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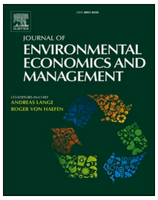

Why green subsidies are preferred to carbon taxes: Climate policy with heightened carbon tax salience

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ABSTRACT

Policy makers must take account of the fact that carbon taxes are highly unpopular. Once policy makers take this into account, they should adopt a modified targeting principle by setting the optimal carbon tax below the Pigouvian tax (i.e., the social cost of carbon) and excessively subsidising products that are made with renewable energy. We numerically illustrate these behavioural biases in climate policies in the face of heightened carbon tax salience and note that this helps to explain distortions in current climate policies. We find that governments might then even take the easy option of green spending and fossil fuel subsidies rather than taxing carbon emissions. This is costly as welfare is lower than it would be without behavioural misperceptions.

1. Introduction

The classic answer to the global warming challenge is to set the tax on emissions equal to the Pigouvian tax or the social cost of carbon or SCC in climate economics and rebate the revenue as lump-sum payments. There is no need for green subsidies unless there are learning-by-doing effects in renewables production or other production externalities that need to be internalised to ensure efficiency. The Yellow Vests protests have, however, made clear that this policy prescription is disastrous for politicians who want to get re-elected. These protests indicate a backlash against carbon pricing in general. They suggest that people have an excessive and possibly irrational dislike of carbon taxes even if it leads to the required substitution away from carbon-intensive towards green goods. Douenne and Fabre (2022) use a representative survey to taken just after the Yellow Vests protests that indicates that the French largely reject a carbon tax cum lump-sum rebate policy. Crucially, households seem to overestimate their net monetary losses, and do not perceive the carbon tax policy as environmentally effective.[2] Households thus perceive carbon taxes as higher than they are when climate policy is presented.

Although economists have advocated to put a price of carbon emissions for many decades via a carbon tax or cap-and-trade permit markets, little progress has been made in practice. In 2019 the average global carbon price was a mere \$1.7 per ton of CO_2 (Nordhaus, 2020). Carbon prices have since risen somewhat. For example, in 2023 globally a quarter of emissions are priced on average at \$22 per

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[2] Households also wrongly think that this policy is regressive. Further, Douenne and Fabre (2022) indicate that respondents that oppose the carbon taxes tend to discard positive information about it.

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equivalent ton of CO_2 corresponding to a global average carbon price of only \$5.5 per equivalent ton of CO_2. Carbon prices are still much lower than the 5%–95% range for the SCC of \$44 - \$413 per equivalent ton of CO_2 calculated by Rennert et al. (2022).[3] Carbon prices are also much lower than fossil fuel subsidies which amount to almost \$10 per equivalent ton of CO_2 in 2019 (Nordhaus, 2020). Parry et al. (2020) estimates that fossil fuel subsidies in the global economy are \$5.9 trillion in 2020 or 6.8 percent of world GDP (and are expected to rise to 7.4 percent of GDP in 2025). Only 8% of the 2020 subsidy reflects explicit subsidies (about \$16 per equivalent ton of CO_2) and 92 percent reflects undercharging for supply costs and implicit subsidies. Hence, price of carbon *net* of fossil fuel subsidies may be *negative*. It is thus not surprising that emissions have continued to increase in recent years. Also, governments that ramp up climate action often prefer hefty subsidies relatively more than raising the emissions price as seems to be the case for the Inflation Reduction Act in the U.S. and the Green Deal in Europe.

One way to take account of this backlash and aversion to carbon taxes is to take a behavioural economics approach and assume that the utility experienced by people is different from the utility they use for their decisions regarding consumption choice. This behavioural approach of salience of carbon taxes implies that the adverse effect of carbon taxes on *experienced* utility is higher than that on *decision* utility. Governments should then abandon the first-best policy prescription and take account of salience to obtain the optimal policies taking account of this behavioural constraint.

The objective of this paper is to analyse to what kind of distortions in climate policies this can lead. We offer a tractable, concise, and back-on-the-envelope effects of heightened salience of carbon pricing and show that this distorts the optimal policy mix away from carbon pricing towards renewable subsidies. This implies that the usual principle of targeting the carbon tax on the emitting good and not taxing or subsiding the non-emitting good is no longer applicable.

We show that heightened salience of carbon taxes might explain such topsy turvy climate policies.[4] First, the optimal pollution tax must be set below the Pigouvian tax or SCC and may even be negative, thus explaining the low prevalence of carbon pricing and high prevalence of fossil fuel subsidies. Second, the optimal subsidy on green products should be strictly positive or higher than what is necessary to correct externalities in green production.

We are inspired by the comprehensive study of Farhi and Gabaix (2020), who offer detailed results for Pigouvian taxation in the presence of behavioural agents which are inattentive with less than full salience of taxes.[5] One of the key insights of this study is that Pigouvian taxes must be divided by the salience and are thus higher. In contrast, we focus on *heightened* (i.e., more than 100% or excess) salience of carbon taxes and analyse how this affects the *optimal mix of carbon taxes and renewables subsidies* when all net revenue from these policies is rebated as lump-sum payments. We focus on externalities with behavioural agents but abstract from distributional considerations and a public revenue target. Farhi and Gabaix (2020) also discuss internalities and nudges. We will discuss these and other issues in section 5.

