Carbon Pricing in Practice

Interdisciplinary Insights to Improve the Effectiveness of CO_2 Pricing

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Abstract: *Following economic theory, carbon pricing is generally regarded as the optimal policy to achieve a reduction in CO_2 emissions. In theory, a carbon price is characterized by its cost-effectiveness, its flexibility as a market-based solution, and its relatively straightforward implementation compared to other regulatory approaches. Moving from theory to practice, however, any political intervention inevitably encounters a complex interplay of political, economic, and social dynamics, leading to unintended consequences that often undermine its effectiveness. Studying these dynamics is crucial to avoid negative outcomes and re-evaluate the policy design to ensure its intended impact. By analyzing existing carbon pricing measures, this chapter aims to address disciplinary blind spots that hinder their effectiveness in reducing carbon emission. In doing so, we identify two key areas: (1) Political feasibility as a concept that can be used to analyze the implementation of carbon pricing depending on key social actors, and (2) behavioral barriers, which result from actual behavior systematically deviating from the rational actor assumptions typically assumed in economic models. We demonstrate that recognizing these dimensions is crucial for designing effective and socially acceptable climate policies.*

Keywords: *Carbon pricing; climate policy effectiveness; political feasibility; public acceptance; behavioral barriers; policy design*

1. Introduction

Climate change and the associated environmental crises are undoubtedly the central challenges of the coming years. For several decades, climate researchers have been warning of the negative effects on humanity and calling on politicians and society to act quickly and profoundly.

From an economic perspective, the answer appears straightforward: to address climate change and place societies on a sustainable path, putting a price on carbon is regarded as the optimal (and often sufficient) solution. However, several challenges arise in the development and implementation of carbon prices (Stoll & Mehling, 2021):

First, the role of carbon pricing is increasingly questioned in scientific discourse—either as a standalone instrument or, in some cases, as a viable solution at all. Concerns have been raised about its capacity to drive the structural transformations required for deep decarbonization.

Second, in political practice, strong resistance often hinders the introduction of new carbon pricing schemes. Once introduced, carbon prices usually remain well below levels considered necessary for meaningful impact.

Third, empirical studies investigating the effectiveness of existing carbon prices report mixed results, but most indicate insufficient emission reductions to meet serious climate targets.

In this article, we argue that the focus on an 'optimal' carbon price is the result of a purely economic perspective. By focusing on a supposedly optimal carbon price, central aspects concerning its effectiveness are neglected and implementation problems arise in practice. To support this argument, we first introduce the standard-economic understanding of emissions as an externality and show how a carbon price is determined on this basis (section 2.1). Following this theoretical introduction, we briefly review the empirical evidence on the effectiveness of carbon pricing policies in section 2.2. As we will show, there is a significant inconsistency between theoretical predictions and the realized effects of these measures. We then use the remainder of this chapter to discuss two central issues contributing to this discrepancy. First, we show how the implementation of carbon prices is influenced by political feasibility. Whether and to what extent a carbon price is implemented depends on various social actors and their political power (section 3). Second, the effectiveness of carbon prices as an instrument for reducing emissions crucially depends on human behavior. In Section 4, we show how the assumption of rationality hinders the design of an effective carbon price. Section 5 summarizes the central insights.

The aim of this article is to show that interdisciplinary cooperation is necessary to design effective carbon prices and complementary policies. Students and young economists in particular must broaden their disciplinary view at an early stage in order to uncover blind spots and to be able to support the design of effective measures to mitigate climate change.

2. Carbon pricing in theory and practice

This section introduces the basic economic understanding of carbon emissions as an externality. We show that current carbon prices can be traced back to the theoretical work of Arthur C. Pigou and the modeling of William D. Nordhaus. We then review the effectiveness of real carbon prices and show that they differ greatly from those modeled.

2.1 The economic theory of carbon pricing

CO2 emissions are a typical example of a negative externality. In economics, negative externalities refer to costs imposed on third parties who are not directly involved in the production or consumption of a good or service. Starting with the standard textbook example, consider a factory that produces near a settlement and emits polluting substances that harm the inhabitants of the adjacent settlement (Coase, 1960). The damage caused in this way should be part of the production costs of the factory, but the manufacturer only takes into account the capital and wage costs of production. As a result, the market price does not reflect the true social costs of the good, preventing the economy from reaching a social optimum through the interplay of supply and demand.

Pigou (1920) argued that in such cases, state intervention is legitimate to correct this market failure. By imposing a tax equal to the social cost on the manufacturer, the state forces it to internalize the damage caused by pollution into the cost of production. Due to the higher market price, production and consumption will be reduced until market equilibrium reaches the socially optimal level. Alternatively, the manufacturer can invest in technologies that reduce pollution until the marginal cost of prevention equals the marginal cost of its damage. The Pigouvian tax is therefore understood as the most efficient market solution as it provides incentives for a change in behavior at the lowest absolute cost (Stern, 2006).

