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A critical assessment of the effectiveness of low-carbon nudges

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Abstract

Many hope that nudges are a useful and effective complement to more traditional instruments of climate and environmental policy. This paper provides a comprehensive, systemic assessment of the potential of low-carbon nudges. It starts by synthesizing recent evidence from reviews and meta-analyses on the effectiveness of stand-alone nudges. Various sources indicate that overall emission-reduction effects tend to be modest. We discuss reasons for why nudges sometimes fail, such as habits, rebound and counter-nudges. Next, we examine how nudges interact with other policies, and what this implies for policy effectiveness and acceptance. The paper ends with a broader discussion of the role of behavioral science and nudges in the context of a low-carbon transition.

Keywords

Behavioral interventions; Climate policy; Green nudges; Policy mix; Systemic effects

JEL classification codes

D90, Q54, Q58.

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1. Introduction

The idea that various policy instruments are needed to achieve a transition to a low-carbon economy can count on broad support. To complement traditional command-and-control and pricing instruments, increasing attention is given to what is commonly called "nudges", denoting interventions that gently and subtly aim to change the choice architecture of actors relevant to the low-carbon transition (Thaler and Sunstein, 2009). Here we zoom in on low-carbon nudges as an instrument to help reach climate targets.

It should be said at the outset that the meaning of nudge is somewhat ambiguous. The notion overlaps with, though is not identical to, notions such as "behavioral interventions" and "information provision". Behavioral interventions often include economic incentives, while nudges can deviate from information provision if they involve physical re-design of choice environments. In fact, one might distinguish between physical and information nudges, and within the latter between private nudges (e.g., information about low-carbon options) and social nudges (information comparing with behavior of peers). Among the most widely cited low-carbon nudges are the communication of social norms, the use of default options, and the framing of information (such as by emphasizing losses rather than gains). Many governments around the world as well as international organizations have established 'nudge units' (OECD, 2017) or articulated their usefulness in achieving environmental goals (UNEP, 2020). In this respect, the term "green nudges" is sometimes used, and "low-carbon nudges" can be seen as a sub-category of it.

It is important to have a good empirical understanding of the effects of nudge interventions. A considerable body of climate-modeling research has highlighted the potential emissions reductions from demand-side interventions. While most of this research focuses on potential emission reductions deriving from changes in relative prices, some studies have estimated *potential* reductions from behavioral changes due to non-price interventions. For example, a much-cited US study has quantified the plasticity of various household actions, such as one-time investments in energy efficiency of buildings, adopting more energy efficient appliances, and changing infrequent or habitual behaviors (Dietz et al., 2009). It finds that, all together, such easy and near-term behavioral interventions can reduce total US emissions by 7.4%. The authors argue that this can be achieved by clever combinations of "behavioral interventions". Other more recent studies point to similar magnitudes of potential emission reductions (Wynes and Nicholas, 2017; Lacroix, 2018; van de Ven et al., 2018).

While these studies estimate modest behavioral changes triggered by nudges (or similar interventions), they may still overestimate their ultimate effectiveness since they lack a complete empirical understanding of what nudges actually contribute. Do they meaningfully complement conventional climate policies or create false expectations? Furthermore, policies need to be assessed on other dimensions beyond the main environmental effects. In particular, environmental policies have often been shown to have unintended side-effects (Gysen et al., 2006). For example, while energy-efficiency policies may increase energy savings, the simultaneous monetary savings can lead to more

energy use in other domains (Sorrell et al., 2020). In view of this, in this paper we will try to answer the following questions: What are limitations of the nudge approach, what are its indirect or systemic impacts, and how might it reduce the effectiveness of, or support for, other climate mitigation efforts? To answer these questions, we will critically discuss, adopting a systemic perspective, what nudges can achieve in terms of emissions reduction.

2. Overview of meta-assessments of low-carbon nudges' effectiveness

In recent years several meta-analyses and quantitative reviews of the effects of nudges (or "behavioral interventions") have been undertaken. We first consider studies that are more general and cover various domains, and then move to those that are focused on concrete areas such as household electricity use.