We need to make two qualifications about our results. First, an important assumption of our analysis is that heightened salience applies to carbon pricing and not to renewable subsidies.[6] We think this makes sense given the Yellow Vests protests and other backlashes against carbon pricing, but the idea of salience can be applied in more general settings too. Second, in many developing countries fossil fuel subsidies are motivated by the need to protect vulnerable groups who need cheap coal-fired electricity (or by industrial interests among others) when changes in the income tax system cannot be used to help the poor. However, in developed countries the income tax system can be used to help the poor. Salience of carbon pricing might then help to explain low carbon prices and fossil fuel subsidies.

2. The model

We abstract from taxes on labour income and endogenous labour supply. Instead, we have an exogenous household endowment M. Households receive lump-sum rebates from the government denoted by T. Households choose their consumption of two energy-based goods which are substitutes, one is the brown good x, and the other is the green good y. They also consume another good, commonly referred to as the 'outside' good, z, which is an aggregate of all other goods, is non-polluting, and used as the numeraire. The outside good thus stands for all other commodities that have zero (or negligible) energy intensity.[7]

Utility is quasi-linear and given by $U = \frac{u(x,y)^{1-\frac{1}{\epsilon}}}{1-1/\epsilon} + z - kX$, where X denotes aggregate consumption of brown goods and kX is the

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[3] This study offers comprehensive evidence drawing on climate science, economics, demography, and other disciplines and takes account of improved probabilistic socioeconomic projections, climate models, damage functions, and discounting methods. It arrives at a preferred estimate of the SCC of \$185/tCO2 (with a range of \$44-\$413/tCO2, 5%–95% range, 2020 U.S. dollars) at a near-term risk-free interest rate of 2%, which is 3.6 times than the U.S. government's currently used value of about \$50/tCO2.

[4] There may be other reasons such as the political economy of lobby groups why governments choose to have a negative net price of carbon and tilt away their policies away from carbon pricing towards green subsidies, but we focus here on the effects of salience on climate policies.

[5] A similar study is Moore and Slemrod (2021). Mullainathan et al. (2012) give an overview of behavioural public finance. Allcott et al. (2014) derive optimal energy policy when there is an "internality", i.e., consumers underestimate the cost of gas, and find that optimal policy may also involve energy taxes below marginal damage and a product subsidy. Gerritsen (2016) and Allcott et al. (2019) study behavioural Ramsey taxation. Earlier public finance studies with misperceiving agents are Chetty (2009) and Chetty et al. (2009), who did not consider optimal taxation.

[6] We abstract from other instruments such as the labour income tax to keep the analysis of salience simple.

[7] Of course, it is hard to think of a good in a modern economy that does not depend on energy at least to some extent. Still, this assumption helps to make our point clear, and the main insights would carry through if the outside good uses much less energy than the other two commodities. We thus think of the outside good as one with negligible energy intensity.

linear damage function from emissions with $k > 0$ the pollution cost parameter. Households are atomistic and take aggregate consumption of brown goods as given. The CES sub-utility function is $u(x, y) = \left(a_x^{\frac{1}{\sigma}} x^{1-\frac{1}{\sigma}} + a_y^{\frac{1}{\sigma}} y^{1-\frac{1}{\sigma}}\right)^{\sigma/(\sigma-1)}$, where $\sigma > 1$ denotes the elasticity of substitution between the green and the brown good. Households choose x, y, z to maximise utility subject to their budget constraint. The budget constraint of the representative household is $p_x x + p_y y + z = M + T$, where M denotes exogenous income of households, T denotes lump-sum transfers received from the government, p_x denotes the consumer price of the brown goods, and p_y denotes the consumer price of the green good. Choosing x and y to maximise utility subject to the household budget constraint gives the demand functions

$$x = a_x p_x^{-\sigma} P^{\sigma-\epsilon} \text{ and } x = a_y p_y^{-\sigma} P^{\sigma-\epsilon} \text{ with } P \equiv \left(a_x p_x^{1-\sigma} + a_y p_y^{1-\sigma}\right)^{1/(1-\sigma)}. \tag{1}$$

(see Appendix A.1). Substituting these optimally chosen quantities into the utility function gives the indirect utility function

$$U^d = M - \frac{P^{1-\epsilon}}{1-\epsilon} + T - kX. \tag{2}$$

We refer to (2) as the *decision* utility function (denoted by the superscript d). It is the usual utility function used by households to decide on household demand. The price index P can be interpreted as an indirect sub-utility function for energy-based goods, and by Roy's identity total demand on x and y together is $u = P^{-\epsilon}$ (i.e., $-\partial U^d/\partial P$) while total expenditure on energy-based goods is $p_x x + p_y y = Pu = P^{1-\epsilon}$. Roy's identity ($(\partial U^d/\partial P)(\partial P/\partial p_x) = -x$ and $(\partial U^d/\partial P)\left(\partial P/\partial p_y\right) = -y$ taking $M, X,$ and T as given) also gives the demand functions for each variety given in (1). Demands for brown and green goods depend negatively on the own price but positively on the price of the other commodity (as we assume $\sigma > \varepsilon$), so the two commodities are substitutes in demand.