The Pigouvian model provides the theoretical foundation for modern attempts to calculate an optimal price on carbon emissions (Nordhaus, 1991; Stern, 2006). Accordingly, the carbon price is intended to reflect the social costs of carbon (SCC). The SCC is defined as the negative change in the discounted value of economic prosperity resulting from an additional unit of CO_2 emissions (Nordhaus, 2017; Nordhaus & Sztorc, 2013). Nordhaus developed a model framework in the 1990s in which he links economic activity, greenhouse gas emissions, the carbon cycle and the resulting economic damage of climate change (Nordhaus, 1991). The Dynamic Integrated Climate-Economy (DICE) model is built on a neoclassical growth framework and forecasts global production from capital accumulation, job growth, and exogenous technological progress, minus mitigation expenditures that reduce CO_2 emissions (Nordhaus, 1991, 2017). The emissions are entered into a simplified sub-model of the carbon cycle, which converts them into atmospheric concentrations, and into a reduced climate module, which translates the concentrations into global mean temperature changes. A damage function then maps these temperature increases in fractions of gross production, resulting in net consumption. Net consumption is aggregated over time via a social welfare function that includes a pure time preference and an inequality aversion parameter to generate a present value measure of well-being. The model then determines the intertemporal allocation of resources between mitigation and consumption by equating the marginal cost of emission reduction with the marginal welfare loss due to additional warming. The carbon price from the DICE model thus corresponds to the marginal discounted welfare loss from emitting an additional ton of CO_2.

To determine the optimal price, a cost-benefit analysis is carried out within the DICE model. Here, the selection of a carbon price is understood as an intertemporal maximization problem where the economic costs of mitigation are weighed against the benefits of preventing climate damage.

In theory, the carbon price determined in this way is the economically optimal price. However, the DICE model is extremely sensitive with regard to central model functions and parameter values (Dietz & Stern, 2015; Nordhaus, 2018; Stern, 2006). For example, the estimated carbon price for 2025 varies between values of $37 per ton of CO_2 to $4185 per ton of CO_2 depending on assumptions such as the discount rate of future damages or the weighting of low-risk high-impact events (Barrage & Nordhaus, 2024). Therefore, it is not possible to determine a clear carbon price, as the parameter values are subject to great uncertainty (Heal, 2017).

While Nordhaus's SCC is the best-known approach to calculating the optimal carbon price, harsh criticism on its modeling assumptions and overall premise have led some researchers to develop alternative methods. For instance, instead of developing the price based on a cost-benefit analysis to determine its economically optimal value, some researchers suggest starting with a specific climate target and 'back-calculating' the price that is necessary to reach this target (Marron & Toder, 2014). This method therefore prioritizes ecological effectiveness over economic optimality, often rejecting the usage of future discounting and putting higher emphasis on low-risk high-impact scenarios. According to the model proposed in the well-known "Stern and Stiglitz Report" (High-Level Commission on Carbon Prices, 2017), for example, a global carbon price of $40-80 in 2020 would be necessary to keep global warming below 2°C.

While many attempts have been made to calculate the 'correct' price, reality often paints a different picture: Instead of careful cost-benefit assessments or climate targets, real carbon prices are the result of political processes and vary in the real world. Consequently, a substantial gap emerges between the theoretically predicted and empirically observed effects of carbon pricing measures, as we will show in the following section.

2.2 Effectiveness of carbon pricing in practice

Following the theoretical discourse and increasing urgency to keep global warming well below 2°C (IPCC, 2021), carbon pricing policies have been implemented all around the world. At the time of writing, 80 pricing schemes—43 taxes and 37 emission trading systems (ETS)—have been implemented by sub-national, national and supranational jurisdictions, covering 28% of global carbon emissions (World Bank, 2025). The average carbon price is roughly $19 per ton of CO2, with prices ranging from less than $1 up to $158. The global emissions-weighted price, which calculates the average price for all priced and non-priced emissions, is around $5.

Despite the increasing adoption of carbon pricing schemes, only a minority of prices reach the level predicted to be necessary for effective climate change mitigation. In fact, less than 4% of priced emissions are covered by the aforementioned $40-80 range (Pryor et al., 2021) and about half are priced with a level below $10 (World Bank & Ecofys, 2018).

These differences in policy schemes and the existence of additional climate policies make it difficult to assess and compare the effectiveness of these pricing schemes in reducing carbon emissions. However, a growing body of ex-post evaluations aims to quantify the impact on carbon emissions, and some review papers and meta-analyses have been published to compare the results of individual case studies.

One of the first comprehensive meta-reviews by Green (2021) analyzes thirty-seven quantitative ex-post evaluations, 70% of which focus on European schemes such as the European Union Emissions Trading System (EU-ETS). Her review finds that, in most instances, the introduction of a carbon price yields only moderate average emissions reductions of 0–2 percent per year. Among some notable exceptions is the United Kingdom's carbon price support mechanism, which reportedly achieved a 41–49 percent decline in power-sector emissions between 2013 and 2017. Green attributes these generally weak outcomes to the low price levels in most schemes, as well as to political constraints and industry lobbying that have limited both the ambition and public acceptance of more rigorous pricing policies. Overall, the review suggests that carbon pricing can only promote marginal emission reductions, mostly via fuel switching and incremental efficiency improvements, but is insufficient to induce the transformation needed to substantially mitigate climate change.

Döbbeling-Hildebrandt et al. (2024) build on this foundation with a comprehensive quantitative meta-analysis covering 21 distinct carbon-pricing programs, synthesizing 483 individual effect sizes from 80 ex-post evaluations. After correcting for publication bias, they estimate an average cumulative emissions reduction of 6.8 percent since policy implementation, with individual reductions ranging from 4 to 15 percent. Their findings also suggest that heterogeneity in observed effectiveness arises mainly from differences in policy design and from contextual factors, including the duration of the pricing policy, the availability of complementary policies, and local economic conditions. In contrast, price levels across countries, sectoral coverage, and the choice between tax and cap-and-trade explain relatively little of the variation in policy effectiveness. The authors interpret this to be the result of heterogeneous abatement costs, leading price levels to have vastly different effects in different countries. They also highlight that differences in effectiveness across schemes do not negate the benefits of increasing carbon prices within schemes. However, due to the limited empirical evidence on high-level carbon prices, the effect of tax increases within pricing schemes cannot be adequately assessed.