One of the most comprehensive quantitative reviews of the impact of nudges in general (e.g. health, pensions) was conducted by DellaVigna and Linos (2020), with a subset of covered studies on environmental issues. The authors analyzed data that was collected by two actually existing 'nudge units' that worked with federal and local governmental agencies in the US, and compared these findings with nudges' estimates derived from the academic literature. They find that nudges implemented in real-life settings tend to have lower effects than the ones conducted in academic studies: 1.4 versus 8.7 percentage points. The authors demonstrate that publication bias in academic journals and differences in nudge features largely explain this sizable gap. The review concludes that one percentage point should currently be viewed as a lower bound of effect sizes of nudges. Interestingly, using questionnaire surveys they also compare their research findings to academics' and practitioners' expectations regarding nudges' effectiveness. These comparisons show that practitioners have more accurate beliefs about what nudges can achieve. However, there are some noteworthy nuances regarding environmental nudges, namely: they are among the least frequently tested in the real-life nudge units (<1% of all assessed nudges), but have relatively high effect sizes, compared to nudges in other areas such as health care or "workforce and education" (encouraging job seekers to improve their search plans), in both nudge units as well as academic publications. This result of the general literature on nudges calls for zooming in on review studies that focus exclusively on environmental nudges.

A study by Nisa et al. (2019) undertook a meta-analysis of randomized controlled trials – what some consider the 'gold standard' of evidence – to reduce household emissions. Areas covered by the study are energy consumption in the home, transport, meat consumption, food waste, water use and recycling. It analyzed 83 studies published between 1976 and 2007, which included 144 estimates of intervention effects. The average effect size captured by Cohen's d equalled -0.09, which is according to the standard interpretation a "very small" effect. A complementary indicator is what the authors call the "probability of benefit" from an intervention, which they estimate to be 6.6%. This can be interpreted as the chance of an individual to reduces emissions at all. Estimatated effect sizes go down further when only studies with larger sample sizes are taken into account. In addition, different types of interventions show varying levels of effectiveness: choice architecture (which they consider as "nudges") and social

pressure are more effective than simple provision of information (e.g., facts and figures). The authors also compared their results with estimates of "behavioral plasticity" of the earlier mentioned study by Dietz et al. (2009). For example, the latter estimated that by using the best interventions, one could achieve that 80% of non-adopters buys more energy-efficient appliances within 10 years. The meta-analysis by Nisa et al., however, finds zero effects of interventions to encourage such purchase behavior. Finally, the analysis indicates that there were no sustained long-term effects once the intervention was terminated. While the results of Nisa et al.'s analysis have been challenged on statistical grounds, with re-estimations leading to slightly bigger effects (van der Linden and Goldberg, 2020), overall they suggest that one cannot expect too much climate mitigation from such interventions for now. One cannot exclude, however, that informed by experiences and evaluation studies, better design of nudges can lead to improved effectiveness.

Another systematic review of "behavioral interventions" covers 40 studies on three high-emitting domains: personal vehicle use, meat consumption and household energy use (Wynes et al., 2018). Emission reductions from interventions, here quantified as the percent of the average American's emissions, amounted to 3.2% for personal vehicle use (translating into a reduction of 571 kgCO2e/yr), 0.3% for meat consumption (51 kgCO2e/yr) and 0.8% for electricity use (149 kgCO2e/yr). However, there are many limitations and nuances to these findings. Most studies (29/40) came from the household energy domain, with the most common intervention being "feedback". The authors note that interventions related to household energy use may depend on the characteristics of the electricity grid of each country. With increasing decarbonization of grids, the magnitude of effects from behavioral interventions may go down over time. A related point, and consistent with Nisa et al. (2019), is the persistence of observed effects, given that most studies have a limited time frame. Success of interventions is different for subpopulations – e.g., higher education groups tend to be more responsive to energy reduction. The authors also hint at the energy rebound effect, a point to which we will dedicate more attention in the next section. Taken together, this study seems to draw mixed conclusions when stating that effects of such interventions are "promising, yet much smaller than the scope and scale necessary to meet international climate targets".

A somewhat higher estimate is found in a meta-analysis of 116 studies by Nemati and Penn (2020). Their analysis covers studies from predominantly the electricity sector as well as about water and gas. What they call "information-based interventions" includes many of the typical types of nudges, such as usage feedback and peer information. Their average effect size is 6.24%. However, the authors find that effect sizes are smaller for randomized controlled trials, as well as for studies with representative samples and longer duration of the intervention. These findings resonate with the aforementioned reviews.

