Chosen Energy Sufficiency: Preference Shocks and Behavioural Biases

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Abstract – There is a lot of expectation surrounding energy sufficiency as part of the energy transition. It may result from an increase in energy prices, but it could also be a conscious choice. In this case, it would be the consequence of an adjustment in preferences or a reduction in behavioural biases. Changes in preferences can be modelled as an adjustment to the relative weights attributed by individuals to durable goods, energy or even non-durable goods. Here, we show that the macroeconomic impacts differ largely based on the type of adjustment, which we can use to guide public policy decisions. This then leads to the question of how to bring these preference adjustments in practice. In addition to nudges to reduce behavioural biases, preference changes can stem from a collective organisation and better information, in particular regarding the co-benefits of energy sufficiency.

JEL: Q58, D91, Q48, C61, D62, D71
Keywords: energy sufficiency, preferences, nudges, behavioural biases

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Achieving energy sufficiency became a frontline topic of public debate relatively recently, when it was presented as one of the mechanisms that could be deployed to enable the transition towards carbon neutrality. The term sufficiency was first used in an IPCC report in 2022 (IPCC, 2022). In this article, we show how changes in preferences or a reduction in behavioural biases, which prevent real preferences from being reflected in demand, may lead to energy sufficiency and therefore contribute to the climate transition. We also identify public policies encouraging this sufficiency.

The notion of sufficiency is not new in scientific literature, although it remains difficult to define, primarily because it refers to a heterogeneous set of behaviours and practices and there are numerous debates regarding its definition. Jungell-Michelsson & Heikkuren (2022) illustrate this difficulty in their literature review. The term sufficiency can be addressed in numerous ways, for example, as a doctrine, vision, paradigm, lifestyle, or even strategy. The literature primarily focuses on the connection between sufficiency and reducing demand as a response to an environmental constraint (i.e. as processes to moderate consumption or change behaviours, value systems or norms, moving away from consumerism). However, sufficiency is also, on occasion, considered from the supply side. At the microeconomic level, it is often seen as a voluntary restriction, associated with a conscious change in values and behaviour, and, in this way, is seen partly as a consumer responsibility. Conversely, at the macroeconomic level, this term refers to the role of public intervention in bringing about a social and institutional change, thereby helping to re-evaluate the role of consumption in well-being and moderate production and supply of services. The difficulty in establishing a single, clear definition of sufficiency inevitably adds additional complexity when it comes to considering its role in society and in climate transition policies (Jungell-Michelsson & Heikkuren, 2022).

In this article, achieving energy sufficiency is defined as a reduction in energy demand (and therefore consumption) that is not brought about because of increases in energy efficiency. The latter would correspond to a reduction in energy consumption without changing the service provided, as efficiency does not imply a behavioural change but a transition towards a less energy-intensive equipment, notably resulting from technological progress. Building insulation that leads to reduced heating consumption to achieve the same level of thermal comfort therefore falls under energy efficiency and not energy sufficiency. Here too, there is no consensus in the literature as to exactly what falls under sufficiency and what falls under efficiency. Some changes that do not necessarily involve equipment replacement, such as increasing passenger vehicles' occupancy, can be seen as an increase in efficiency brought about by improved organisation of a service (Grubler *et al.*, 2018). However, equipment pooling can also be seen as one of the aspects of sufficiency (see négaWatt typology below).

Energy sufficiency efforts largely helped during the winter of 2022–2023: here, we observed a 13% drop in gas consumption, normalized to correct the climate effect[1] (GRTgaz, 2023), and a 9% drop across the electricity network[2] (RTE, 2023). The survey conducted in May 2023 by IPSOS-RTE of more than 11,000 people found that 38% of those asked were restricting their heating for budgetary reasons. In this case, the (actual or anticipated) price increases are undoubtedly the reason behind these reductions in consumption, which can therefore be seen as constraints. However, transitioning to a state of sufficiency may also be voluntary. From a theoretical point of view, a change in "real" preferences (for example, choosing to travel by plane less frequently, or not wanting to live in a rural area far from public transport) may lead to the integration of climate into the utility function, illustrating a transition towards this "chosen" sufficiency.[3] Furthermore, demand from agents is not always a direct result of their preferences: it may also include what are known as behavioural biases, which lead to overconsumption for example in case of a poor information on waste costs or on the existence of co-benefits. Chosen sufficiency therefore still applies where the changes in behaviour bring consumers closer to their real preferences. For example, voluntary moderation of energy consumption due to ecological considerations has been observed for a long time (Leonard-Barton, 1981), although such behaviour was considered to apply only to the minority compared with restrictions imposed by budgetary constraints (Dillman *et al.*, 1983).