Köppl and Schratzenstaller (2023) further complement these insights by analyzing not only the ecological effectiveness, but also economic impacts of various carbon pricing schemes. In terms of effectiveness, their findings confirm the evidence discussed so far—most pricing schemes result in some emission reductions, but effectiveness differs greatly across schemes and most effect sizes found so far are insufficient to achieve substantial changes in carbon emissions on their own. They also find that the use of revenues to finance improvements in energy efficiency can significantly contribute to carbon reductions. Finally, the authors highlight the importance of economic conditions, including the structure of the energy system and availability of low-carbon alternatives, for successful mitigation practices.

The observed findings on the economic impact of carbon pricing are more inconclusive, however—while no reductions in GDP or employment could be observed in the reviewed literature, the findings on competitiveness and innovation are found to be rather sparse, partially due to measurement issues. However, the evidence concerning the effect on innovation suggests that carbon pricing alone is insufficient to drive the structural and technological changes needed for deep decarbonization; instead, carbon taxes need to be complemented by a wider policy mix, including subsidies, standards, and infrastructure investments.

Overall, four recurring insights emerge from these reviews:

1. While carbon pricing seems to have the intended negative effect on emissions, the reductions observed so far are far below the reductions needed to reach any serious climate target.
2. Effect sizes vary greatly. Statistical analyses suggest that policy context (e.g. the presence of other climate policies, the (macro)economic conditions and emission-intensity of national industries, or the potential for carbon leakage) plays a vital role in determining the effectiveness of carbon pricing.
3. Carbon pricing seems to be a useful tool to incentivize substitution away from carbon-intensive technologies and products *as long as* cleaner alternatives are available or efficiency improvements achievable. Its potential for initiating the structural transformations needed for deep decarbonization, however, remains questionable.
4. Despite rigorous efforts to calculate the optimal carbon price, few pricing schemes come close to the supposedly optimal or necessary price levels discussed above. Instead, political feasibility often determines (and limits) the price level implemented in practice. As Green (2021, 11–12) puts it, "after nearly four decades of experience with carbon pricing, the empirical evidence to date suggests that low prices are a feature of this policy, rather than a bug.".

Based on these findings, two problems of current pricing schemes become evident. On the one hand, political feasibility is a core issue, preventing prices from being in ranges necessary to keep global warming below 2°C. On the other hand, even high carbon prices do not seem to work as effectively as predicted by economic models. Thus, the behavioral incentives intended by carbon pricing seem to face some barriers that are not accounted for in those models.

We will discuss these two issues in more detail in the remainder of this paper.

3. The general concept of political feasibility

The concept of political feasibility is prominently addressed in areas of transition research and focuses on possible pathways from a fossil to a decarbonized society (Roberts et al., 2018). Techno-economic scenarios provide starting points for what a sustainable society based on renewable energies could look like. However, these scenarios are assessed with regard to their feasibility by means of an economic cost-benefit analysis, and aspects of social and political feasibility tend to be omitted (Hoffart, 2022; Hoffart et al., 2021; Jewell & Cherp, 2020). It is precisely these political and social factors that are decisive for the successful implementation and long-term stability of climate policy measures (Cherp et al., 2018; Kallbekken, 2023). In particular, the long-term stability of climate policy measures is demonstrated by the example of the promotion of renewable energies in Germany. In the period from the 1990s to the beginning of the 2010s, the expansion of renewable energies in Germany was promoted across the board and received broad political and social support (Kern & Markard, 2016). In the wake of the Euro crisis, political support for the promotion of renewable energies declined as political will waned due to the economic recession (Meckling, 2019).

This shows that the concept of political feasibility cannot be defined universally and instead depends on the social environment and temporal developments (Gilabert & Lawford-Smith, 2012). In contrast to technical or economic feasibility, political feasibility is often used less precisely, sometimes vaguely equated with political costs or judgments about political possibilities (Meltsner, 1972). However, its analytical usefulness depends on explicitly naming the political constraints at play. Political feasibility is not just about whether something is desirable, but whether it is feasible in practice (Jewell & Cherp, 2020; Peng et al., 2021).

Majone (1975) classifies these constraints on the basis of three dimensions. First, a policy measure must have the necessary resources in terms of support within politics: In order for a policy measure to be implemented in general, policymakers must support it (Majone, 1975; Meltsner, 1972).

Second, policies are subject to distributional constraints. A political proposal must be evaluated according to how it benefits and disadvantages different groups of people. Coercing individuals or groups to accept decisions that they see as unfair or overly burdensome can lead to appeal, litigation, and ineffectiveness. This, in turn, can jeopardize the policy measure or the implementing body itself. Thus, political feasibility is significantly influenced by the distribution of costs and benefits across different social actors (Pierson, 1993).

As a third constraint, Majone (1975) refers to the institutional framework. The implementation of policies follows certain institutional rules that exist in the form of parliamentary procedures, rule of law and also cultural norms (North, 1990). These institutional constraints are beyond the direct influence of political decision-makers and represent structures that have grown over the long term. They are understood as soft constraints that do not make the feasibility of a policy measure impossible, but can make its implementation less likely (Gilabert & Lawford-Smith, 2012).

