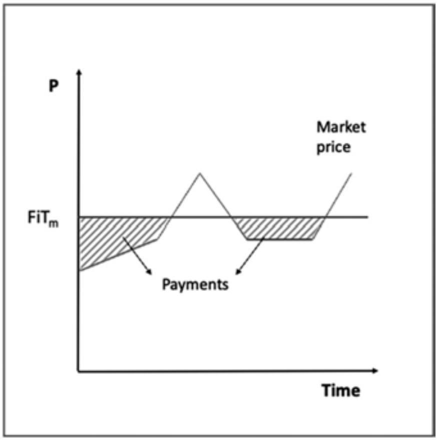

Figure 7.18 Variable premium price feed-in-tariff

2. Non-variable premium FiT model – in this model, an additional payment ('premium') is paid on top of the spot market electricity price to developers. The developer then receives payment for the total electricity generated (at market prices) and, in addition, a constant FiT payment, as is illustrated by the two parallel lines in the second graph. Examples of countries that have implemented this policy are Spain, Slovenia, Czechia, and the Philippines (although these countries have also offered a fixed price FiT).
3. Variable premium price FiT model – projects are guaranteed to receive a minimum total payment (shown in the third graph below as FiT_m). When the prevailing spot market electricity price is lower than this minimum threshold, the developer receives the difference between FiT_m and the market price. If the price is higher than this threshold, the developer will just receive FiT_m. In the figure, we can see the level of FiT_m, the evolution of the market price over time, and the shaded regions represent the total payments received by the developer when the spot price is lower than FiT_m. This type of FiT has been used in the Netherlands and in Finland.

7.2.2.4 Challenges with Using Subsidies as Instruments

Subsidies are a very popular and well-accepted policy instrument (understandably so, more than taxes). However, there are some issues that should be considered in the choice of this instrument. For instance, subsidies may tend to bias a consumer's decision on how best to reduce their energy consumption. This might result in a sub-optimal deployment of economic resources, with the possibility of consumers getting locked into certain technologies, and not shifting to newer ones. This might lead to inefficient solutions, depending on how the market for energy efficiency or renewable technologies develops. Finally, there is also the possibility that governments hand out subsidies to producers or consumers who would have adopted the technology anyway, even without being given the subsidy. This is yet another example of an inefficient market outcome that may arise with the use of subsidies as a policy instrument.

To conclude, subsidies are attractive policy measures that can be used to reach various goals. However, the design and implementation of these policy measures should be done carefully, to avoid reducing their effectiveness and to bring out the economic advantages of using these instruments.

7.2.3 Pollution Permit Trading Systems

In this section, we present the last monetary market-based policy instrument, namely the market for pollution permits, also known as a cap-and-trade pollution permits system. In this framework, the government decides to regulate the level of emissions, for instance, the level of GHG emissions (mostly CO_2), by issuing and allocating pollution permits across polluters and allowing them to buy and sell unused permits among each other. Such a pollution permit trading system establishes a market for the rights to pollute, with the help of tradable pollution allowances. A well-known example of a permit trading system is the EU Emissions Trading Scheme (ETS) for CO_2. Note that this policy instrument can also be used to promote the adoption of renewable energy sources, or to promote energy efficiency. In this case, for example, the state can define a general target for the number of renewables produced by electricity companies, and assign individual targets for these companies. Firms have the flexibility to deviate from this target, by buying or selling renewable energy certificates on a market. The functioning of this market for renewable certificates is similar to that of the market for pollution permits. In this chapter, we will focus on the latter, because they are more commonly used.

> **Can carbon emission trading scheme achieve energy conservation and emission reduction? Evidence from the Iindustrial sector in China**
> Hu et al. (2020) [102] explored the impact of the 2011 CO_2 ETS pilot policy in China on emissions reduction and on the conservation of energy. For the econometric analysis, they used province-level panel data on industries between 2005 and 2015. The results of the analysis confirmed that regulated industries achieved a reduction in energy consumption and CO_2 emissions by 22.8 and 15.5 per cent, respectively, when compared to the areas where the pilot was not conducted. These results mainly arose due to industrial structure adjustments and increases in technical efficiency. The authors thus argued that using market-oriented environmental policies to tackle environmental challenges may be effective in developing countries as well, and highlight the importance of monitoring and tracking the sources of pollution and obtaining accurate information regarding pollutant emissions.

7.2.3.1 Functioning of the System

A cap-and-trade system for pollution permits consists of two main components:

- A fixed number of permits that are issued based on a target pollution level/accepted level of emissions, that is set by the government
- A market in which these permits can be traded

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The implementation of the system follows several steps. These are:

1. Setting the total pollution allowance (also known as the cap); for example, the total CO_2 emissions target that is optimal for society.
2. Allocating permits between polluters.
3. Allowing the permits to be freely traded.
4. Monitoring individual pollution levels and imposing a (sufficient) penalty for any infraction. No polluter is allowed to emit more pollution than it has acquired permits for.

