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8. Carbon taxes

8.1 Introduction

Carbon taxes, along with emissions trading systems, are instruments for pricing carbon emissions, which account for three-quarters of global greenhouse gas (GHG) emissions, and are therefore the main drivers of climate change. Carbon pricing policies are widely used: to date, 36 carbon taxes and 32 emissions trading systems are implemented worldwide and cover almost 24 percent of global GHG emissions.[1] Yet, carbon prices are still low, with only 3.8 percent of global emissions covered by a carbon price above US\$40/tCO_2, which is the lower bound that may allow the world to meet the 2°C temperature goal of the Paris Agreement (World Bank, 2021).

A carbon tax is a surcharge to be paid on a fuel, product, or service in proportion to the quantity of carbon embodied or emitted. By making activities that release carbon in the atmosphere more expensive, the tax creates a financial incentive to limit polluting activities, thereby allowing policy makers to curb emissions and ultimately mitigate climate change. Because they increase the price of certain goods and activities, carbon taxes raise distributional and acceptability concerns.

Carbon taxes are thus complex instruments, appealing to chemistry, physics, economics, sociology, and politics. This entry discusses their functioning and main properties.

8.2 Chemical and physical aspects

A carbon tax is a per-unit (or specific) tax, which means that the level of the tax is defined as a fixed monetary amount (USD or another currency) per ton of CO_2. Before explaining the economic principles underlying carbon taxes, it is therefore useful to understand what is – concretely – 1 ton of CO_2.

One ton of CO_2 literally weighs 1 ton, or 1000 kg, even though it is a gas. Such a mass of CO_2 would fill a cube slightly taller than 8 m (i.e., a volume of about 540 m^3). Given that the atomic mass of carbon (C) is 12, while that of oxygen (O) is 16, the mass of 1 mole of CO_2 is $12 + 2 \cdot 16 = 44$ grams. Therefore, one ton of CO_2 contains about $12/44 = 0.273$ tons of carbon, or conversely, 1 ton of carbon released in the air, once combined with oxygen, corresponds to 3.67 tons of CO_2. A carbon tax can thus be formulated as well as a CO_2 tax, and the two expressions are in fact often used interchangeably. It is nevertheless crucial to explicitly define whether the tax applies to carbon (C) or to carbon dioxide (CO_2), since the rate of a CO_2 tax will have to be 3.67 times higher than that of a carbon tax to be equivalent.

To make things more tangible, consider the following examples from the two sectors that are among the largest emitters worldwide: transport and housing. When driving a car, burning one liter of gasoline releases 0.64 kg of carbon, which then ultimately results in the emission of 2.3 kg of CO_2.[2] Hence, driving a car with a fuel consumption of 7 liters/100 km (equivalent to a fuel economy of 34 miles per gallon [mpg]), or the global average fuel consumption of a light-duty vehicle in 2020 (International Energy Agency, 2021), produces 161 grams of CO_2 per km, or 1 ton of CO_2 every 6200 km.

In the residential sector, the average US home consumes about 10 000 kWh of electricity per year,[3] roughly the energy delivered by the consumption of 1000 m^3 of natural gas. Given that 1 m^3 of natural gas contains 0.51 kg of carbon, hence producing 1.9 kg of CO_2, heating the average home for a year emits almost 2 tons of CO_2. Considering that about 50 percent of households in the United States (Energy Information Administration, 2021) and 40 percent of those in the European Union (Eurostat, 2021) use natural gas for space and water heating, the amount of CO_2 produced due to natural gas consumption in the residential sector is considerable.

These calculations moreover provide indications of what a carbon tax would represent for fuel consumers. For instance, a tax set at US\$80 per ton of CO_2 would correspond to about 18 cents per liter (or 70 cents per gallon) of gasoline and about 15 cents per m^3 of natural gas.[4] These amounts constitute upper bounds for the price increases that may be observed following the implementation of a CO_2 tax set at this level.