These three aspects are the basic prerequisites for the conditions under which a policy can be considered politically feasible. In the case of carbon pricing, however, its political feasibility is not just central for the introduction, but also the long-term perpetuation of the policy. Thus, two challenges emerge: On the one hand, there must be the social and political will to implement carbon prices. On the other hand, carbon prices must be accepted by society in the long term. Since the introduction and existence of a carbon price is an inherently political endeavor, various social actors must be brought into focus.

In the following subsections, we apply these three constraints to societal actor groups that play central roles in the long-term implementation of climate policies. In doing so, we will first address political actors, which, through their role in government and opposition, determine the legislative implementation and policy design of these measures.

3.1 Political feasibility within politics

In Western democracies, most states consist of parties that form the government and parties that act in the opposition. Within this construct, there are formal and informal frameworks that influence legislation and the political process in general. In order to initiate a carbon price, parties in government must create majorities within the political process. Such majorities in the form of coalitions can be understood as political resources as defined by Majone (1975).

With a carbon price, the negative effects of the use of fossil fuels are to be priced into the economic process and at the same time further economic growth is to be made possible. Thus, political actors are exposed to a conflict of goals within fossil economies. Their central task is to moderate different interests. On the one hand, the state pursues the containment of climate-damaging emissions and strives to comply with international obligations. Emissions must be reduced throughout the economic system and at the same time continuous economic growth must be sought. On the other hand, the state must moderate different and often conflicting economic interests and meet the expectations of voters in order to continue to be able to act.

This conflict of goals is reflected in the design of a carbon price. To be ecologically effective, it must make the use of fossil fuels unprofitable. As explained earlier, the carbon price would be significantly higher than its current level and lead to massive conflicts within society that prevent the implementation or existence of a carbon price. For a long-term effective climate policy, politicians and bureaucrats must design measures in such a way that they at least weaken opposition and, in the best case, promote support (Edmondson et al., 2019, 2020). In order to make policies resistant to negative pressures, a carbon price must be flanked by other climate and social policies (Jordan & Matt, 2014).

A central aspect here is the fundamentally regressive character of a carbon price, which negatively affects acceptance. To ensure that broad sections of the population do not oppose a carbon price, it is necessary to link state revenues through a carbon price with redistributive measures. On the part of industry representatives, funding programs are being demanded for a phase-out of fossil fuels and the further development of renewable alternatives. At the same time, such funding programs run the risk of manifesting technologies that contribute to further conflicts and open up the space for further influence by interest groups (Rosenbloom et al., 2019). In addition, the state has the potential to determine economic development paths for long periods of time through support programs (Pierson, 2000). For example, there is a risk that after the phase-out of coal and nuclear energy in Germany, the expansion of the natural gas infrastructure could delay the transition to a decarbonized economy (Kemfert et al., 2022). The state must therefore ensure a long-term perspective for the transformation path with the help of climate policy measures, anticipating possible obstacles due to a lack of acceptance and resistance (Edmondson et al., 2020).

This again highlights the complex interplay between politics, business and the broader public. The introduction and maintenance of a carbon price is the subject of constant social negotiation processes that are determined by the structure of the political process.

In the following, another social actor group in the political process is discussed. The focus here is on interest groups that are influenced differently by the distributional effect of a carbon price and therefore try to influence the design of a carbon price.

3.2 Political feasibility and organized interests

The introduction or adjustment of a carbon price influences the cost structure of companies or entire industries. For example, a carbon price increases the production costs of carbon-intensive industries, whereas carbon-efficient industries are relatively better off. Based on these distributional effects, either support for or opposition to a carbon price can form (Edmondson et al., 2019; Pierson, 1993). Interest groups[1] are particularly interesting from a political science and politico-economic perspective because, in contrast to the general population, they have direct access to the political process through lobbying (Klüver & Zeidler, 2019; Pierson, 1993).

In this context, the formation, mobilization and political influence of interest groups do not only depend on the re-allocation of resources, but are also conditioned by the market structure of the affected industries (Peng et al., 2021). Klüver and Zeidler (2019) show that both the size, measured in terms of the number of companies, and the value added are reliable predictors of lobbying activity within an economic sector. Interest groups in these sectors benefit from synergy effects and the financial resources invested in political influence. Notably, the results also show a reciprocal relationship between lobbying and

1 *The term interest groups includes not only economic interest groups, but also NGOs and trade unions. These are omitted from this consideration, as they are not considered here as direct representatives of the economic interests of affected industries. Nevertheless, these interest groups are also important actors in the political process and can support the implementation of a socio-ecological transformation (Cremer 2024; Trappmann et al., 2024).*

parliamentary initiatives—as the number of administrative requirements increases, so does lobbying, and the same applies vice versa.

In this way, established industries generally have an advantage over newer industries in influencing the political process. This advantage in the basic economic endowment and the resulting influence of interest groups can consolidate existing power structures over time and lead to path dependencies (Pierson, 1993; 2000). This hinders the introduction or increase of a carbon price due to the relatively strong power position of interest groups of fossil fuel industries. Michaelowa (2013) outlines the shift in the positioning of fossil interest groups since the 1990s in Germany. Initially, exemptions from climate policy regulations were obtained for certain industries. When pollution rights were then freely distributed within the framework of the EU ETS and unexpected profits could be achieved, the headwind weakened somewhat. In addition, an industry formed around renewable energies and a broader social commitment to environmental protection emerged.