In step 2, permits may be auctioned off (in an auction-based system) or issued for free (a so-called grandfathering system). In an auction, several allowances based on the total abatement target of an economic system are auctioned to bidding polluters. This process generates additional revenue for the government, unlike the grandfathering approach, in which each polluter receives allowances based on their past pollution levels or based on an egalitarian principle after a share is subtracted to meet the overall emission target. The advantage of assigning the permits through an auction is that the revenue stream obtained with the auction can be used to fund R&D activities, to compensate economic agents affected by the pollution, or to finance policy measures such as subsidies for renewable energy sources or energy efficiency.

The functioning of a cap-and-trade system can be represented in the simplest case of two polluting firms. In Figure 7.19, two distinct MAC for the two individual firms are shown, MAC_1 and MAC_2. The primary vertical axis represents the costs for Firm 1, corresponding to the origin point a. Thus, MAC_1 represents increasing MACs for Firm 1, as total abatement levels (with respect to origin a) increase. Likewise, MAC_2 is drawn with respect to the origin for Firm 2, which is denoted by point b, and the secondary vertical axis denotes the costs for Firm 2.

Now, assume that the total CO_2 emissions by these two firms are 20 units and a total abatement of 10 units is necessary to reduce the negative effects of the CO_2 emissions. In this situation, the government decides to put a cap of 10 units of emissions. These

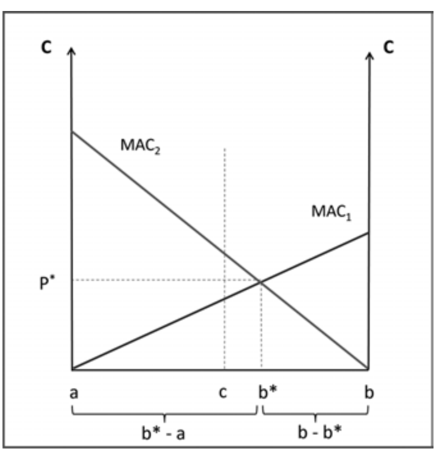

Figure 7.19 A cap-and-trade system

10 units are shown in the graph as the distance between *a* and *b*. Suppose now that the state introduces a cap-and-trade system to obtain a reduction of 10 pollution units. As we have seen, in this system, the government can decide to allocate permits either through an auction, or distribute an equal number of permits to firms, or use some other criteria. Assume, for our example represented in Figure 7.19, that permits are distributed equally between the two firms (denoted by point *c* in the figure).

After receiving the permits, the firms can start producing, and simultaneously making investments to lower emissions. Given the difference in their MACs, Firm 1, characterised by having lower marginal costs, might consider selling some of the permits to Firm 2, with higher MACs. This trade would potentially benefit both firms across all quantities where the MAC of Firm 1 is lower than the MAC of Firm 2. In this case, for Firm 2, it is cheaper to buy permits from Firm 1, as long as the price of the permit is lower than its marginal cost and higher than the marginal cost of Firm 1. As can be seen from the figure, the process of bargaining and trading permits, even after initially distributing them equally, leads to a price (P*) and quantity equilibrium (b*) that corresponds to the point where MAC_1 and MAC_2 intersect.

In this situation, Firm 1 will invest in abatement technologies to abate b*-a units of CO_2, use permits equivalent to the distance (b*-b) to pollute, and sell (b*-c) worth of permits to Firm 2. Firm 2 will abate a lower amount of CO_2 emissions (b-b*) because its MACs are higher than those of Firm 1. It will buy permits from Firm 1 to pollute for the quantity b*-c, at the price P^*. Note that in this simple example, the most efficient solution could also be reached with the introduction of a tax set at the level of the equilibrium price P^*, where MAC_1 and MAC_2 intersect. This implies that a pollution tax is equivalent to a cap-and-trade system in a very simple economic system. However, these two policy measures are not identical in a more realistic economic scenario, with several sectors and several economic agents, as well as in the presence of uncertainty.

The pollution permit trading system is mainly used to internalise negative externalities due to GHGs by industrial sectors. For the implementation of this system, the government can use an upstream emission source approach, that is, the cap-and-trade system is introduced for fossil fuel producers, transporters, petroleum refineries, and other firms that create emissions, or a downstream approach, which implies that the level of emissions is regulated at the point of emissions (such as at the power plants that use fossil fuels).