All other consumption is on the outside good which does not require any energy (and appears linearly in utility), so $z = M + T - P^{1-\epsilon}$. The utility function is quasi-linear in all other commodities, so that there are no income effects in demands for the brown and green goods. We assume $\sigma > \varepsilon > 1,$ so that x and y are two close-substitute, energy-based commodities to be interpreted as carbon-based and carbon-free energy-based demand, respectively, with elasticity of substitution, σ. The ideal of Hicksian consumption price index for energy-based goods P depends on the consumer prices of brown and green goods. Demand for the aggregate energy-based commodity has price elasticity ϵ and the income elasticity is zero.

Global warming damages depend linearly on aggregate consumption of the carbon-intensive or brown good, which equals $X = Nx$ in equilibrium with N the number of households, and on the constant damage coefficient, $k > 0$.

Production displays constant returns to scale, so that per-unit production costs are constant. They are given by $c_x > 0$ and $c_y > 0$. Let carbon-based demand be subject to an ad valorem carbon tax τ_x, and green demand be subject to an ad valorem subsidy s, so consumer prices are $p_x = t_x c_x$ and $p_y = t_y c_y$ with $t_x = 1 + \tau_x$ and $t_y = 1 - s_y$. The corresponding specific carbon tax and green subsidy are $\tau \equiv \tau_x c_x$ and $s \equiv s_y c_y$, respectively. The government rebates carbon tax revenue net of the cost of green subsidies, $T = \tau x - sy$, as lump-sum handouts.

In equilibrium demands for the carbon-based and green commodities are thus

$$x = a_x (t_x c_x)^{-\sigma} P^{\sigma-\varepsilon} \text{ and } y = a_y \left(t_y c_y\right)^{-\sigma} P^{\sigma-\varepsilon} \tag{3}$$

with $P = \left(a_x (t_x c_x)^{1-\sigma} + a_y \left(t_y c_y{}^{1-\sigma}\right)^{1/(1-\sigma)}\right.$. The cross-price demand elasticities, $\theta_x \equiv \frac{p_y \partial x}{x \partial p_y} = (\sigma - \varepsilon) a_y \left(P/p_y\right)^{\sigma-1} > 0$ and $\theta_y \equiv \frac{p_x \partial y}{y \partial p_x} = (\sigma - \varepsilon) a_x (P/p_x)^{\sigma-1} > 0$, are positive, since the elasticity of substitution between carbon-based and green goods exceeds the price elasticity of aggregate energy, $\sigma > \varepsilon$. Own price elasticities of demand are $\varepsilon_x \equiv \frac{-p_x \partial x}{x \partial p_x} = \sigma - \theta_y > 0$ and $\varepsilon_y \equiv \frac{-p_y \partial y}{y \partial p_y} = \sigma - \theta_x > 0$ (Appendix A.2).

We follow Farhi and Gabaix (2020) and Moore and Slemrod (2021) and distinguish between *experienced* utility and *decision* utility U^d given in equation (1). Experienced utility is relevant for policy making and is the one that captures the feeling of the population. It allows for carbon tax aversion or excess salience of carbon taxes by adjusting the experienced carbon tax. It equals

$$U^e = M - \frac{(P^e)^{1-\varepsilon}}{1-\varepsilon} + (\tau y - sx) - kX \tag{3}$$

with $P^e = \left(a_x (p_x{}^e)^{1-\sigma} + a_y \left(t_y c_y\right)^{1-\sigma}\right)^{1/(1-\sigma)}$ the price index of the energy-based commodities experienced by households. Here $p_x{}^e \equiv t_x{}^e c_x$ with $t_x{}^e = 1 + \lambda \tau_x$ is the experienced price of carbon-based goods, so $p_x{}^e = c_x + \lambda\tau$ and $\lambda\tau$ is the *experienced* specific carbon tax. The constant $\lambda > 1$ captures heightened salience of carbon taxes and indicates that carbon taxes push up the energy price index more and thus get excessive negative attention in experienced utility.

Policy makers use experienced utility (3) but take account of people making decisions based on their decision utility (2). Hence, households choose consumer demands to maximise U^d while governments when choosing the carbon tax τ and the green subsidy s take account of how carbon taxes are experienced and thus maximise experienced utility U^e subject to household demand (2) and the government budget constraint.

3. Bias in optimal climate policies

Proposition 1. *The specific carbon tax and green subsidy that maximise experienced utility (3) subject to household demands (2) are*

$$\tau = kN - \Upsilon p_x,\ \Upsilon \equiv \left[\lambda\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}\left(\frac{p_x}{p_x{}^e}\right)^{\sigma} - 1\right]\frac{\varepsilon_y}{\sigma\varepsilon} + \left[\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon} - 1\right]\frac{p_y y}{p_x x}\frac{\theta_y}{\sigma\varepsilon}, \tag{4}$$

and

$$\frac{s}{p_y} = \left[\frac{kN-\tau}{p_x}\right]\frac{p_x x}{p_y y}\frac{\theta_x}{\varepsilon_y} + \left[\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon} - 1\right]\frac{1}{\varepsilon_y}. \tag{5}$$

Proof. See Appendix A.3.