On the part of industrial and corporate interest groups, the opposition to climate policies uses common lines of argumentation. Possible losses in sales, the reduction of investments, layoffs of employees or even the relocation of the production site are cited as threatening scenarios in order to directly influence the political process or to mobilize the general population against climate policy intervention via the media (Lockwood, 2013; Meckling, 2019). Thus, interest groups of carbon-intensive industries generally have an effective lever and can actively influence the political process.

The last actor group to be addressed is the broader public. Similar to economic interest groups, it is also affected by distributional effects. The special feature here is that the broader public does not directly influence the political process. However, it can express its interests through its voting behavior.

3.3 Political feasibility and the broader public

The distributional effect of a carbon price has a significant impact on the broader public in the form of income effects, the intensity of which varies across the income distribution. On average, wealthier households cause more CO2 emissions than low-income households. But these low-income households bear a higher burden from carbon pricing, as they have to spend a higher proportion of their income on necessary consumption (Grainger & Kolstad, 2010). Thus, a carbon price in an unequal society has a regressive effect and places a greater burden on those households that have fewer opportunities to adapt their consumption behavior (Muth, 2023).

Survey studies on the acceptance of carbon prices show that acceptance depends largely on the social compatibility of a carbon price and the reuse of government revenues. In general, a progressive distribution of costs is preferred, in which wealthier households pay relatively more and poorer or vulnerable ones are compensated proportionately (Klenert et al., 2018; Maestre-Andrés et al., 2019). In addition, a targeted use of the revenues collected for further climate protection measures is appreciated. (Levi, 2021; Maestre-Andrés et al., 2019). If the revenues from carbon pricing simply flow into the state budget, this tends to reduce the acceptance of carbon pricing (Klenert et al., 2018; Mildenberger et al., 2022).

Certainly, the public acceptance of carbon prices depends on other factors, such as the fundamental political attitude, confidence in the state's ability to act and the public debate (Maestre-Andrés et al., 2019; Mildenberger et al., 2022; Savin et al., 2024). Nevertheless, a socially acceptable design of carbon pricing is crucial in order not to risk the support of the population or strengthen political forces that oppose climate protection.

Depending on the social compatibility of carbon prices, acceptance among the broader public can lead to ecologically progressive political parties being elected to government. To this end, however, socio-economic lines of conflict must be considered and mechanisms of social cushioning included in the design of carbon pricing schemes.

4. Behavioral barriers

The previous chapter has addressed the question of how to implement and maintain a sufficient carbon price given political interests and their influence on the realizability of the measure. However, chapter 2 has shown that even some historical carbon prices that have come close to or even exceeded the presumed optimal price level fail to induce the necessary emission reductions. Apparently, therefore, there seems to exist an ongoing discrepancy between theoretical predictions and the realized outcomes of carbon pricing policies.

We argue that part of this misprediction lies in the way the standard economic model portrays human behavior and behavioral change. Building on the rational actor, the model describes a form of decision-making that, as empirical studies have shown, can only be observed in some contexts and is not adequate to describe the everyday behavior that is ultimately resulting in most carbon emissions (Frederiks et al., 2015). Instead, human behavior depends on a multitude of both internal (e.g. values, perceptions, habits) and external factors (e.g. resources, infrastructure, social norms), which are interdependent and shape behavior to different degrees based on the relevant context (Milfont & Markowitz, 2016; Wang et al., 2021).

The following sections summarize the literature on how real-world behavior differs from the standard economic model in the context of carbon pricing and sustainable behavior. We start by investigating the role of the rational actor in the standard-economic model of carbon pricing in more detail. Afterwards, we discuss various empirical findings of 'imperfect' decision-making and the role of voluntary pro-environmental behavior to understand how the ineffectiveness of carbon pricing can be counterbalanced by additional, behaviorally informed policies.

4.1 Rationality in Pigou's model

Like most standard-economic models, Pigou's model (1920) places humans in a world where markets are the only place of interaction and all decisions to be made are economic in nature. The economic agent (homo economicus) follows the basic principle of optimization—consumers maximize their private utility and firms maximize their private profits. In a free market with full information and no market power, the coordination of supply and demand via price signals produces a pareto-efficient allocation of resources such that costs will be minimized and welfare maximized. By means of a Pigouvian tax (here as carbon price), the social costs are internalized into the individual cost calculations and a welfare-maximizing equilibrium is achieved again.

The initial idea of carbon pricing is therefore fundamentally based on the assumptions of a rational, optimizing agent whose welfare depends exclusively on economic cost-benefit considerations. While it cannot be denied that people make cost-benefit assessments and that prices do in fact influence firm and consumer behavior, behavioral research shows that there is far more to (economic) decision-making (Milfont & Markowitz, 2016). But how do deviations from the rational model affect the effectiveness of carbon pricing?

To answer this, we will first examine the basic characteristics of the rational actor and consider how, in theory, a violation of these characteristics might affect his reaction to a carbon price.

Urbina and Ruiz-Villaverde (2019) define homo economicus based on five distinct characteristics: Individualism, optimizing behavior, full rationality, exogenous preferences and universality. We discuss each of these in turn.

First, *individualism* describes the assumption that the economic agent exclusively considers his own interest. While this does not exclude social preferences per se, pro-social behavior itself can only be the result of self-interest. In addition, the agent's social environment does not influence the decision-making process, i.e. his decisions are made in a 'vacuum'.

Individualism is a central assumption for the economic model of carbon pricing because it constitutes the fundamental source of the externality problem: Since agents only consider their own welfare, private costs and social costs can deviate and need to be aligned by the Pigouvian tax. And as an agent's social environment does not influence his choices, prices are the only way to alter behavior.