The upstream approach is generally easier to implement than the downstream approach because the number of firms is normally fewer at that stage. If one were to consider the inclusion of households into such a system, that would further complicate the implementation and functioning processes and increase the administrative costs (including the cost of organising the market and monitoring/compliance). One important advantage of the downstream approach is that the price increase in fossil fuels brought about by the cap-and-trade system is directly passed on to the economic agents, namely firms and households, when they make investment and consumption choices. The price signal is thus more salient and immediate in the downstream approach than in the upstream approach. Economic literature suggests that consumers and firms tend to react more to price changes arising due to the introduction of an environmental tax, for example, if this were apparent to them. This may be due to the presence of behavioural anomalies.

Role of salience

The role of the salience of policy instruments such as taxes has been explored in different contexts. In a study, Li et al. (2014) [103] showed, using national data from the US, that increasing gasoline taxes were associated with consumers reducing gasoline consumption more than a comparable increase in gasoline prices. For instance, the authors found that a USD 0.05 increment in the gasoline tax led to a reduction in gasoline consumption by 0.86 per cent, which they argued was much larger than the effect found by not separating gasoline prices into tax and tax-exclusive components. Thus, consumers are more likely to respond to tax increases that are visible, rather than to pre-tax price increases. This has been shown in another context (unrelated to energy or climate) by Chetty et al. (2009) [104], who used an experimental approach at a grocery store to highlight the salience of sales tax in consumer purchase decisions. They found that including the sales tax in the posted price of some products, as opposed to consumers only learning about the amount of tax when they later paid at the cashier, resulted in them making correct calculations of the total price of a basket of goods. These studies pinpoint that with policy instruments such as taxes, it is important to make consumers aware of them when they make their choice, in order to distil an optimal response.

7.2.3.2 Advantages and Disadvantages of Tradable Permits Compared to a Pollution Tax

A pollution tax and a cap-and-trade system are similar market-oriented policy instruments. Both introduce a pollution price and, therefore, a monetary incentive to reduce pollution. The main difference between these two methods to internalise negative externalities is in the way that the pollution price is set, and the mechanism used to define the level of emissions reduction. In a cap-and-trade system, the price for emission allowances is determined by the emission trading system, and a limit on emissions is set by the government (the cap), whereas the pollution tax is set by the government, and in this case, no limit on emissions is defined.

Both systems have advantages and disadvantages. For instance, a cap-and-trade pollution permit system allows governments to define and reach a goal in terms of the quantity of emissions reduction. Therefore, there is certainty on the allowed emissions, which also enables easier estimation of the benefits that can be accrued by the emissions reduction. However, the cap-and-trade system provides less certainty regarding the price level of the pollution permits. Pollution taxes, on the other hand, result in a high degree of certainty about the price level, but induce uncertainty about the quantity of emissions that will be reached, because this depends on the reactivity of energy demand to the price change introduced by the tax across all sectors.

Another difference between the two systems is the level of simplicity in terms of the implementation and management of the system, and their administrative costs.

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The cap-and-trade system, if applied to all sectors, is rather difficult and complex to implement and manage, and therefore also costly. The pollution tax system is relatively simple to introduce in all sectors of an economic system, with a relatively easy administration as well. If we consider the level of acceptance by the civil society and politicians, we can observe that the pollution trading system has a higher acceptance level than the pollution tax. This may be because the emissions trading system has, thus far, largely been introduced in the industrial sector, which means that the price of pollution may not actually be salient (or even too high) for the final consumers. The introduction of a pollution tax has a direct impact on final consumers and is also more salient. We can conclude by stating that a combination of these two market-based instruments, that takes into account these benefits and disadvantages, may be a prudent approach for policymakers to adopt.

The Weitzman (1974) perspective on price versus quantity instruments

In a seminal paper, Weitzman (1974) [105] proposed a simple framework to evaluate price instruments (such as pollution taxes) and quantity instruments (such as permit trading schemes), in the context of environmental policy. He postulated that under the condition of full certainty of MACs, there is said to be a duality of price and quantity instruments, that is, the two instruments may be equivalent to one another. On the introduction of uncertainty in MAC curves, however, using a pollution tax may be more efficient than a permit trading scheme, when the damages from emissions increase slowly (i.e., the MSB curve is relatively flat compared to the MAC). However, if the MSB curve is relatively steep, that is, if the damages from emissions increase catastrophically (e.g., if we are on the brink of a climate tipping point), an immediate reduction in emissions is more advisable, and thus, a quantity-based instrument such as a permit trading scheme (or a standard, which we will discuss in more detail in Chapter 8) would be better. This study offers an important perspective on the choice of price- and quantity-based instruments, under the case of uncertainty in MACs.