Some studies are more focused on individual domains, such as household electricity use. Delmas et al. (2013) reviewed 59 articles which included 156 field experiments that were aimed at reducing household energy use. On average, they found that individuals in the experiments reduced their

electricity consumption by 7.4%. Regarding specific types of interventions, the analysis shows that providing individualized audits and consulting are more effective at inducing conservation behavior than interventions that provide energy feedback using historical or peer comparison. An important further insight, consistent with Nisa et al. (2019), is that the average treatment effect diminishes with an increasing quality of studies. The latter refers to studies having a control group and controlling for relevant factors underlying energy use, such as demographics or weather effects. Distinguishing between low and high quality studies, the authors find that the average reduction in electricity use goes down to 1.9% for what they consider as high-quality studies. This estimate resonates with a more recent meta-analysis of 52 studies of residential electricity behavior (Buckley, 2020). It finds a 1.9-3.9% reduction of consumption from nudges. Of the studies covered, 79% involve individual electricity feedback, 27% social norms and 25% injunctive norms. Social and injunctive norms are found to have no statistically significant effect on electricity use, in contrast to other strategies, such as individual and real-time feedback, which do lead to energy conservation. Another (unpublished) meta-analysis investigates 122 studies and 360 effects sizes related to interventions on energy demand in residential buildings (Khanna et al., 2020). It finds standardized effect sizes ranging from 0.13 for feedback and social comparison to 0.19 for motivation. They find that newer studies, as well as those with less bias in the selection of respondents, report lower effect sizes. Finally, evidence suggests that effect sizes of interventions are not higher in more recent years (Khanna et al., 2020).

To conclude the overview of evidence in this section, some comments on, and interpretations of, methodological aspects are in order. First, there is heterogeneity in methodological features of studies, such as sample sizes or self-selection bias, which can lead to different estimates of nudges' effects (Nisa et al., 2019). For example, it seems that studies with larger sample sizes have lower effect sizes. Second, several meta-reviews indicate that effects are lower in studies with a longer timeframe, suggesting a lack of persistence of in the impacts of respective interventions (Khanna et al., 2020; Nemati and Penn, 2020). Third, the fact that effect sizes in more recent studies tend to be lower (rather than higher) suggests that researchers are not necessarily moving up the learning curve of nudge effectiveness.

3. Why nudges sometimes fail

As the previous section already indicated, nudges do not always work. In fact, research is beginning to pay attention to the question of why nudges are ineffective or even backfire (Sunstein, 2017; Osman, 2020). Such failures have to do with individual-level as well as systemic factors. Here we discuss several reasons, without claiming to be exhaustive.

3.1 Heterogeneity in individual and group characteristics

Effects of nudges can differ greatly between people or groups of people. A well-known example is that social-norm nudges in the US have been shown to promote energy conservation much more among

politically liberal than conservative households (Costa and Kahn, 2013). This may be explained, among others, by certain nudge messages being identified as "environmental", which can lead to indifferent or even defiant reactions by certain people inclined towards conservative politics. Other individual characteristics matter. For example, certain green nudges work better for lower levels of income and education (Akbulut-Yuksel and Boulatoff, 2021). Sometimes a nudge can even promote backfire effects among subgroups, leading to zero effects at the aggregate level. For example, one study reports that social norms have induced increases in energy consumption among those that initially used very little energy (Ayres et al., 2013). Overall, this suggests that nudges require substantial efforts of targeting and customizing in order to produce high effects. This in turn may be challenging in terms of administrative capacity and skills. Some nudges come with the need to make decisions about various design features, such as the amount of information provided, which can be either too low or too high (Tyers, 2018). Despite such technical challenges, some heterogeneous reactions may be improved by clever design of nudges, incorporating lessons from experiences.

3.2 Habits

Whether a nudge works or not depends on the type of behavior it targets. Some nudges may target behaviors that are very habitual, which are notoriously hard to change. To illustrate, consider a study that conducted five large-scale field experiments on commuter behavior (Kristal and Whillans, 2020). It involved almost 70,000 employees of a company in the US and it was specifically aimed at reducing single-occupancy driving. Various types of interventions were tested, including distinctly framed letters and emails to increase carpooling registration, or simplifying the matching systems of carpoolers. Across the five experiments, they found limited evidence for behavioral changes, which is argued to be due to habitual nature of commuting behavior. It could also mean that the costs of the alternative options, such as more time use or sharing a small space as in the case of carpooling, are too high to be overcome by a nudge. In view of these arguments, recent research suggests that to avoid the need to change use habits, nudges might better focus on stimulating the adoption of cleaner technologies (Brandon et al., 2017).