A deviation from the individualism assumption itself must not necessarily reduce the effectiveness of carbon pricing, but taxing emissions might be less crucial to solving the climate problem. If we assume that most people care about others and are willing to forego personal gains in order to act pro-socially, other measures might be just as important to motivate sustainable behavior—information provision, norm-based messaging or collective projects could encourage behavioral change without having to rely on the continued upkeep of a monetary incentive. Even more, if unsustainable patterns of behavior are the result of people's social context, price signals might actually be less effective—in this case, motivating sustainable behavior via non-market interventions would be even more crucial.

The second characteristic, *optimizing behavior*, expresses the utility- and profit-maximizing motive described above. By this assumption, each decision is made based on an elaborate, often intertemporal, cost-benefit-analysis to optimize private gains. When social costs are adequately represented in market prices, individual optimization will also lead to collective welfare optimization.

If people do not optimize, price changes alone may fail to induce the predicted shifts in behavior. Instead, people might rely on simple rules of thumb (heuristics) or follow a "good enough" approach (satisficing), as has been studied extensively by behavioral economists (Mullainathan & Thaler, 2000). In such cases, choice-architecture interventions—like setting green options as defaults or providing targeted nudges—can compensate for the lack of optimization and induce low-carbon behavior more effectively (Frederiks et al., 2015).

Third, the rational actor is assumed to possess *full rationality*, allowing him to perfectly process all available information and choose the best option available. In the case of carbon pricing, it follows that agents are immediately aware of the change in prices and instantly switch to a more sustainable (i.e. cheaper) alternative. If the government communicates a fixed price path for the carbon tax, the rational actor can flawlessly integrate those expected future prices into his investment and consumption plans. Finally, homo economicus is not interested in the origin of the increased price, but will adapt his behavior to the tax in exactly the same way as he does to usual market-based price changes.

If we loosen the assumption of full rationality, people either have incomplete access to the relevant information or they are not able to perfectly process them. Consequently, they might not notice or care about the price changes. Moreover, they might be unable to identify or access lower-carbon alternatives—in this case, the tax would merely raise costs without lowering emissions, reducing material welfare without the environmental gain.

In addition, the concept of tax aversion shows that people do not react to taxes the same way as they do to regular price changes (Kallbekken et al., 2011). If they refuse to accept the tax, they might also deliberately ignore it and resist the behavioral adjustment.

Fourth, the standard-economic framework treats individual *preferences as exogenous*. While strong assumptions about the structure of preferences are made to ensure the consistency needed for mathematical optimization—they are usually assumed to be complete, transitive, and monotonic—the initial process of forming preferences is beyond the scope of traditional economics. Under the assumption of stable preferences, shifting relative prices is therefore the only viable lever for influencing consumption patterns.

Treating preferences as endogenous, on the other hand, might show that personal needs, desires and tastes are not stable, but shaped by context, learning or socialization (O'Hara & Stagl, 2002). If the formation of preferences depends on such external factors, carbon pricing would not be the only (or even most effective) strategy to motivate more sustainable behavior. It would even be possible that modern economic activity, expressing current socially-shaped preferences, might be sub-optimal in terms of well-being compared to an economy in which other things are valued and other goals pursued.

Lastly, the *universality* assumption claims that every person acts according to the rational actor model, independent from context, culture or personality.

Thus, if everyone applies the same rational decision-making process in every situation, a global and universal carbon price is the best instrument to achieve the social optimum.

If instead we assume that people apply varying decision processes in different social roles, economic contexts and stages of life, policy instruments too would need to consider these differences. For instance, promoting sustainable consumption choices might require a different strategy from decarbonizing the energy sector.

To summarize, we have demonstrated how the theoretical superiority of carbon pricing fundamentally relies on assumptions of a perfectly rational actor. If those assumptions are violated, efficiency and effectiveness might be strongly diminished, and other sustainability strategies and policy instruments gain significance.

4.2 Price signals and behavioral change

Behavioral economics has indeed shown that people do not always act rationally, but that our behavior is often guided, for instance, by cognitive biases and heuristics (Shogren & Taylor, 2008). This can lead to individuals not recognizing or caring about price changes, or not having the willingness or capacity to adjust their behavior. Consequently, people tend to stick to high-carbon consumption patterns despite the additional cost of a carbon tax (Stoll & Mehling, 2021).

To solve the persistence of unsustainable patterns of behavior, understanding its root causes can help guide decision-makers in designing adequate responses and interventions to complement the financial incentive of carbon pricing.

The range of cognitive biases and behavioral anomalies studied by behavioral economists has grown steadily in recent decades and found application in various fields (Mullainathan & Thaler, 2000). The strand of literature focusing on sustainable behavior such as household energy use (Wilson & Dowlatabadi, 2007), low-carbon transport (Gaker et al., 2010) or green consumer choice (Sunstein & Reisch, 2014) has identified a subset of these biases that seem particularly relevant to these contexts. We categorize them in two groups according to how they influence the effect of carbon pricing: First, they affect whether any behavioral changes are made at all, and second, they influence the kind of behavior that is adopted instead.