7.2.4 Behavioural Anomalies and Monetary Market-based Instruments

So far, we have considered the introduction of market-oriented monetary instruments in situations where economic agents are rational and well-informed, that is, before taking any decision, they go through an optimisation process and evaluate the costs and benefits of several alternatives. The demand and supply functions drawn thus far in this chapter assume that consumers and firms are rational and that they maximise utility and profits, respectively. This implies that economic agents react in full effect to monetary incentives such as subsidies or taxes. However, as discussed in Chapter 2, some consumers or firms may be characterised by limited rationality, that is, they may exhibit different behavioural anomalies. In this case, the change in consumption from the introduction of a subsidy or a tax may be lower than can be expected from rational consumers.

Consider, for example, the provision of a grant (or subsidy) to promote the adoption of energy-efficient heating systems. Rational consumers will incorporate this subsidy into their investment calculation when computing the savings in energy expenditures throughout the life cycle of the heating system. In this case, the subsidy can be an attractive monetary incentive to convince these consumers to invest more in energy efficiency. The same argument is valid for an energy tax on fossil fuels. In this case, rational consumers will fully consider the increase in costs of using the fossil fuel-based heating system for the next 20–30 years, due to the energy tax. Boundedly rational consumers, on the other hand, tend to lack competency in evaluating the different investment options in heating systems, and they may not completely recognise the potential future benefits of switching to more energy-efficient heating systems. Therefore, these consumers are not likely to fully incorporate either a subsidy or an energy tax in their choice of heating system, which reduces the efficacy of these instruments.

We will analyse this situation using Figures 7.20 and 7.21 representing the market for heating systems that have the same energy source but are characterised by different levels of energy efficiency. Therefore, these figures are similar to the ones we presented earlier in Section 7.2.2 on subsidies. We first illustrate the demand functions for the two types of consumers and then, in a Figure 7.21, present the effect of introducing a subsidy. In Figure 7.20, we can see the MPBs functions of improving energy efficiency that will result in a reduction in energy expenditures. We show this for a rational consumer (MPB_R), as well as for a boundedly rational consumer (MPB_{BR}). On the graph's horizontal axis, we plot the level of energy efficiency (LEE) of the heating system, while on the vertical axis, its benefits. The demand function (MPB_R) reflects the willingness to pay for a rational consumer, whereas, in contrast, the demand function (MPB_{BR}) illustrates the willingness to pay for the boundedly rational consumer. Due to anomalies in the optimisation process, the willingness to pay of the boundedly rational consumer for energy efficiency is lower than that of the rational consumer, at each level of energy efficiency. For this reason, the demand function for energy efficiency of the boundedly rational consumer (MPB_{BR}) is located left to one of the rational

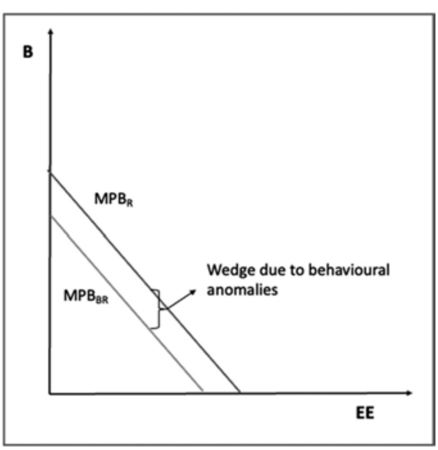

Figure 7.20 Demand for energy efficiency by rational and bounded rational consumers

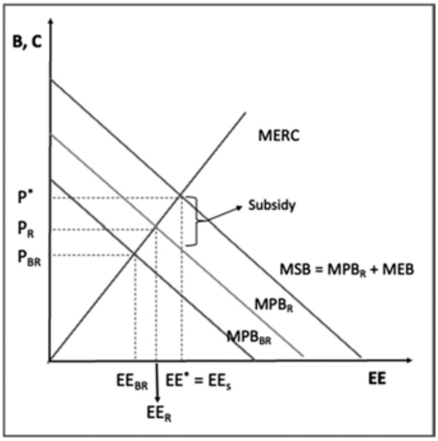

Figure 7.21 Optimal solution considering subsidy

consumers as illustrated in Figure 7.20. The wedge between the two demand functions arises due to a range of underlying anomalies described above (and in Chapter 2).

It is interesting to understand the implications of these two types of demand functions on the effectiveness of market-oriented monetary policy instruments that, generally, are designed assuming that consumers and firms behave rationally.

In Figure 7.21, we plot a graph illustrating the choice of the level of energy efficiency of heating systems. The graph includes three demand functions: the MPBs function demand of a rational consumer (MPB_R), the MPBs function of a boundedly rational consumer (MPB_{BR}) and the MSBs function (MSB) for energy efficiency of heating systems for a rational consumer from a societal point of view. This demand function is obtained by summing the MPB for rational consumers with the MEB, and it represents the MSBs of increasing the level of energy efficiency of the heating systems. The external benefit is due to the fact that an increase in energy efficiency reduces fossil fuel consumption and, therefore, diminishes air pollution and increases the security of supply. The graph also includes the upward-sloping marginal energy reduction cost curve ($MERC$), which indicates the increasing marginal costs of improving the heating system's energy efficiency and of reducing energy consumption.