3.3 Rebound and spillovers

To assess the effectiveness of climate policies, a systemic perspective is essential, that is, one cannot be satisfied with only direct policy effects but must also account for any indirect effects. An important category concerns energy rebound. This denotes unintended secondary energy use effects following initial energy savings due to adopting more energy-efficient technologies or energy sufficiency behaviors (sometimes referred to as "downshifting"), such as less car use. Two important ways in which rebound occurs is through intensity-of-use and re-spending effects: the first means that an adopted technology with lower energy costs will in the user phase tend to be used more intensively (e.g., more car trips or longer trips); the second means that energy savings go along with money savings if energy prices are not affected by policy (like a nudge), which in turn can be spent on other energy-using goods

and services (e.g., lower the heating but buy a few extra sweaters made in China). The latter category is more relevant for nudges that alter behavior without involvement of new technology, while the first is also relevant for nudges that encourage adoption of a more energy-efficient technology or product.

Rebound may involve mechanisms of a behavioral nature, referred to as (negative) spillovers (Truelove et al., 2014). For example, people may have the feeling they have made a serious sacrifice for the climate and feel morally licensed to spend time and money on energy-intensive goods and activities. A review by Sorrell et al. (2020) finds that rebound and spillover effects can erode a significant proportion of potential energy savings from sufficiency actions, to an extent that such actions have a limited influence on aggregate energy use and emissions. Whether so, depends on the type of consumption and actions involved, and is moderated by bounded rationality and social influence. Against this background, Exadaktylos and van den Bergh (2021) conclude on the basis of a literature review that behavioral interventions such as gain frames and energy labels limit inattention, default and mental accounting effects, which can help reduce intensity-of-use and thus direct rebound effects, but are less effective in terms of directing re-spending behavior. Smart meters are suggested as an important tool to provide relevant feedback to households as they can reduce inattention and inertia, thus helping to alter habits in low-carbon directions. According to Wynes et al. (2018) rebound effects may also differ between domain. They give the example that motivating consumers to conserve energy can result in higher rebound and lower emissions reduction than motivating them to switch to more expensive green energy, since the latter goes at the cost of spending budgets.

To avoid the rebound effect of nudges they are best complemented by pricing instruments, such as energy taxes or carbon prices. If implemented in a systemic way, these will limit indirect effects on energy use and carbon emissions as energy savings will go along with higher energy costs, and hence both rebound through the energy-intensity effect and re-spending effect will be discouraged (van den Bergh, 2010; Font Vivanco et al., 2016; Freire-González, 2020). For an overall judgement, of course, interaction effects of the two types of instruments need to be accounted for then as well.

3.4 Counter-nudges

One field of application of low-carbon nudges is to stimulate more sustainable consumption choices. In fact, many opportunities for emission reductions by households involves shifting important one-shot consumption choices, such as purchase of a house, car or holiday package. However, while nudges intend to stimulate consumption in a low-carbon direction, there are often strong "counter-nudges" at work (Sunstein, 2017). Advertising for high-carbon products can be considered as such a counter-nudge. Consider an experiment that intended to motivate the purchase of a more energy-efficient laptop by using a classic social norm intervention in the presence or absence of product advertising (Castro et al., 2021). Participants from the US were presented with a Facebook-like homepage containing advertising for either the high- or low-carbon laptop, as well as a weak or strong pro-environmental social norm. In isolation, both types of social norms (as well as low-carbon advertising) were effective in shifting

choices towards the low-carbon option. However, when combined with advertising for the high-carbon laptop, the positive effects of norms were offset. These results indicate the limits of social norms as drivers of low-carbon consumption in a world dominated by advertising for high-carbon options. They highlight that nudges may only reach their potential when combined with "old-school" regulation.