The first challenge then lies in ensuring that the carbon price provides sufficient incentive for individuals to adjust their behavior in the first place. Empirical research indicates that people exhibit strong *inertia*, favoring familiar routines and only reluctantly modifying their existing habits even when behavioral changes would benefit them (Marechal & Lazaric, 2010). The cognitive component of the same phenomenon has been studied under the notion of *status-quo bias* – a systematic preference to maintain or repeat prior choices even when better alternatives are available (Samuelson & Zeckhauser, 1988). In general, habituation arises from a cognitive mechanism designed to minimize mental effort, reduce learning costs, and preserve one's sense of competence and self-control (Galla & Duckworth, 2015; Jager, 2003). Such strong habits are especially relevant in every-day activities such as personal mobility, dietary choices, and residential energy use (Wang et al., 2021) and have been found to impede switches to low-carbon behaviors in these contexts (R & Perumandla, 2023; Watkins & Musselwhite, 2025). This highly habitual nature of most carbon-intensive consumer behaviors has led some authors to declare habits as the most important barrier to sustainable behavior (Huebner et al., 2013; Wang et al., 2021).

The second challenge lies in ensuring that individuals who do respond to the carbon price by altering their behavior do so in ways that effectively reduce their carbon footprint.

Behavioral economics shows that the optimization assumption of traditional economic models does not apply to many real-world behaviors, but that most decision processes are guided by heuristics, satisficing and social cues (Frederiks et al., 2015). *Satisficing* refers to the human tendency to exert only the effort needed to achieve a satisfactory rather than an optimal result. Instead of systematically processing all available information to maximize utility, people often settle for 'good enough' or the first available option that meets minimum requirements (ibid). Similarly, heuristics describe choice strategies that do not rely on careful cost-benefit analyses, but use simple rules of thumb to reduce the complexity of decision-making processes.

Consequently, consumers facing a carbon price might reduce high-carbon behaviors or switch to less carbon-intensive goods, but do so in ways that are not as effective as predicted. For example, consumers might rely mainly on product marketing to choose more sustainable products, which can lead them to overestimate the carbon reductions from products labeled as 'eco-friendly', ultimately causing only minimal environmental impact despite the intention to act more environmentally-friendly (Hossain et al., 2022). Indeed, survey evidence indicates that many consumers misjudge the carbon-reduction potential of various actions (Ipsos, 2021).

These findings underscore the difficulty of influencing consumption patterns that have been reinforced by habit and familiarity, as well as encouraging behavior change that truly decreases consumer's carbon footprint. Consequently, for carbon pricing to trigger meaningful emission reductions, a carbon price must be complemented by interventions that directly lower these behavioral barriers. Promising approaches include implementing green default settings and opt-out programs that leverage inertia in favor of sustainable outcomes—for instance, making renewable energy the standard option in new electricity contracts (Pichert & Katsikopoulos, 2008) or offering plant-rich meals in school cafeterias by default (Marcano-Olivier et al., 2020). Similarly, providing consumers with clear information on effective carbon-reduction strategies can steer their decision-making toward more sustainable practices.

4.3 Carbon taxes meet pro-environmental behavior

While the behavioral economics perspective is concerned with strategies to correct behavioral failures and promote decisions that resemble that of the rational agent, it still follows the standard-economic argument that consumer behavior must be regulated from the "outside" to achieve the social optimum. In doing so, the economic perspective assumes that people have no intrinsic incentive to make decisions for the sake of sustainability itself—a direct consequence of the individualism assumption discussed above.

While most economists probably would not deny the existence of pro-environmental values, one argument for carbon pricing is that we do not *have to* rely on moral considerations to solve the climate crises (Baranzini et al., 2017).

However, this argument faces two major problems.

First, carbon pricing and the focus on a purely economic solution has been shown to interfere with pro-environmental behavior. Experimental research shows that people's intrinsic motivation to act pro-environmentally can be diminished or replaced by an extrinsic incentive that is aimed at promoting the same behavior, such as the carbon price (Gowdy, 2008). This *crowding-out effect* has been studied in other contexts by both psychologists (e.g. Deci, 1971) and behavioral economists (e.g. Gneezy & Rustichini, 2000), but has gained more attention with regards to carbon pricing in recent years.

Experimental studies confirm that the price effect of a carbon tax intended to reduce consumption is partially offset by an (openly communicated) carbon tax (Grieder et al., 2021; Lanz et al., 2018), suggesting that consumer's intrinsic motivation to reduce emissions is indeed reduced by their awareness of the tax. One explanation is so-called 'moral licensing'—paying a higher price for carbon-intensive goods can make consumers feel they have 'earned' the right to continue harmful behavior, as the extra cost is perceived as compensating for the environmental damage (Stoll & Mehling, 2021).

This line of argument is further supported by evidence that earmarking the tax revenues, i.e. using them to finance green projects or subsidize sustainable alternatives, further increases the willingness to buy a high-carbon good (Grieder et al., 2021). Again, it is assumed that part of the perceived moral obligation to act pro-environmentally is crowded out by the knowledge that the tax revenues are utilized for sustainable purposes. In addition, consumers might actively believe the product to be 'greener' as their purchase is indirectly used to mitigate climate change elsewhere.

Interestingly, the observed negative effect of earmarked carbon taxes on sustainable behavior mirrors the evidence that earmarking carbon prices increases the acceptance of the policy. While the latter finding is often used to recommend implementing carbon taxes and using the revenues for environmental purposes, the former literature suggests avoiding explicit earmarking to not reduce the effectiveness of the tax. Thus, the question of revenue use seems to face a trade-off between public acceptance and behavioral effectiveness.