If no positive externalities are considered, the private optimum for the rational consumers is reached at the level of energy efficiency denoted by EE_R, and the private optimum for the boundedly rational consumers is reached at EE_{BR}. However, since these energy efficiency improvements are associated with positive externalities, economic efficiency is achieved at EE^*, where the MSB curve intersects the MERC curve. To reach this optimum level, the state could introduce a subsidy that shifts the demand function to the right to reach the socially optimal level of energy efficiency EE^*. As can be seen from Figure 7.21, however, a subsidy designed to increase the demand of rational consumers would be insufficient to shift the demand function of the boundedly rational consumers to the right, in order to reach the optimum social EE^*.

The shift in the demand function of boundedly rational consumers would depend on how these consumers react to the subsidy, that is, how they integrate the subsidy into doing an economic analysis of investments in heating systems. In any case, even if we assume that the subsidy is highly effective for this group in increasing demand, it will not be enough to reach the social optimum. To ensure that all types of consumers reach the social optimum, that is, choose the right level of energy efficiency of the heating system, the state could try to reduce the extent of the behavioural anomalies through some non-monetary market instruments that we will introduce in Section 7.3, or by using standards that will be discussed in Chapter 8.

An analogous analysis could be done for the implementation of a pollution or energy tax on fossil fuels. The introduction of the tax would increase the MPBs obtained from investing in energy efficiency. Indeed, increasing the level of energy efficiency will reduce the level of energy consumption and, therefore, the level of energy and tax expenditures. The graph would be very similar to the one for the subsidy, whereby the tax will shift the demand functions of both consumers to the right to reach the social optimum. However, in this case, as well, the tax will not shift the demand function of the boundedly rational consumers to the social optimum bundle.

7.3 Non-monetary Market-based Instruments

In this section, we will shortly present two non-monetary market-based instruments that can increase the level of well-functioning of a market. As we know, in order to take sound decisions, economic agents have to be well-informed about the choices and have to act rationally. Information and educational programmes, as well as nudges, are policy instruments that can help economic agents to make sound and informed decisions.

7.3.1 Information and Educational Programmes

Informational and educational programmes are examples of policy instruments used to address imperfect information and asymmetric information that may prevent individuals from investing in energy-efficient or renewable technologies, or not conserving energy adequately. These policies are designed to enable consumers or firms to make better decisions, while not compelling them to take any particular action. The underlying assumption is that either providing consumers or firms with information, or the right incentive structure, can enable them to realise the benefits of adopting more energy-efficient technologies or of switching to renewable energy sources, and this would lead them to increase their demand towards the socially optimal level.

The following are some examples of informational or educational policies:

- Information campaigns on climate change
- Information campaigns on the implementation of energy and climate instruments
- Educational programmes on sustainable development
- Educational programmes on environmental or general energy-related knowledge
- Educational programmes on undertaking investment analysis with respect to the purchase of energy-consuming durables

- Information campaigns to inform about adaptation measures to climate change and improve resilience

> **The light at the end of the tunnel: impact of policy on the global diffusion of fluorescent lamps**
> To study the determinants of energy policy choice in developing countries, and to better understand whether these policies are effective in fostering clean technology diffusion, Srinivasan (2019) [106] used data on the diffusion of compact fluorescent lamps (CFLs) in seventy-two developing countries spanning 1993–2013. She found that in general information provision policies (explaining the benefits of using CFLs, compared to incandescent lamps) had a strong and positive effect on the diffusion of this technology, while subsidies and a ban on the use of incandescent bulbs (a non-market-based instrument) did not have any effects, in this sample of countries. The study also showed that governments that were more 'effective' in terms of implementing policies were more likely to provide information and less likely to subsidise CFLs. This study sheds light on policy choice and effectiveness in developing countries, where very little is known on the functioning of energy policies.

7.3.2 Nudges

Nudges are defined as subtle positive reinforcements that influence a person's behaviour without imposing any prohibitions on them. Proposed by Richard Thaler and Cass Sunstein in their 2008 book 'Nudge: Improving Decisions about Health, Wealth and Happiness', nudges have shown good promise in encouraging individuals to make better decisions.

They essentially comprise suggestions and invitations that encourage people to take decisions that are in their broad self-interest, as well as in the interest of society. They work without providing any explicit economic incentives for behavioural change or establishing any rules or conditions. This is closely linked to the idea of Libertarian Paternalism, defined as '... an approach that preserves freedom of choice but authorises both private and public institutions to steer people in directions that will promote their welfare' (Thaler and Sunstein, 2003) [107].