1. For the period from 1 August 2022 to 12 March 2023 compared to the same 2018–2019 winter period.
2. Calculated over the last quarter of 2022, compared with historic averages.
3. We define chosen sufficiency as sufficiency that is in no way the result of constraints. A carbon price imposes restrictions on the choices of individuals, even if the level of restriction is lower than that imposed by regulations.

These distinctions between energy sufficiency and energy efficiency on the one hand, and between chosen sufficiency and forced sufficiency on the other, are not sufficient to cover all the channels for reducing energy demand required for decarbonisation (see Schubert, 2023, for a review of the international academic literature on sufficiency). There are thus several typologies, including that established by the négaWatt association, a pioneering French body in this field, which puts forward four types of sufficiency (négaWatt, 2016). This classification is interesting because it partly overlaps with the distinctions made above, and makes it possible to describe the various public policies seeking to achieve sufficiency:

- *"structural" sufficiency* can be achieved through the organisation of spatial aspects or activities in order to moderate energy consumption. This mainly relates to reduced travel requirements for accessing work or getting to shops, for example via land planning policies;
- *"dimensional" sufficiency* can be achieved by adapting the size of durable goods acquired by households in line with their usage (for example, adjusting the size, weight or power of private cars);
- *"usage" sufficiency* involves changing how equipment is used so as to reduce energy consumption. This primarily relates to switching off appliances on standby, limiting driving speed on roads, increasing equipment lifetimes, etc.;
- *"cooperative" sufficiency* is based on the pooling of equipment (for example, car sharing, shared housing or workspaces, etc.)

Dimensional sufficiency and cooperative sufficiency are closely related, primarily where the capital good using the energy is housing: in both cases, this relates to having fewer square metres per person. However, even though this is undoubtedly a secondary concern for housing, and an even lower priority for cars, we should point out that cooperative sufficiency emphasises pooled use of equipment (shared spaces such as kitchens, bathrooms and living rooms, for example), a factor that is not included in usage sufficiency.

There are also other bodies interested in sufficiency and reducing energy demand, which in particular assess the significant contribution that these can make to achieving climate and energy goals. The sixth report from the IPCC's Working Group III (IPCC, 2022) looks into the potential for reducing greenhouse gas emissions by controlling demand: this mitigation method uses various channels, a large proportion of which require changes in behaviour and urban planning and infrastructure policies enabling a fall in energy demand. These channels, which correspond to the "*Avoid*" and "*Shift*" strategies of the *Avoid-Shift-Improve* (ASI)[4] approach, may be said to fall under the broadest definition of sufficiency (i.e. not limited to direct action by households to reduce energy consumption), and could constitute a potential to reduce global greenhouse gas emissions by around 30% across end-consumer sectors compared with a trend-based scenario. This would primarily affect the food (15%), construction (5%) and terrestrial mobility (5%) sectors. For France, négaWatt believes that energy sufficiency could reduce final energy consumption by 15% compared with current levels. Finally, the French electricity transmission network (RTE) focuses its analysis of the potential for sufficiency measures on electricity consumption: these would lead to savings of 90 TWh of electricity in 2050 compared with a reference scenario, which equates to a 14% reduction in consumption. It must, however, be borne in mind that the various scenarios considered generally differ in terms of the indicator used (final energy consumption, greenhouse gas emissions) and in terms of the role allocated to sufficiency efforts or to energy efficiency to reduce that indicator by 2050. Conducting a comparison between these scenarios and deducing the decarbonisation potential of achieving sufficiency is therefore a difficult task.

Whether the result of changes in preferences or a reduction in behavioural biases, chosen energy sufficiency involves purely individual choices (reducing the temperature at home to reduce energy bills), changes in collective norms (reducing the use of planes due to "flight shame" (*Flygskam*, Brunet, 2021), eating less meat[5] following studies on negative health impacts (Harguess, 2020), see section 3.1, and principles of collective organisation (improved town planning coupled with low-impact or collective means of transport facilitating a shift away from individual car ownership, legislating

4. The ASI approach establishes three strategies for reducing energy demand. The first is to Avoid *unnecessary consumption through the implementation of "no-regrets" actions whatever the sector. The second is to* Shift *to low-carbon goods and services. The third is to* Improve *energy efficiency and does not therefore fall under sufficiency.*

5. Emissions associated with meat consumption result from the methane emissions from cattle rather than from the energy used to raise them. Strictly speaking, we should therefore use the term "greenhouse gas emission sufficiency" rather than "energy sufficiency" on equipment lifetimes to reduce the need to buy new products, etc.). In many cases, this is not spontaneous, but instead results from measures imposed to a greater or lesser extent by public authorities, which may take the form of information on individual and collective consequences of consumption (communication, education), nudges to guide choices, or standard public policies (taxes, subsidies, regulations). In addition to direct public action, the media, associations, NGOs, etc. may also contribute to these changes in preferences. For example, the French Agency for Ecological Transition (ADEME) launched a humorous publicity campaign[6] in 2023 to raise awareness of overconsumption of electric household appliances and even clothing.