Corollary 1: *Without behavioural biases, $\lambda = 1$, the optimal specific carbon tax equals the Pigouvian tax, $\tau = kN$, and the green subsidy is zero, $s = 0$. If a small degree of salience is introduced, $\lambda > 1$ but λ close to 1, a sufficient condition for the optimal specific carbon tax to be smaller than the Pigouvian tax, $\tau < kN$, is that $\sigma < p_x/\tau$. This is also a sufficient condition for green goods to be subsidised, $s > 0$.*

Proof. See Appendix A.4

The case without salience gives the usual first-best prescription: price emissions at the Pigouvian tax ($\tau = kN$) and do not subsidise green demand ($s = 0$, given that there are no production externalities such as learning by doing or directed technical change). But with heightened salience, carbon taxes affect experienced welfare more negatively (i.e., $\lambda > 1$) so that the experienced carbon tax exceeds the actual carbon tax, and the resulting experienced price of energy-based goods exceeds the actual price ($P^e > P$) if $\sigma < p_x/\ \tau_x$. This condition is typically satisfied.[8] Hence, the optimal carbon tax falls short of the Pigouvian tax if $\lambda > 1$. For high enough degrees of carbon tax salience and low enough Pigouvian taxes, it may even be optimal to have a negative carbon tax corresponding to fossil fuel subsidies, $\tau < 0$. With $\lambda > 1$ it is optimal to have a strictly positive subsidy on green goods, $s > 0$, despite there being no externalities in green demand. The net proceeds of the carbon tax net of the costs of the green subsidy, $T = \tau x - sy$, are rebated as lump-sums handouts.

4. Excess salience of carbon taxes and optimal government climate policies

We interpret x and y as demand for fossil fuel and for green energies, respectively. We calibrate to BAU outcomes in 2017 with $\tau = s = 0$ when global GDP was 80.25 trillion US dollars and global carbon emissions 9.8 GtC or 35.93 GtCO$_2$.[9] We set the costs of carbon-based and green products to $c_x = \$540$ per ton of carbon emitted, and $c_y = \$660$ per equivalent ton of carbon emitted (cf. Bremer and van der Ploeg, 2021).[10] Papageorgiou et al. (2017) finds empirically that the elasticity of substitution between green and carbon-based energy input is about 2 for the electricity sector and about 3 for the non-energy industries, hence we set $\sigma = 2.5$. The elasticity of demand for energy is less than one, so we set $\epsilon = 0.6\ \langle\sigma$.

We calibrate the parameters a_x and a_y such that the demand for carbon-intensive goods measured in terms of their emissions corresponds to $x = 9.8$ GtC (i.e., total emissions in the global economy in the base year) and the demand for green goods equals $y = 1.48$ GtCe (corresponding to the BAU share of fossil-fuel consumption of 6.6% of world GDP) in the BAU equilibrium with $p_x = c_x = \$540$ per ton of carbon emitted, and $p_y = c_y = \$660$ per equivalent ton of carbon emitted. This yields $a_x = 0.8 \times 7.63 \times 10^{-11} = 6.10 \times 10^{-11}$ and $a_y = 1.53 \times 10^{-11}$.[11], so 0.8 is the share coefficient and 7.63×10^{-11} is the scale parameter. Total energy spending, $p_x x + p_y y$, equals \$ 6.27 trillion. Since GDP is \$80.25 trillion in the base year, consumption on other non-energy goods is $z = \$\ 73.98$ trillion.

At a constant Pigouvian carbon price of $kN = 55$ \$/tC or 15 \$/tCO$_2$ (cf. Nordhaus, 2008), the cost of global warming without climate policy equals $kNx = 539$ billion dollars. Social welfare net of global warming losses in BAU is then $M + T - \frac{P^{1-\epsilon}}{1-\epsilon} - kNx = 57.8$ trillion dollars. We measure social welfare relative to this outcome, so that social welfare in the BAU outcome is zero.

We also consider a variant with a higher value of $kN = \$183.3$/tC or \$50/tCO$_2$, which has a lower BAU value of 56.5 trillion dollars.

4.1. Effects of salience on climate policies

Table 1 gives the optimal carbon tax and green subsidy for three different values of salience λ and for a low and higher values of the

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[8] For example, in the illustration discussed in section III we have a Pigouvian tax of 55 \$/tC and a cost of carbon-based energy of 540 \$/tC, so that the condition becomes $\sigma < \frac{540}{55} = 9.8$. Since empirical values of σ vary between 2 and 3 (e.g., Papageorgiou et al., 2017), the condition is satisfied.

[9] The conversion factor is that 1 tC equals (44/12) tCO$_2$.

[10] If one unit of the brown good corresponds to A_1 Joules of energy used and A_2 tC emitted and one unit of the green good corresponds to A_3 Joules of energy used and zero tC emitted, then one unit of the brown good can be measured as A_2 tC and one unit of the green good can be measured as A_3 $A_{2/}$ A_1 equivalent tC.

[11] We can rewrite $a_x = 0.8 \times 7.63 \times 10^{-11} = 6.10 \times 10^{-11}$, so that 0.8 is the share parameter and 7.63×10^{-11} is the share parameter in energy demand.