3.5 Further reasons

Focusing on the specific case of (non-environmental) default options, Sunstein (2017) argues that 'strong antecedent preferences' may lead people to choose another option than what public policy aims to encourage. For instance, some people may have developed so strong preferences for driving a personal car that it is almost impossible to change choices to public transport via nudging. Nudge failure might also derive from a lack of consideration of cultural factors (Strassheim, 2019). For example, the well-known heuristic of loss aversion, that is, the preference for gains over equal losses, varies across countries. Losses are much more acceptable in the United States compared to, e.g., Eastern European countries. This calls for careful consideration of what types of nudges to use, or heuristics to exploit. Finally, Strassheim (2019) discusses the role of bounded rationality shown by a regulator, that is, the way biases and heuristic affect policy-makers (and not just policy-takers). For example, some research indicates that politicians rely more than average citizens on prior beliefs and less on information when judging policies (Christensen and Moynihan, 2020). Apart from these various reasons for why nudges do not always work, they can create undesirable effects, as will be discussed in the next section.

4. Other considerations in assessing low-carbon nudges

4.1 Interactions with economic incentives

Nudges hardly ever act in isolation. Instead, they implicitly interact with other policies, such as economic incentives or they are even explicitly combined with these to create positive synergistic effects (Bergh et al., 2021). The aforementioned meta-analysis by Khanna et al. (2020) finds that interventions combining incentives with social comparison and feedback are more effective than individual interventions, while Nisa et al. (2020) argue more theoretically for the presence of such positive synergies. However, a recent review of existing experimental studies of synergy between nudges and incentives arrives at a less optimistic conclusion (Drews et al., 2020). It notes that experimental research that has been undertaken in this respect suffers from serious shortcomings and provides a framework for improving further study. Of the 10 studies reviewed, only one indicates a clearly synergistic effect of nudges and incentives, with the others show zero (complementary) effects and some even point to negative synergies. It is well-known that economic incentives can crowd-out people's intrinsic motivation to engage in certain behaviors. Drawing on the theory of motivation crowding, the authors call for more research looking into whether nudges may also crowd out the effectiveness of economic incentives. A more recent study (not covered by Drews et al., 2020), using hypothetical choices related to food consumption, finds positively synergistic effects of incentives and nudges as well (Osman et al.,

2021). Specifically, when two price instruments (carbon tax and subsidy) were combined with either an ecolabel or a social norm, the shift towards low-carbon food choice was higher compared to both single interventions. Clearly, more research is needed to resolve this important research question.

4.2 Equity

In general, nudges are seen as cheap and having few distributional impacts compared to other instruments, which may be considered selling points. However, nudges – like other policy instruments – can in fact have distributional effects. A study for Switzerland analyzes such effects for the residential electricity market, where consumers can be nudged by a default option for the contract setting (Ghesla et al., 2020). Customers of an electricity utility were invited to participate in a survey in which they could choose a hypothetical contract. Four years before taking the survey, the company implemented a green default option, that is, out of five available contracts, customers are by default in an intermediately "green" and expensive contract. Green here refers to hydropower and 5% renewable energy, complemented by fossil fuel energy sources. The authors estimate so-called "preference mismatches": for example, 40% of those customers who at the moment had an actual green default contract stated they preferred a more "grey" (and cheaper) contract. This preference mismatch increased with decreasing levels of income, education and property ownership. In contrast, there was a preference mismatch for richer, more educated and pro-environmental people in the sense that they preferred a "greener" contract compared to the actual contract they held. In addition, some types of nudges can induce emotional costs, which however seem to be present across all income groups (Thunström, 2019).

However, others argue that nudges (and so-called "boosts"), in principle, have the potential to improve poverty outcomes, for example by empowering consumers to participate in policy decisions on energy structures (DellaValle and Sareen, 2020). Nudging in non-environmental areas, such as immigration, have also been shown to produce equitable outcomes (Hotard et al., 2019). Overall, the equity implications of nudges are a nascent research topic which deserve further attention.