Each type of sufficiency has its own mechanisms. Changes in behaviour can be encouraged by adjusting the way the production supply is structured. This could involve, for example, promoting A-segment vehicles (dimensional sufficiency) or car sharing (cooperative sufficiency). They may also be the result of land planning policies (structural sufficiency) or policies to develop infrastructure, for example the development of railway lines to encourage the use of trains rather than planes (usage sufficiency).

Analysing the macroeconomic impact of sufficiency requires the changes in behaviour to be modelled. In this article, we focus on sufficiency in terms of demand, in particular by addressing the question of changes in preferences among individuals. Focusing on changes in preferences gives an incomplete overview of the total sufficiency effort required (achieving sufficiency also requires a change in the supply of goods and services, which does not necessarily affect preferences), but does allow us to address a key aspect of its macroeconomic impact.

Firstly, we look at the macroeconomic consequences of a change in preferences that reduces household energy consumption, using two simple models. The main mechanisms are first highlighted in a static microeconomic model with two goods, one brown (which uses a lot of energy) and one green (which uses a lot less). Here, energy sufficiency refers to replacing the first with the second. By drawing on Henriet *et al.* (2014), we then expand the analysis to take into consideration the dynamic effects within a general equilibrium framework, calibrated with French data to obtain quantitative results. We show that the impact of these mechanisms depends on the channel through which they operate. In particular, there may be a sustained increase in total consumption in the case of "usage" or "cooperative" sufficiency, which contradicts the widespread opinion that a transition to sufficiency is synonymous with a reduction. Conversely, in the case of "structural" or "dimensional" sufficiency, total consumption may fall. This effect is mainly due to the reaction in terms of consumption of durable goods. We also compare the effects of these changes in preferences with those brought about by a carbon tax, where the preference shocks are calibrated so as to generate the same reduction in energy consumption as the tax. Assuming that the revenue from the tax is distributed on a fixed basis, the results on GDP ultimately differ only slightly.

Following this, we look at the reasons why preferences may change and at the behavioural biases that may guide decisions. Understanding the reasons why choices may change appears to be necessary in order to determine the relevant policies to put in place to encourage preference changes or reduce behavioural biases. In line with Thaler & Sunstein (2008), Farhi & Gabaix (2020) and List *et al.* (2022), we examine the nudges seeking to change the way people behave in a predictable way, without taking away options or significantly changing their economic incentives. For example, this could be the order in which dishes are presented on a restaurant menu or the default option in a questionnaire. Furthermore, collective changes of social norms or lifestyles can also foster sufficiency, notably as they may involve an increased awareness of the many co-benefits of decarbonisation.

The rest of the article is organised as follows. Section 1 assesses the macroeconomic impacts of various energy sufficiency shocks on the preferences of agents. The various mechanisms for changing choices are explained in sections 2 (reduction in behavioural biases) and 3 (change in preferences), before a conclusion is drawn.

1. Macroeconomic Impacts of Changes in Preferences

To date, little attention has been paid in the literature to changes in preferences, undoubtedly due to the difficulty that this raises in terms of measuring the effect of shocks (on the cost of living or increase in real income, for example) when the metric changes at the same time (Blanchet *et al.*, 2023). However, the assumption

6. The "dévendeur" [non-salesperson: a salesperson who encourages repair over replace]: https://communication-responsable.ademe.fr/campagne-de-lademe-posons-nous-les-bonnes-questions-avant-dacheter

of fixed preferences in terms of climate change, i.e. over the long term and in a field that has experiences major upheavals, seems unrealistic. Furthermore, we are relying on changes in preferences to facilitate the transition (Mattauch *et al.*, 2022).

Firstly, we use a very simple static model to analytically compare the effects of a tax on brown goods with the effects of a change in preferences in favour of green goods. To assess the size of these effects and consider various preference shocks that will allow us to report on structural and dimensional sufficiency on the one hand and usage and cooperative sufficiency on the other, we then develop simulations based on the model proposed by Henriet *et al.* (2014). Although the expected change in preferences is gradual in reality, we simulate brutal preference shocks, which therefore give a representation encompassing quicker economic responses than would be expected in reality.