Pigouvian tax or SCC.[12] Consider the case of the low Pigouvian tax or SCC of \$55/tC or \$15/tCO$_2$ first. The first-best outcome requires setting the carbon tax to this SCC. As a result, demand for carbon-based products drops from 9.8 to 8.96 billion dollars while demand for green products rises from 1.48 to 1.73 billion dollars. The CPI for energy rises from 3.11 to 3.37 \$/tCe. Social welfare increases relative to BAU by 23.4 billion dollars.

Now raise excess salience of carbon taxes by a mere 5% (i.e., $\lambda = 1.05$). This curbs the optimal carbon tax substantially from \$55/tC to \$15.6/tC and leads to the introduction of a hefty green subsidy of \$32.8/tCe. This curbs net revenue for the government, so lump-sum handouts are cut from 493 to 90 billion dollars. Green goods are substitutes for carbon-based goods, so it makes sense to subsidise them if carbon taxes must be cut back. As a result of this distorted policy package, demand for green goods rises a bit from 1.73 to 1.74 GtCe. Excess salience thus hardly affects demand for green energy. However, demand for carbon-intensive goods increases from 8.96 to 9.39 GtC which is still less than under BAU.

The CPI for energy rises compared to BAU from \$3.11/tCe to only \$3.16/tCe instead of to \$3.37/tCe, while the experienced CPI for energy is only a little higher at 3.17 \$/tCe. Taking account of excess salience thus introduces a wedge between experienced and actual energy prices and between experienced and decision utility. Both decision utility and experienced welfare decrease with salience. The change in decision utility relative to the BAU outcome drops from 23.43 under the first-best policy to 14.71 billion dollars but the change in experienced utility drops further to 7.39 billion dollars (but is still an improvement relative to BAU).

Provided the degree of salience of perceived carbon taxes stays below 7%, the optimal carbon tax will be positive. If salience increases beyond this, optimal carbon taxes turn negative corresponding to fossil fuel subsidies.

Table 1 also reports what happens if the degree of excess salience doubles to 10% ($\lambda = 1.1$). The optimal carbon tax is then negative corresponding to a fossil fuel subsidy of \$22.8/tC while the green subsidy almost doubles to \$63.2/tCe. Decision utility relative to BAU drops further from 23.43 billion dollars with no salience and 14.71 billion dollars with 5% excess salience to −13.34 billion dollars with 10% excess salience. For experienced utility this figure changes from 23.43 for the first best to 7.39 or 9.23 billion dollars for 5% and 10% salience, respectively. Although a high enough salience distortion in climate policies produces a worse outcome for conventional welfare than under BAU, experienced welfare increases relative to BAU.

The experienced and actual CPI for energy fall to 2.94 and 2.96 \$/tCe, respectively. Demand for carbon-based goods now increases to 9.88 GtC, which is even higher than under business as usual. There is a small drop in demand for green goods. There is now no money to finance rebates; instead, the government must raise lump-sum taxes by 344 billion dollars which hurts welfare.

The policy mix with excess salience of the carbon tax greens the economy and leads to lower emissions, X, and global warming damages, kX, compared to the business-as-usual outcome. However, it does not the green the economy as much as when carbon taxes are correctly perceived when making policy. The resulting combination of carbon taxes and fossil fuel subsidies is thus a less effective policy to control carbon emissions compared to the situation when there are no behavioural misperceptions. Table 1 indicates that emissions rise as salience rises which also indicates that behavioural misperceptions make it more difficult to control emissions.

4.2. Higher Pigouvian cost of carbon

Table 1 also repeats these policy experiments when the Pigouvian cost of emissions is \$183.3/tC or \$50/tCO$_2$. Internalising these much larger global warming externalities in the absence of salience gives the first best and raises welfare with respect to BAU by much more, by 235 instead of 23 billion dollars. Due to the much higher carbon tax, demand for carbon-based goods drops from 9.8 to 7.45 GtC and demand for green goods rises from \$1.48 to \$2.33/tCe. With excess salience of 5%, perceived carbon taxes are 5% higher, and thus carbon taxes drop from \$183.3/tC to \$143.5/tC and the green subsidy increases from zero to \$30.8/tCe.

If we double the degree of excess salience from 5% to 10%, the carbon tax drop further to \$105.4/tC but now does not turn negative due to the much higher Pigouvian cost of carbon. The green subsidy rises further from 30.8 to 58.8 \$/tCe. Lump-sum rebates are higher as the higher Pigouvian cost and carbon tax implies more carbon tax revenue. As before, lump-sum rebates decrease with salience. Both experienced and decision utility fall with salience of the carbon tax, where the gap between decision and experienced utility increases with salience.

Doubling the SCC to \$100/tCO$_2$ or \$367/tC, we find that the carbon tax is \$317/tC, and \$270/tC while the renewable subsidy is \$14.9/tCe and \$27.7/tCe with 5% and 10% excess salience, respectively. Raising the SCC further to the preferred value of \$185/tCO$_2$ or \$678/tC found in Rennert et al. (2022) taking account of all kinds of risk and using a low discount rate, we find that the carbon tax is \$151/tCO$_2$ or \$555/tC while the renewable subsidy is \$12/tCe with 10% excess salience. Hence, for higher values of the SCC, the absolute value of the gap between the SCC and the carbon price rises while the renewable energy subsidy falls.