8.3 Economic rationale

From an economic point of view, carbon emissions create so-called "negative externalities" in the sense that agents who participate in the polluting market and make decisions impose costs on others without compensating them. Consider, for instance, the market for fossil motor fuels. Drivers of vehicles with internal combustion engines (ICE) and fuel sellers are the market participants. Pedestrians, bike riders, people whose dwelling is located close to a road, and other non-ICE vehicle owners do not purchase any fossil motor fuel, yet they incur some costs because of fuel consumption by others: they breathe polluted air, which may affect their health. At a broader level, emissions from fossil fuel consumption cause global warming, which impacts everyone, fossil fuel consumers and non-consumers alike.

Negative externalities are illustrated in Figure 8.1, which represents the market for a fossil fuel. When the market is unregulated, fuel price depends on the buyers' willingness to pay and the sellers' private costs (i.e., the costs incurred by the sellers only). None of the participants consider the external costs, emitting polluting substances in the atmosphere is free, and quantity Q_0 fuel will be exchanged at price P_0 (point *D*). The external costs that fall on non-participants in that situation are given by the surface *ACDF*. The quantity exchanged in the unregulated market is therefore too large, and a deadweight loss equivalent to the surface *BCD* arises. This situation constitutes a market failure.

To achieve economic efficiency, a "Pigouvian tax" (named after Arthur Cecil Pigou, 1920) may be introduced. The rate of the Pigouvian tax corresponds to the marginal external costs. Market participants are hence forced to consider external costs as their own, and they adjust their behavior. The optimal tax rate in Figure 8.1 is given by the distance between point *E* and point *B*. Such a tax level would raise the marginal private cost up to the level of the marginal social cost, and the equilibrium of the market would therefore move to point *B*, where the deadweight loss is completely eliminated. Quantity exchanged would decrease to Q_1 whereas market price would increase to P_1. Importantly, note that the price increase is usually lower than the tax rate, implying that buyers and sellers share the burden of the tax. Compared to the free market equilibrium, not only does the price paid by the buyers increase (*B* is above *D*), but the price received by the sellers also decreases (*E* is below *D*).

One may also note that, even in the efficient situation, polluting emissions are not down to zero. The costs for eliminating completely the polluting activities would be larger than the benefits of decreased pollution. When setting the efficient level of a carbon tax, the costs of pollution are to be compared with the benefits of the activities associated with pollution. However, comparing costs and benefits is challenging, in particular in the context of climate change, because damages are difficult to assess and will mostly occur in the future. Several attempts exist in the literature (e.g., Tol, 2019; Taconet et al., 2021), but in general, climate policy objectives are not determined on efficiency grounds. In this context, carbon taxes are instruments that can be used to reach emission reduction objectives cost-effectively (Tietenberg, 1973), or at the lowest global cost.

8.4 Cost-effectiveness

With a carbon tax, property rights on the atmosphere belong to society, and emitters must thus pay a charge for each ton of carbon emitted (or in proportion to the carbon content). Each emitter is then free to decide whether it is worth polluting and paying the tax, or if it is preferable to avoid paying the tax by reducing emissions (i.e., abating). However, abatement activities may be costly because they require investments in more efficient devices, behavioral changes, and so forth. A carbon tax will thus incentivize polluters to compare the costs of emitting and paying the tax versus the abatement costs. To save money, polluters with low abatement costs will have to achieve significant emission reductions. On the contrary, polluters with higher abatement costs will reduce smaller amounts of emissions, but they will conversely pay higher amounts of taxes. This situation leads to cost-effectiveness.

More precisely, since the carbon tax rate is unique, each polluter will abate up to the point where the marginal cost of abatement is equal to the tax rate. At higher abatement levels, it would become cheaper to pay the tax. This characteristic of carbon taxes is particularly interesting compared to more traditional approaches, like command-and-control,