In addition to the crowding-out effect, the economic focus on monetary incentives might have another downside with respect to pro-environmental behavior: Experimental evidence indicates that money itself can undermine cooperative behavior, with the mere mention of money resulting in more self-regarding attitudes and reduced pro-social decisions (Vohs et al., 2006). Therefore, arguing that behavior is best regulated via economic incentives because people inherently follow their own interest might turn out to be a self-fulfilling prophecy.

Concluding the first problem of exclusive reliance on carbon taxes to mitigate climate change: In cases where people are self-motivated to reduce their environmental impact, a carbon price that undermines this motivation can lead to less effective emission reductions than would occur through their unaided, voluntary actions.

Second, the economic perspective ignores the fact that extrinsic and intrinsic motivation have qualitatively different behavioral consequences.

Extrinsic motivation, on the one hand, faces the disadvantage that it often needs to be permanently maintained in order to trigger a lasting change in behavior; once the incentive is removed, behavior is often found to revert back to baseline levels, especially when the behavior change has not resulted in new habits (James, 2005). Moreover, some studies find that the behavioral effect of the incentive declines over time as individuals get used to it, resulting in the need to increase the size of the incentive to maintain persistent behavioral adjustments (ibid).

Intrinsic and autonomous motivation, on the other hand, have been shown to produce long-lasting behavioral patterns that are not only independent from the existence of an extrinsic incentive, but which also deepen investment in the behavior itself and improve peoples' psychological well-being (Ryan & Deci, 2000). Indeed, individuals who act out of genuine concern for the environment have been found to develop stronger habits and green lifestyles, which can positively influence others and foster a collective culture of sustainability (Faraz et al., 2021). Research on the determinants of persistent pro-environmental behavior also confirm the importance of moral conviction, environmental values and voluntary action (Bamberg & Möser, 2007).

Unfortunately, pro-environmental attitudes do not always translate into pro-environmental behavior, as extensive research on the value-action-gap, attitude-action-gap and intention-action-gap shows (Kollmuss & Agyeman, 2002). To bridge these gaps, efforts need to be made to remove structural and institutional barriers hindering the adoption of sustainable behaviors. For instance, providing a safe bicycle infrastructure, reliable public transport and walkable environments have been found to be the key instruments for reducing transport-related carbon emissions (Javaid et al., 2020). Similarly, governments can promote longer product life spans by setting standards on product durability and repairability or promoting business models that specialize on repair, refurbishment and repurposing of products (Milios, 2021). Lastly, subsidies or 'green' loans can help lower-income households overcome financial barriers that might otherwise prevent them from investing in energy-efficient technologies (Wilson & Dowlatabadi, 2007).

In light of these findings, it becomes evident that placing singular focus on carbon prices risks missing the chance to encourage meaningful, long-term behavioral change through policies designed to close the value–action gap and promote collective sustainable action.

5. Conclusion

This article has outlined the basic, economic foundations of carbon pricing. Its origins go back to Pigou, whose idea of taxing an externality to correct the market failure it caused has laid the foundation for how economists understand the problem of (and solution to) climate change today. Decades later, William Nordhaus advanced Pigou's idea by integrating it into formal climate-economy models to derive a carbon price that balances the economic benefits of fossil fuel use with the costs of climate change. Despite criticism on core modelling assumptions, as well as on the overall approach that prioritizes economic optimality over effective environmental protection, Nordhaus's work forms the basis for most of today's carbon prices.

As empirical evaluations show, however, the majority of carbon prices implemented to date are neither as high as supposedly necessary, nor as effective as predicted. We argued that two aspects, among others, lack in the economic conceptualization of carbon pricing which hinder its effectiveness in practice: The issue of political feasibility and the diversity of human behavior beyond the assumptions of the rational actor model.

From a politico-economic perspective, the introduction and implementation of a carbon price are shaped by the heterogeneous interests and influence of societal actors. Political feasibility depends on the support of these actors, typically divided into the mass public, interest groups, and the political elite. Consumers, who experience carbon pricing mainly through income effects, represent the central actors of the mass public. Social support depends less on the price level itself than on compensatory measures that offset income losses and facilitate sustainable choices. Interest groups, representing firms and sectors, are likewise affected by distributional effects but can shape political decisions through lobbying; their resources and interests must therefore be considered in policy design. Finally, the state, composed of diverse political actors, seeks to represent voter interests. The design of a carbon price can thus create path dependencies that either reinforce or mitigate social inequalities.

The analysis of psychological and behavioral factors shows that carbon pricing models fundamentally rely on the rational actor assumption, which is central to their conclusion that putting a price on CO2 is the most efficient solution to climate change. Real-life behavior, however, has been shown to regularly deviate from these assumptions, which ultimately reduces the observed effectiveness of the policy. These findings highlight the need for behaviorally informed and complementary policies to make the theoretical efficiency work in practice. This includes removing behavioral and structural barriers from low-carbon choices, as well as fostering the sense of collective action and pro-social attitudes necessary for people to practice sustainable behaviors on their own volition and conviction. Finally, for those behaviors that are not easily accessible or have high initial costs, subsidies and increased availability can foster behavioral changes that carbon pricing alone cannot achieve.

In sum, our analysis of the political-economic, psychological and behavioral economic factors shows that a carbon price alone is not an effective measure to sufficiently reduce carbon emissions. Based on these findings, we argue that, in addition to economic factors, a broader, interdisciplinary view is crucial when designing a carbon price in order to make the policy both socially acceptable and ecologically effective. Economists must include such interdisciplinary factors in their analyses if they want to make a goal-oriented contribution to the socio-ecological transformation of our societies.

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