5. Discussion

Farhi and Gabaix (2020) also offer results for Ramsey taxation (linear commodity taxation to raise public revenues and redistribute) and Mirrleesian taxation (nonlinear income taxation) as well as Pigouvian taxation (linear commodity taxation to correct for externalities) in the presence of behavioural agents with less than full salience of taxes. They find that optimal Ramsey taxes should be

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[12] There is not much empirical work on salience. However, Taubinsky and Rees-Jones (2018) offer an online experiment to study heterogeneous perceptions of sales taxes, which suggests an expected value and variance of salience of 0.25 and 0.13, respectively. These values are relevant for using commodity taxes to attain a public revenue target and to take care of income distributional concerns and are discussed by Farhi and Gabaix (2020), but they are not relevant for our study of heightened salience of carbon taxes and the effects on the mix of climate policies.

Table 1
Salience, climate policies, and outcomes.

Variable	Business as usual (BAU)	Pigouvian carbon cost, $kN =$ \$55/tC = \$15/tCO$_2$			Pigouvian carbon cost, $kN =$ \$183.3/tC = \$50/tCO$_2$		
Salience, λ	n.a.	1	1.05	1.1	1	1.05	1.1
CPI for energy, P (\$/tCe)	3.11	3.37	3.16	2.96	3.94	3.74	3.54
Experienced CPI, P^e (\$/tCe)	3.11	3.37	3.09	2.94	3.94	3.77	3.58
Demand dirty goods, x (GtC)	9.8	8.96	9.39	9.88	7.45	7.69	8.00
Demand green goods, y (GtCe)	1.48	1.73	1.74	1.73	2.33	2.36	2.39
Emissions tax, τ (\$/tC)	0	55	15.6	−22.8	183.3	143.5	105.4
Green subsidy, s (\$/tCe)	0	0	32.8	63.2	0	30.8	58.8
Lump-sum rebate, T (billion dollars)	0	493	90	−344	1,358	1,031	703
Pollution loss, kX (billion dollars)	539/1,796	493	516	543	1,366	1,410	1,466
Decision utility, $U^d - U^d_{BAU}$	0	23.43	14.71	−13.34	235	229	210
Experienced ut, $U^e - U^e_{BAU}$	0	23.43	7.39	9.23	235	174	126

Key: In the BAU policy makers do not price pollution or subsidise energy. Welfare in BAU is 57.8 and 56.5 trillion dollars and pollution losses in BAU are 539 and billion dollars for an emission cost of \$55/tC = \$15/tCO$_2$ and \$183.3/tC = \$50/tCO$_2$, respectively.

divided by the salience squared (i.e., λ^2) and are thus higher (as $0 < \lambda < 1$). Pigouvian taxes, on the other hand, must be divided by the salience (λ) itself and are therefore higher (e.g. equation (9) and Proposition 5 in Farhi and Gabaix (2020)). We show how *heightened* salience of carbon taxes affects the *optimal mix of carbon taxes and renewables subsidies* when net public revenue is rebated as lump-sums and find that policy makers shy away from carbon taxes in favour of green subsidies.[13] We abstract from Mirleesian taxation or distributional considerations. We do not have a public revenue target, so do not have Ramsey taxation either. We have three remarks on how our results compare with those of Farhi and Gabaix (2020) and one on future research.

First, if all taxes/subsidies are perceived correctly, then the green good should be untaxed and the brown good should be taxed to correct for the global warming externality. This is the classic principle of targeting, which also holds in our analysis. However, if there is heterogeneous attention to the carbon tax (and homogenous attention to the price net of subsidy of the green good), Proposition 7 of Farhi and Gabaix (2020) gives a modified principle of targeting which implies that the green good must be subsidised (taxed) if and only if the brown and green goods are substitutes (complements). This is in line with our Proposition 1 which finds a rationale for green subsidies and lower carbon taxes, since we have assumed that brown and green goods are substitutes in our analysis. Our modified targeting principle does not require heterogeneous attention of the carbon tax but follows from abstracting from a public revenue target. Therefore, the green subsidy is a result of the excess salience of the carbon tax while the green subsidy is correctly perceived.

Second, Proposition 2 of Farhi and Gabaix (2020) gives the first-order condition for a commodity tax when there is an externality in the presence of behavioural agents. There will be the usual agent-specific externality wedges and mis-optimisation wedges, where the latter wedges capture that if a particular good is over-consumed then taxing this good is at the margin more attractive. Interestingly, these wedges enter symmetrically in this condition. It does not matter whether the price is under-perceived or whether there is a negative internality. The difference with Proposition 1 above is that we assume that net public revenue from the climate policies is rebated as lump-sum rebates while Farhi and Gabaix (2020) assume an exogenous constant value of the net public revenue generated by the taxes. Furthermore, we have a representative framework and abstract from heterogeneous effects of externalities on households. Since all revenue is rebated and do not have the mis-optimisation wedges (as we abstract from internalities), it is harder to compare results.

Third, Farhi and Gabaix (2020) discuss internalities (i.e., a benefit or cost to an individual that is not considered when making the decision to consume a good) and nudges too. They find that, to the extent that internalities are more prevalent among the poor, pollution taxes have adverse distributional effects that imply a trade-off between internality correction and redistribution. They argue that nudges are an attractive policy for circumventing this trade-off and target internalities while avoiding adverse distributional effects. Nudges are thus a behavioural tool to address behavioural biases. We do not allow for internalities, hence there is no need for nudges in our framework. But in future research it is important to allow for internalities and to show how nudges can play a role to improve outcomes.