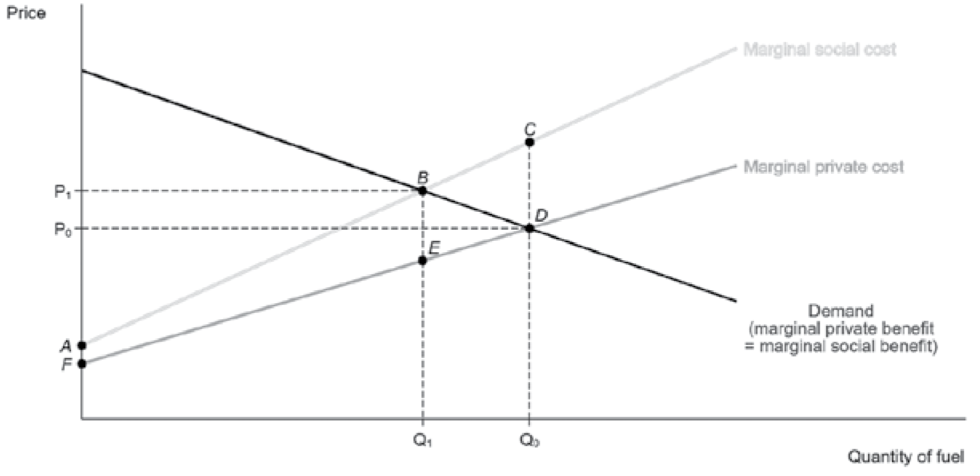

Figure 8.1 Externalities and environmental taxes

in which polluters are assigned reduction targets. Under such a centralized system, the distribution of abatement efforts between polluters will be different from the one obtained with a tax. Most certainly, the total costs for achieving the same abatement level will also be higher since the regulator does not possess precise information on abatement costs and thus cannot allocate abatement efforts consequently. Decentralized pricing mechanisms let emitters make decisions for themselves, thereby making it possible to find cost-effective solutions.

Two points must be highlighted. First, with a carbon tax, there is uncertainty regarding the abatement efforts and therefore no guarantee that any policy target will be reached. If the total amount of abatement is lower than the target, the tax rate should be increased. For this reason, modern carbon tax laws (e.g., those in Switzerland) allow tax rates to vary depending on total abatement achieved. As a corollary, if the number of emitters rises, the tax rate must be increased to maintain the policy target.

Second, all polluters have to pay the carbon tax on their remaining emissions, even the ones making the greatest abatement efforts. Carbon taxes have, thus, two main consequences: (i) they generate substantial revenues, and how to use these revenues is largely debated in the literature (e.g., Bourgeois et al., 2021); and (ii) they create sustained incentives to abate through time and may thus contribute to innovation (e.g., Acemoglu et al., 2012).

Next to carbon taxes, markets for trading carbon emission allowances constitute another pricing mechanism. In an emission trading system (ETS), a cap is defined for the total amount of allowed emissions and allowances are then distributed to polluters, either free of charge or by auction. Under this approach, polluters must cover each ton of CO_2 emitted with the corresponding number of allowances. The demand and supply for allowances will result in an equilibrium price for carbon emissions.

As carbon pricing instruments, carbon taxes and ETSs possess a similar rationale and share the main properties (for a survey, see Baranzini et al., 2017). In some circumstances, they may even yield equivalent results. In particular, if the ETS equilibrium price matches the tax level, and if there are no market distortions, emission reductions will be identical with the two instruments, both at the global level and for each individual polluter. Also, for a given amount of abatement, both instruments are cost-effective. The major difference is that, in the case of a tax, the cost of emitting carbon is known in advance, while there is uncertainty regarding the final amounts of abatement and emissions. Conversely, the quantity of pollution is fixed in an ETS – the cap indeed sets the upper bound for emissions – but the cost of carbon emissions will fluctuate according to supply and demand of allowances (see Weitzman, 1974, for the seminal comparison of price versus quantity instruments, and Stavins, 2022, for an extensive discussion of the similarities and differences between carbon taxes and ETS).

8.5 Carbon taxes in practice

Carbon taxes may differ along various characteristics that must be defined when a tax is implemented. The first component of a carbon tax is the tax base, which defines which fuel and which activities are subject to taxation. Ideally, 1 ton of carbon should be taxed at the same rate, regardless of the activity generating the emissions, to avoid market distortions and maximize cost-effectiveness. In practice, however, for political, social, or acceptability reasons, some sectors or industries are usually exempted. In Sweden, for instance, where a carbon tax was implemented in 1991, a lower tax rate has historically been applied to firms compared to households. As of 2018, however, the industry rate is the same as the general rate. Since 2008, Switzerland applies a carbon tax covering heating fossil fuels but totally exempting the transport sector.