Nudges designed as energy or climate policy instruments aim to promote sustainable behaviour and encourage individuals to voluntarily contribute to energy and climate goals. Some examples of nudges to encourage sustainable choices and behaviour are:

- Nudges that provide clearer and/or salient information or help in processing information: they work to simplify product information or make certain product characteristics more salient (e.g., smart metres or eco-labels or energy labels).
- Nudges that provide some form of stimulus to follow a behaviour (e.g., messages in hotels to reuse towels).

- Nudges that provide information on the behaviour of peers. They exploit people's inclination to follow social norms, to imitate the behaviour of their peers (e.g., home energy reports, energy consumption comparisons, etc.).
- Nudges that change the choice architecture to enable easier decision-making. For instance, nudges that, in the presence of *status quo* bias or loss aversion, do not require consumers to actively choose something (e.g., setting renewable electricity contracts/green electricity contracts as the default option).
- Nudges that provide information on extreme weather events (such as flooding and heat wave risk) and suggest precautionary behaviour (such as staying home, and minimising outdoor activities)

Nudges are particularly useful to promote the more sustainable behaviour of boundedly rational consumers. For instance, if we consider again Figure 7.21, the implementation of a subsidy is intended to shift the demand functions of both boundedly rational and rational consumers to the right. However, as discussed earlier, a subsidy may not be enough to incentivise boundedly rational consumers to reach their social optimum. In this case, a nudge could help to shift the MPB_{BR} curve additionally to the right for these consumers, over and above the subsidy.

Nudges in the marketplace: the response of household electricity consumption to information and monetary incentives

Sudarshan (2017) [108] studied the impact of various behavioural interventions on the levels of electricity consumption of a sample of households in India based on a field experiment as well as a quasi-experimental analysis. The interventions included peer comparison reports for electricity consumption every week, reports with associated monetary incentives to help reduce consumption, and variations in the prices. The study revealed that peer comparison nudges led to an electricity consumption reduction of 7 per cent in the summer season. The price elasticity was estimated to be −0.56. However, households that received monetary incentives along with the peer-comparison reports increased their electricity consumption, thereby crowding out the non-monetary intervention. The author argued that principal-agent problems, with a lack of trust in the utilities and government, may have led to this unexpected outcome. This result showcases the need of designing policy instruments carefully to ensure that they may have the intended impact on the outcome variable and that they cannot be applied generically.

Table 7.3 is drawn from a report published by the Nordic Council of Ministers, and it provides some additional examples of nudges relevant to the energy and climate domains.

7.3.2.1 An Example of Nudges: Eco-labels and Energy Labels

Eco-labels and energy labels are designed to solve typical information problems related to the use of energy-efficient technologies. Not all consumers are fully

Table 7.3 Types of nudges [109]

Type of Nudge	Examples
Provision of information	• Information on energy use, for example, of household or office units. • Real-time displays providing current information on energy consumption and prices, either through green lights or information on prices and quantities. • Information on current energy prices through green lights system. • Energy labels on housing, household appliances, and products. • Information campaigns to households. • Social media campaigns.
Changes in the physical environment	• Change in waste-sorting equipment. • Changing the plate size.
Changes in the default options	• Change in default for CO_2 offsetting. • Change in default temperature in offices. • Change in default to accept the installation of smart-grid technology. • Green electricity contracts as default. • Change in default menus in restaurants to a meat-free version.
Use of social norms and regular feedback	• Feedback on energy and water usage compared to social reference groups, such as similar neighbours. • Information campaign focusing on social responsibility to sort waste.

informed about various aspects of energy-consuming technologies, such as their operating costs or the characteristics of a product or energy service. Eco-labels and energy labels can be effective in alleviating imperfect information. Additionally, they might also create better outcomes in the face of the limited attention paid by consumers to critical information (such as energy or fuel consumption).

Eco-labels and energy labels provide consumers with an objective and accurate evaluation of a product's energy consumption and environmental impact. They are often implemented with energy standards, and it may be either mandatory or voluntary for firms to print labels on their products. Energy labels can be either endorsement labels (such as the Energy Star label from the US, which endorses the product as being energy-efficient) or comparative labels (which compare the performance of the appliance or vehicle with that of other similar products on the market).

Labels have been implemented in many industrialised as well as developing countries. For example, the European Commission has a website that lists all eco-labels that member states are obliged to implement in the European Union [110], as well as the corresponding regulations.