Finally, the analytical results in Farhi and Gabaix (2020) suggest many directions for further research in the interface between behavioural public finance and environmental economics. The main ones are to fully take account of heterogeneity in incomes, salience and the effects of the externality and thus to consider Ramsey and Mirrleesian taxation in tandem with Pigouvian taxation. Such analysis should also consider nudges and externalities. Also, there is a need for questionnaires and experimental research to measure empirically the extent of less than 100% or excess salience for different types of taxes and subsidies.

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[13] If we constrain the policy package so that policy makers are not allowed to subsidise the green good, the resulting second-best behavioural policy looks much more like the outcome of equation (9) in section I.C and Proposition 5 in Section 2.B of Farhi and Gabaix (2020). This gives the adjusted Pigouvian tax as the Pigouvian tax divided by the salience parameter, i.e., $\tau = kN/\lambda$, so that $\lambda > 1$ gives a *lower* carbon tax. For a SCC of, say, \$183.3/tC or \$50/tCO$_2$, the second-best behavioural carbon tax is \$174.6/tC and \$166.6/tC with 5% and 10% excess salience, respectively. These are rather higher than the \$143.5/tC and \$105.4/tC reported in Table 1. The reason is that the second-best behavioural carbon tax must now compensate for the lack of a green subsidy.

6. Conclusion

We have shown that modest degrees of salience of the carbon tax can radically change the optimal policy mix by reducing carbon taxes below the social cost of carbon and introducing green subsidies (above what may be needed to correct for production externalities such as learning by doing). If salience is large enough, carbon taxes may turn into fossil fuel subsidies. These results suggest that behavioural economics is crucial to understand why, in the presence of resistance to carbon pricing, governments rely on fossil fuel subsidies at the same time as green subsidies to get the economy to switch to green energies rather than use the carbon price incentive. Clearly, this is a costly way to green the economy in the sense that conventional welfare is lower than it would be without behavioural misperceptions. The usual targeting principle of taxing the emitting good and not taxing or subsidising the non-emitting good is thus not applicable. Shying away from carbon taxes and introducing renewables subsidies due to excess salience of carbon taxes leads to more emissions and higher global warming costs. In this sense, the policy is a less effective policy to control carbon emissions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDICES.

A.1. Household decision problem

Households choose x, y, and z to maximise their utility subject to their budget constraint. This gives the optimality condition $v^{-1/\varepsilon} = P$, so that $v = P^{-\varepsilon}$ with ε the price elasticity of demand for the composite energy-intensive good and $z = M + T - P^{1-\varepsilon}$ consumption of the numeraire. Optimality requires that $v_x/v_y = p_x/p_y$, so that $x = a_x {p_x}^{-\sigma} P^{\sigma-\varepsilon}$ and $y = a_y {p_y}^{-\sigma} P^{\sigma-\varepsilon}$ are the energy demands with the ideal consumer price index given by $P = \left(a_x {p_x}^{1-\sigma} + a_y {p_y}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$. Upon substitution we find that indirect utility is $M + T - P^{1-\varepsilon}/(1-\varepsilon)$.

A.2. Own-Price and Cross-Price Elasticities

Making use of $P = \left(a_x {p_x}^{1-\sigma} + a_y {p_y}^{1-\sigma}\right)^{1/(1-\sigma)}$, we can establish that the demand functions $x = a_x {p_x}^{-\sigma} P^{\sigma-\varepsilon}$ and $y = a_y {p_y}^{-\sigma} P^{\sigma-\varepsilon}$ have cross-price elasticities $\theta_x \equiv \frac{p_y \partial x}{x \partial p_y} = (\sigma - \varepsilon) a_y \left(P/p_y\right)^{\sigma-1} > 0$ and $\theta_y = (\sigma - \varepsilon) a_x (P/p_x)^{\sigma-1} > 0$, and have own-price elasticities $\varepsilon_x \equiv \frac{-p_x \partial x}{x \partial p_x} = \sigma - \theta_y > 0$ and $\varepsilon_y = \sigma - \theta_x > 0$. We thus obtain

$$\begin{aligned} &\varepsilon_x \varepsilon_y - \theta_x \theta_y = \sigma^2 - \sigma\left(\theta_x + \theta_y\right) = \\ &\sigma\left[\sigma - (\sigma - \varepsilon)\left\{a_x {p_x}^{1-\sigma} + a_y {p_y}^{1-\sigma}\right\} P^{\sigma-1}\right] = \sigma\varepsilon. \end{aligned} \tag{A2}$$

We will use this expression in (A7) below.