The level of the tax is the second crucial component. A higher tax rate will have a larger impact on the price of polluting activities, thereby inducing larger reductions of emissions. The cost for consumers will, however, increase, which may cause acceptability issues. Carbon taxes are thus often introduced at low levels and then scaled up over time. Sweden and Switzerland, where carbon taxes are currently around US\$130/ tCO_2,[5] launched their taxes at very modest levels and then gradually increased them.

The literature provides relatively few empirical evaluations of the effects of carbon taxes on emission reductions. Green (2021) provides a review of the analyses based on real observations in countries or regions that have actually implemented carbon pricing policies. Most studies suggest that aggregate emission reductions from carbon pricing are limited – generally between 0 percent and 2 percent per year. The low level of the tax rate and the presence of exemptions are the common reasons offered as explanations for this low effectiveness.

A related concern is that the tax burden will impact households differently. In particular, low-income households are affected more adversely than others because energy takes a larger share of their budget than for high-income households. Ohlendorf et al. (2020) use a meta-analysis to investigate distributional impacts of carbon taxes and show that most carbon taxes are indeed regressive. The survey by Pizer and Sexton (2019), in which all types of energy taxes are considered, however, finds that this is not always the case and that the regressive impact is generally small. Nevertheless, the "yellow vests movement" that took place in France at the end of 2018, following the announcement of an increase in diesel taxes, illustrates how carbon taxes may matter for their acceptability. The discontent was most intense in rural regions, which often face lower economic development but have to bear a higher fuel tax burden in comparison with large urban centers (e.g., Beck et al., 2016).

A further concern is the competition distortion that may hit firms because of carbon tax rate differentials across countries or sectors. Firms located in countries or sectors with relatively high carbon tax rates may indeed face competitive disadvantages compared to firms located in countries or sectors with lower or no taxes, their tax-inclusive prices becoming higher, everything else equal. That may induce local consumers to start buying goods imported from low-tax countries, causing a phenomenon known as "carbon leakage" (e.g., Aichele and Felbermayr, 2015). The magnitude of the competitive disadvantage induced by carbon taxes, however, appears to be small and may even be offset if the tax revenues are recycled to lower employers' costs for social security contributions (e.g., Andersen and Ekins, 2009).

The third component to be defined in the implementation of a carbon tax is the use of the generated fiscal revenues. Revenues can be left unassigned and added to the state's budget. This approach is relatively unpopular because it implies an increase of a state's activities, and most people then consider carbon taxes as a pretext to raise fiscal revenues. Alternatively, revenues can be earmarked, that is, assigned to specific objectives. Most countries in fact decide to assign the revenues from carbon taxes to environmental projects. This approach is generally well supported, since people often overlook the incentive impact of carbon taxes and thus expect tax revenues to be earmarked to environmental purposes (see Baranzini and Carattini, 2017; Dresner et al., 2006; Kallbekken et al., 2011; Ott et al., 2021). Another possible approach is to use fiscal revenues to decrease other taxes (e.g., on labor or capital), which could give rise to the so-called "double dividend" since reducing distortionary taxes may have positive impacts on economic growth, employment, or technological development in addition to reducing carbon emissions. Freire-González (2018) conducts a comprehensive literature review and concludes that the double dividend remains an ambiguous question that deserves further research.

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Notes

1. See World Bank's "Carbon Pricing Dashboard" at https://carbonpricingdashboard.worldbank.org/ for updated figures.
2. CO_2 emissions coefficients are available from the EIA's webpage, "How Much Carbon Dioxide Is Produced when Different Fuels are Burned?" (https://www.eia.gov/tools/faqs/faq.php?id=73&t=11).
3. Obviously, energy used for heating purposes varies substantially according to a number of parameters, such as building size, efficiency of heating system, quality of building's insulation, or the differential between internal and external temperatures.
4. The upper bound of the price range for 2020 recommended by the World Bank's High-Level Commission on Carbon Prices Report (2017) is US$80/t$CO_2$.
5. More precisely and in local currencies, the tax level is SEK 1200/tCO_2 since 2021 in Sweden and CHF 120/tCO_2 since 2022 in Switzerland.

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