Field interventions for climate change mitigation behaviours: a second-order meta-analysis

In their study, Bergquist et al. (2023) [111] provided a meta-analysis of studies involving interventions to promote climate change mitigation behaviour. They found that among the different types of interventions normally studied, field experiments based on social comparisons or financial incentives were likely to have the largest effects on pro-environmental behaviour, while information provision and education-based interventions had the least impact. Thus, comparing an individual's behaviour to that of others has been found, across several studies, to induce consumers to react, in terms of observable behaviour, such as littering, use of sustainable transportation, meat consumption, or saving electricity and water. This study provides some evidence on the types of interventions that can have an effect in influencing certain types of sustainable behaviour.

Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances

Energy labels usually provide information on the energy use of an appliance, light bulbs, or a car, but not on the monetary savings of expenditures. In this study, Blasch et al. (2019)[112] study the effects of providing monetary information on an energy label for electrical appliances and light bulbs. The empirical analysis based on a randomised controlled trial with a sample of more than 2000 Swiss households indicates that individuals provided with labels containing monetary information had a higher likelihood of performing a lifetime calculation, and correctly identifying electrical appliances that minimise these costs. Therefore, this study shows that the type of information included on energy labels can have significant effects on choices.

7.3.2.2 The Limitations of Informational and Educational Programmes and Nudges

A standard criticism levelled against nudges (and more generally, against informational or educational policies) is that they are insufficient by themselves to reach energy and climate policy goals. Policymakers may need to supplement them with other market- or non-market-based instruments that can provide the impetus for consumers and firms to make sustainable decisions. For instance, educational programmes about how to perform an investment analysis or calculate the lifetime cost of an electrical appliance or a heating system can increase the effectiveness of a pollution tax. In fact, if consumers do not consider the lifetime cost in their investment decisions, then the increase in the fuel cost determined by a pollution tax will not be completely considered in the choice. Although information and educational programmes and nudges are unlikely to be capable of bringing about lasting changes, they are relatively cost-effective policies that can have sizeable effects in some cases. Of course, in this chapter, we discussed the use of nudges in order to maximise societal welfare. However, we should not forget that nudges can also be designed, especially by firms, to sell goods and services as well as technologies that are promoting sustainable development.

7.4 Issues in Developing Countries

We discussed several market-based policy instruments in this chapter, including taxes, subsidies, permits as well as information-based policies. In this section, we elaborate on the benefits and weaknesses of some of these instruments in a developing country context, especially pollution and product taxes, permits, and fossil fuel subsidies, which are quite salient in many developing countries. In the last part of this section, we shed light on some unintended effects of market-based instruments that may materialise in developing countries.

7.4.1 A Comparison of Product Taxes and Pollution Taxes in Developing Countries

The implementation of pollution taxes, as we saw in Section 7.3, requires regulators to have an idea of the MACs of average economic actors. If regulators do not know this, they will be unable to accurately predict the responses of economic agents. Moreover, it also requires monitoring of environmental parameters and enforcement, which is costly in developing countries where a higher share of firms belong to the informal sector, and thus they are more difficult to monitor. Other factors that may be important in determining the performance of pollution taxes are the quality of institutions and the enforcement of contracts (which is often substantially weaker in developing countries). An example of a pollution tax in a developing country is South Africa, which implemented an emissions-based pollution tax back in 2019. In this system, the tax is imposed on the use of fuels, based on emission factors.

Product taxes and energy taxes, on the other hand, may be relatively easier to implement in developing countries (since they are imposed on quantities of goods produced or inputs used, and not on actual environmental performance). As we discussed, they are not as efficient as pollution taxes, because they are not explicitly reducing emissions, but they may be the best solution for developing countries, at least in some cases. Product and energy taxes, for instance, have weaker monitoring and enforcement requirements than emissions-based pollution taxes. They also tend to be managed centrally, making them less subject to corrupt practices. Examples of energy taxes in the developing world include fuel taxes in countries such as India, Colombia, and Mexico.

7.4.2 A Comparison of Carbon Taxes and Permit Trading Systems in Developing Countries

As the arguments in Section 7.3 illustrated, in a simple economic setup, taxes and permit trading systems should be equivalent’ however, in practice, often differences may arise in their effectiveness as instruments. This is particularly plausible in developing countries. For instance, while permits offer the advantage of certainty with respect to the number of emissions (and no requirement of knowing the MAC of a unit of pollution), in developing countries, their performance may be hindered by the fact that plant-level emissions data is mostly unavailable, and the difficulties of monitoring a large informal sector. In practice, other problems arise due to the illegitimate reporting of emissions.

On the other hand, carbon taxes offer some certainty with respect to the price, and the transaction costs of implementing tax-based policies are also low, even though inadequate regulatory/legal institutions, political pressure by large firms, a lack of political will, and negligence/corruption of enforcement agents may undermine this instrument, particularly in developing countries. As discussed previously, there are some challenges with the implementation of carbon taxes (and product/energy taxes may be better in some cases).