A.3. Proof of Proposition 1

The government must choose the taxes on x and y to maximise experienced utility $U^e = M + (t_x - 1) c_x x + \left(t_y - 1\right) c_y y - \frac{(P^e)^{1-\varepsilon}}{1-\varepsilon} - kX$ from (3) subject to the demand functions (2). This gives the first-order optimality conditions

$$\begin{aligned} &\frac{\partial U^e}{\partial t_x} = c_x x - \left({}^{P^e} \lambda c_x \frac{\partial P^e}{\partial p_x^e} + [(t_x - 1)c_x - kN] c_x \frac{\partial x}{\partial p_x} + \left(t_y - 1\right) c_y c_x \frac{\partial y}{\partial p_x} = \right. \\ &c_x x - \left({}^{P^e} \lambda c_x a_x \left(p_x + [(t_x - 1)c_x - kN] c_x \frac{\partial x}{\partial p_x} + \left(t_y - 1\right) c_y c_x \frac{\partial y}{\partial p_x} = \right. \right. \\ &[1 - \lambda (P^e/P)^{\sigma-\varepsilon} (p_x/{p_x}^e)^{\sigma}] c_x x + [(t_x - 1)c_x - kN] c_x \frac{\partial x}{\partial p_x} + \left(t_y - 1\right) c_y c_x \frac{\partial y}{\partial p_x} = 0 \end{aligned} \tag{A3}$$

and

$$\frac{\partial U^e}{\partial t_y} = [1 - (P^e/P)^{\sigma-\varepsilon}] c_y y + [(t_x - 1)c_x - kN] c_y \frac{\partial x}{\partial p_y} + \left(t_y - 1\right) {c_y}^2 \frac{\partial y}{\partial p_y} = 0, \tag{A4}$$

where $P^e = \left(a_x ({p_x}^e)^{1-\sigma} + a_y \left(t_y c_y\right)^{1-\sigma}\right)^{1/(1-\sigma)}$ with ${p_x}^e = [1 + \lambda (t_x - 1)] c_x$.

Equation (A3) gives

$$\left[\frac{(t_x-1)c_x-kN}{p_x}\right]\varepsilon_x=\left[1-\lambda\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}\left(\frac{p_x}{{p_x}^e}\right)^{\sigma}\right]+(t_y-1)c_y\frac{y}{x}\theta_y. \tag{A5}$$

and equation (A4) yields

$$(t_y-1)c_y\varepsilon_y=[1-(P^e/P)^{\sigma-\varepsilon}]p_y+[(t_x-1)c_x-kN]\frac{x}{y}\theta_x. \tag{A6}$$

Substitution of equation (A6) into (A5) yields

$$\frac{(t_x-1)c_x-kN}{p_x}=\frac{-[\lambda(P^e/P)^{\sigma-\varepsilon}(p_x/{p_x}^e)^{\sigma}-1]\varepsilon_y-[(P^e/P)^{\sigma-\varepsilon}-1]\dfrac{p_y y}{p_x x}\theta_y}{\varepsilon_x\varepsilon_y-\theta_x\theta_y}. \tag{A7}$$

Since from (A2) above the denominator of expression (A7) equals $\sigma\varepsilon$, we obtain $\frac{kN-(t_x-1)c_x}{p_x}=\left[\lambda\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}\left(\frac{p_x}{{p_x}^e}\right)^{\sigma}-1\right]\frac{\varepsilon_y}{\sigma\varepsilon}+\left[\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}-1\right]\frac{p_y y}{p_x x}\frac{\theta_y}{\sigma\varepsilon}\equiv\Upsilon_x^{SB}$ or equation (4). Equation (A6) then gives $\frac{(1-t_y)c_y}{p_y}=\left[\frac{kN-(t_x-1)c_x}{p_x}\right]\frac{p_x x}{p_y y}\frac{\theta_x}{\varepsilon_y}+\left[\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}-1\right]\frac{1}{\varepsilon_y}$ or equation (5).

A.4. Proof of Corollary 1

It follows immediately from equations (4) and (5) of Proposition 1 that with no carbon tax salience, $\lambda=1$, that $\tau=\tau_x c_x=kN$ and $s=s_y c_y=0$ or $t_y=1$.

Corollary 1 states that a small degree of carbon tax salience reduces the second-best optimal carbon tax and increases the green subsidy. To establish this, we need to verify whether the first term in equation (4) increases in λ evaluated at the point where $\lambda=1$, $p_x^e=p_x$ and $P_e=P$. Define $Z\equiv\lambda\left(\frac{P^e}{P}\right)^{\sigma-\varepsilon}\left(\frac{p_x}{{p_x}^e}\right)^{\sigma}-1$ and note that $\left.\frac{dZ}{d\lambda}\right|_{\lambda=1}=1+\left[(\sigma-\varepsilon)\frac{p_x^e}{P^e}-\sigma\right]\frac{dp_x^e}{p_x^e d\lambda}$ or

$$\left.\frac{dZ}{d\lambda}\right|_{\lambda=1}=1-\sigma\left(\frac{\tau_x}{t_x}\right)+(\sigma-\varepsilon)\frac{p_x}{P}\left(\frac{\tau_x}{t_x}\right)=1+\left[(\sigma-\varepsilon)\frac{p_x}{P}-\sigma\right]\left(\frac{kN}{c_x+kN}\right). \tag{A8}$$

The second term is positive as $\sigma>\varepsilon$, so that a sufficient condition for this expression and the expression in equation (4) to be positive is $\sigma<\left(\frac{1+\tau_x}{\tau_x}\right)=\frac{p_x}{\tau_x}$.

This is also a sufficient condition for the expression in equation (5) to be positive.

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