4.3 Ethics, trust and policy support

Several ethical problems of (green) nudges are discussed in the literature (Schubert, 2017), namely regarding whether it means the end of non-paternalism, and whether nudges compromise autonomy and self-legislation. It is not the place here for a comprehensive discussion of this , but it is worth noting that many people, generally speaking, perceive some nudges as deceptive and manipulating. The use of nudges could thus reduce public trust in regulators. This in turn could again have negative effects for other more effective policies. To be fair, research from 16 countries suggests that environmental and non-environmental nudges received majority support from citizens in most countries (Sunstein et al., 2019). This general approval increases with respondents' level of trust in public institutions. Furthermore, trust may be increased by improving the transparency of nudges. One study analyzes how a default nudge intended to increase contributions to a 'climate protection fund' was affected by creating

more transparency about the aspects of the default, namely its potential influence, its purpose, or both (Bruns et al., 2018). The experiment showed that the default increases contributions and that disclosure of information does not change this result. It suggests that policy-makers can be more open about nudges, which could generate positive side-effects in terms of winning people's trust.

Nudges may not only interfere with the effectiveness of other policies, but – arguably even more importantly – with the public acceptance of them. Hagmann et al. (2019) examine the interactions of green nudges and carbon taxes in terms of public acceptability. In a series of studies, they show that the presence of nudges in a policy mix can crowd-out public support for carbon taxes. This is because a nudge makes the decreases the perceived necessity of stronger policies. The paper also shows, however, that when people are informed about the relatively low effectiveness of nudges, crowding-out of public support for carbon taxes can be prevented. Similarly, showing co-benefits of carbon taxes like the possibility to reduce other non-environmental taxes also prevents crowding-out.

4.4 Dynamic effects and scaling of nudges

Let us assume that nudges stimulate low-carbon behavior by 2% per year, as was roughly an average of the estimates reviewed earlier. Does this mean that the same nudge will stimulate an additional behavior change in the following year? To answer this question, consider two examples. The first is a low-carbon default option of an electricity provider. People who were nudged to use a green electricity option will show a one-time reduction in emissions. The nudge will thus not encourage further emissions reduction. Instead one would need another nudge encouraging consumers to switch to an option that is even more low-carbon. A second example is the communication of social norms. Once households have been informed about lower energy use by their neighbors and respond by reducing their own energy use and related emissions, they are unlikely to further reduce use/emissions in response to the repeated message over time. At best, their effort is maintained, but as was reported earlier, effects may actually often regress over time.

One could of course communicate *dynamic* norms, i.e. norms that become more ambitious over time (Loschelder et al., 2019). It is, however, unclear whether this leads to equally large emission reductions compared to *static* norms. Staying with the particular case of household electricity use, energy conservation will also conflict with other personal goals such as comfort (Sovacool et al., 2021). Overall, this suggests that raising the stringency of nudges may not lead to the same magnitude of effects over time. The nudge approach thus also contrasts with other conventional policies such as economic incentives, whose stringency, and hence effectiveness, can be raised more easily.

Another relevant issue is the potential to scale up nudge interventions. Most low-carbon nudges are implemented at local or regional levels. Others, such as green electricity tariffs, are undertaken at the company level (though possibly at national scope). To achieve a wider spread of low-carbon nudges, all policy-makers in all lower-level scales must have sufficient knowledge and capacity to choose from the many existing nudges. Another option would be to implement country-wide nudges, if this is

administratively feasible. Practicioners using nudges state that due to institutional and legal constraints, they often need to implement interventions that are different from how they would have ideally wanted to run them (DellaVigna and Linos, 2020). Evidence from non-environmental domains suggests that effectiveness goes down with higher levels of scaling (Bird et al., 2021). The latter is a more costly and laborious effort, which requires that nudge implementors have the necessary capacity everywhere. The benefit of a local approach is that one can tailor the intervention to the specific context.

5. Complementary uses of low-carbon nudges and behavioral insights

As we have discussed before, nudges can stimulate some climate-relevant behavioral change, but their current use has several shortcomings and limits. In the broader (non-environmental) literature on nudges, there are calls for putting nudges in perspective (Loewenstein and Chater, 2017) and to extend the nudge framework towards a broader understanding of behavioral public policy (Ewert, 2020). In this vein, in the following we propose several alternative uses of nudges in the context of climate policy.