The choice between these instruments, as already mentioned, will depend on which of these (advantages or disadvantages) policymakers choose to weigh more heavily, and on public acceptability, as well as the strength of regulations and institutions in the country. We will touch upon these issues in more detail in Chapter 9.

Another interesting and important permit trading system is the clean development mechanism (CDM) that is still in place and has interesting positive effects for developing countries. The CDM is an international offset programme for carbon emissions that was proposed under the Kyoto Protocol in 1992. It allows countries that have committed to emissions reductions under the Kyoto Protocol to implement an emission-reduction project in developing countries. These projects are eligible to earn Certified Emission Reduction (CER) credits, which can be sold, each equivalent to one ton of CO_2, and these can be counted towards meeting Kyoto targets. In the scope of this project, industrialised countries have invested in both small-scale and large-scale projects in renewable generation, reduction of GHG emissions in industries such as cement and coal, demand-side energy-efficiency projects, and in afforestation and reforestation projects in developing countries.

7.4.3 Inefficiency of Fossil Fuel Subsidies

In general, many countries, particularly developing countries, have spent a lot on fossil fuel subsidies (including petroleum, natural gas, coal, and end-use electricity). A typical subsidy in developing countries is for the use of coal. These subsidies are often designed with the purpose of helping low-income consumers and stifling energy poverty. However, such subsidies are economically inefficient, because not only do fossil fuels contribute to climate change (and thus these subsidies are generating negative externalities), but their presence also implies that private investments in energy efficiency may not reach socially optimal levels.

Fossil fuel subsidies can either be producer subsidies (that reduce the costs for fossil fuel producers, for example, subsidies to produce electricity or transmission and distribution of natural gas) or consumer subsidies (that are applied to reduce the price of energy to end consumers, such as subsidies on cooking fuels such as liquified petroleum gas (LPG)).

There are multiple sources of inefficiency from the use of fossil fuels. This is illustrated in Figure 7.22, depicting the effects of subsidies in a hypothetical market for

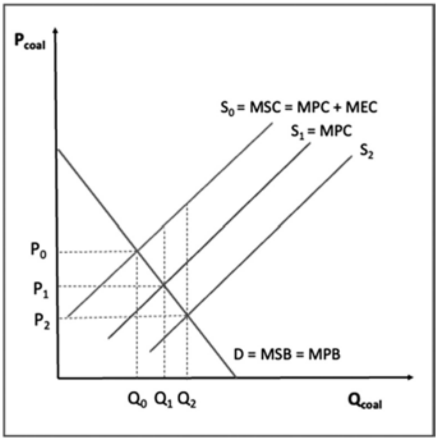

Figure 7.22 Market for coal

coal. As earlier, in this graph, we plot the demand function for coal that corresponds to the MSB curve, which in this case equals the MBP curve. Further, we have several upward-sloping supply functions that correspond to the MSC and the MPC curves, with and without considering the MEC.

The initial social welfare maximising equilibrium is denoted by (P_0, Q_0), where both producer costs and external costs from the use of coal are accounted for (given that it is the point where the MSC curve intersects the demand curve that corresponds to the MSB).

Now, we evaluate how the equilibrium in this market shifts if, first, policymakers were to ignore the negative externality from the production of coal; the new equilibrium point would be denoted by (P_1, Q_1) (where the MSB curve intersects the MPC curve), and this equilibrium gives rise to a dead-weight loss. This is the first source of inefficiency in this market. Furthermore, if policymakers incentivised the extraction of fossil fuels such as coal by subsidising its production, the supply curve for coal further shifts to the right to S_2. Thus, the equilibrium supply of coal increases further from Q_1 to Q_2, whereas the price of coal declines to P_2. Thus, subsidies not only imply lower coal prices and increased production but also lead to an increase in the total dead-weight loss to society.

This simple graphical framework illustrates that fossil fuel subsidies are both unsustainable and economically inefficient. Their presence also hampers investments in energy efficiency, as well as in renewable energy. For these reasons, many countries have taken active steps to phase out fossil fuel subsidies.

7.4.4 Unintended Effects of Market-based Instruments in Developing Countries

Given the low levels of energy access and electricity-consuming durable ownership in many parts of the developing world (such as of electric cook stoves), introducing policies such as taxes on the use of certain kinds of fuels (such as kerosene, or charcoal) can shift households away to sources of fuel that are outside the scope of taxation.

For example, households may switch to using firewood for cooking purposes after the introduction of such a tax. This would stem the effectiveness of the tax and still increase local environmental and health costs due to indoor air pollution. These considerations imply that policymakers need to consider context-specific constraints and changes in behaviour that may lead to unintended consequences from implementing market-based instruments.

7.4.5 Review Questions and Problems

The online question bank contains review questions and problems for this chapter, including solutions (see https://wp-prd.let.ethz.ch/exercisesfortextbookeep/).