Nudges have been used against carbon pricing – notice the "anti-carbon pricing stickers" used in Ontario, Canada. The question is whether they can also be used to support them, namely to frame economic incentives to improve their effectiveness and acceptability. In the remainder of the text, we illustrate this for the case of framing of carbon pricing. Rather than reducing public support for carbon pricing as discussed above, it is possible to think that nudges can increase support. Would it be helpful to better communicate carbon pricing information, and if yes, how can this be achieved? For example, is it possible to nudge support through clever communication of revenues? Standard economic theory suggests that the principle purpose of carbon pricing is to change relative incentives between high- and low-carbon goods and services. This suggests that the revenues should be returned in a neutral way to all citizens, or possibly relatively more to low-income households if equity concerns play a role as well. Behavioral science offers additional insights (Klenert et al., 2018). First, because many people misunderstand or doubt the incentive effects of the policy, they prefer a climate use of the revenues that aims at additional emissions reduction (Maestre-Andrés et al., 2019). Thus, if policy-makers want to build policy support, is it recommendable to go at least partially for green spending. Second, lump-sum recycling is another revenue use that is often considered (e.g., in the US under the label "carbon fee and dividend). At least some economists are wary of this option, as the additional income may trigger further emissions. To reduce such an effect, one can consider the behavioral phenomenon called "mental accounting" (Hahnel et al., 2020). This refers to people's tendency to organize savings and expenditures in "mental" boxes. If the lump-sum transfer is understood as a general additional income, then that money may be used to pay for the next (long-distance) holidays. If, however, the money is understood as subsidy to take low-carbon action, then it may be used to pay for switching to a cleaner, potentially more expensive product or service. Mental accounting may be one of the motivations of the Canadian government to call their transfer to revenues a "Climate Action Incentive Payment", to stimulate investment in low-carbon options, such as more efficient cars or house insulation.

Other authors have argued for a "nudge plus" approach (Banerjee and John, 2021), meaning to embed reflective, slow elements into the classic nudge approaches, which are typically based on fast thinking and more automatic behavior. This approach is said to increase effectiveness but also autonomy and persistence (i.e. durable responses or even new habits). For example, a traffic-lighting nudge exploits automatic behavior by communicating to agents that the green option is the desired one. Such visual cues can be overlooked and may thus be enhanced by providing additional information. This seems to resonate with a more general movement to go beyond nudge-only, as evidenced by "think" (John et al., 2009) or "boost" strategies. Applied to climate policy, this may involve providing more rationale for other climate policies. For instance, learning about the potential as well as limits of nudges has been shown to reduce some of the unintended effects on other policies mentioned before (Hagmann et al., 2019).

Since most carbon emissions are not the result from consumer decisions but derive from the production side of the economy, extending nudges to organizational behavior is another way forward. Lawton (2020) analyzes nudging of organizational behavior in the context of an emission-reduction scheme. It is found that social-norm nudging can increase (or decrease) companies' reputation, as well as encourage both collaboration and competition aimed at improving environmental outcomes. A more interventionist behavioral application to companies are so-called "budges" (Oliver, 2015). These are behaviorally informed bans of certain company practices of knowingly manipulating the subconscious choices of consumers. An example would be to limit advertising of high-carbon products, such as long-distance holiday travel or oversized cars, which tend to make much use of appeals to emotions and self-image.

6. Conclusions

We have provided a comprehensive assessment of direct, indirect and systemic effects of low-carbon nudges. A first insight is that various review and meta-studies show rather moderate effects to generate climate-relevant behavioral changes. It may be argued that nudges are still in a learning phase and can become more effective in the future. Nevertheless, policy-makers are probably well-advised to consider that the main role of nudges is complementing conventional policy instruments (regulation and monetary incentives). In addition, we discussed various reasons why nudges can fail, notably: i) they may be ineffective among subgroups of the population if they conflict with personal or collective values, ii) behavior is often habitual, iii) there can be rebound effects offsetting the initially positive effects of the nudge, iv) counter-nudges, such as strong advertising of high-carbon behavior, can be simultaneously at work. All this means that policy-makers need to adopt a contextual perspective on nudges. While nudges are usually considered a cheap instrument, addressing such context-dependence and reducing unwanted systemic effects may increase associated implementation costs (see also Carlsson et al., 2021).

We further discussed limitations and problems of low-carbon nudges, such as their (adverse) impact on the effectiveness and feasibility of other policies like economic incentives. In addition, nudges

may create undesirable regressive effects or meet ethical objections. We ended with some proposals for alternative uses of nudges in the context of a broader understanding of behavioral climate policy, particularly to support the effectiveness, implementation and stringency of other policies.

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