1.1. Chosen or Forced Sufficiency?

In order to clarify some of the mechanisms and orders of magnitude, we start by examining the consequences of a preference shock and a price shock as part of a very simple partial-equilibrium static model.

Consumption index C is a CES (Constant Elasticity of Substitution) aggregation of the consumption values for brown goods C_b and green goods C_g:

$$C = \left(\alpha C_b^{\frac{\sigma-1}{\sigma}} + (1-\alpha) C_g^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where σ is the elasticity of substitution between the brown and green goods and α is the distribution parameter, with $\sigma > 0$, $\sigma \neq 1$ and $\alpha \in (0,1)$.

The representative consumer seeks to maximise their utility subject to their budgetary constraints. Their income I is exogenous. Their instantaneous utility function is an increasing function of the composite consumption indicator:

$$U(C) = \ln C.$$

The first-order conditions are:

$$C_b = \left(\alpha \frac{p}{p_b} \right)^{\sigma} C,$$

$$C_g = \left((1-\alpha) \frac{p}{p_g} \right)^{\sigma} C,$$

with $p = \left(\alpha^{\sigma} p_b^{1-\sigma} + (1-\alpha)^{\sigma} p_g^{1-\sigma} \right)^{\frac{1}{1-\sigma}},$

and $pC = I.$

The price of the green good is normalized $p_g = 1$. A simple calculation shows that, following a shock to the price of the brown good (similar to a carbon tax) and a shock to the preference parameter α, consumption is affected as follows:

$$\widehat{C_b} = -\left(\omega + \sigma(1-\omega)\right)\widehat{p_b} + \sigma(1-\omega)\frac{1}{1-\alpha}\widehat{\alpha},$$

$$\widehat{C_g} = -(1-\sigma)\omega \widehat{p_b} - \sigma\omega \frac{1}{1-\alpha}\widehat{\alpha},$$

where $\hat{x}$ is the percentage of variation between x at final equilibrium and x at initial equilibrium, and $\omega = \frac{p_b C_b}{pC}$ is the share of the brown good in the value of aggregated consumption at initial equilibrium. By equating the first equation to zero, we deduce the percentage of variation of the preference parameter $\widehat{\alpha}_{eq}$ leading to the same reduction in consumption of the brown good as brought about by a price policy:

$$-\left(\omega + \sigma(1-\omega)\right)\widehat{p_b} = \sigma(1-\omega)\frac{1}{1-\alpha}\widehat{\alpha}_{eq}.$$

Thus, $$\widehat{\alpha}_{eq} = -(1-\alpha)\left(1 + \frac{1}{\sigma}\frac{\omega}{1-\omega}\right)\widehat{p_b}.$$

As $0 < \alpha < 1$, $0 < \omega < 1$ and $\widehat{p_b} > 0$, then $\widehat{\alpha}_{eq} < 0$. In other words, α should decrease. Further, the magnitude of this reduction is even greater where σ is small, i.e. where the brown and green goods are not exchangeable, where ω is large, i.e. where, at initial equilibrium, the brown product represents a major share of the aggregated consumption, and where α itself is large.

This calculation shows an impact on green good consumption that is very different depending on whether the reduction in brown good consumption comes from a price policy or a change in preferences. When preferences change, green good consumption increases. In the case of a price policy, the result depends on the substitutability of the two types of goods: the consumption of green goods falls if $\sigma < 1$ and increases if $\sigma > 1$. Indeed, a price policy leads to an increase in the aggregate price index, which in turn causes a decrease in aggregate consumption (recalling that income is fixed). When there is a high level of substitutability between brown and green goods, this may lead to an increase in consumption of green goods, while when this level is low, consumption of both types of goods should decrease.

Finally, if the price policy corresponds to a carbon tax with redistributed revenue, the preference shock required will be lower as, following the income effect of the redistribution, a 10% tax has a lesser effect in terms of reducing brown good consumption. This gives:[7]

$$\widehat{C}_{b\,red} = -\sigma(1-\omega)\widehat{p_b} + \sigma(1-\omega)\frac{1}{1-\alpha}\widehat{\alpha},$$

$$\widehat{C}_{g\,red} = \sigma\widehat{p_b} - \sigma\omega\frac{1}{1-\alpha}\widehat{\alpha},$$

and $\widehat{\alpha}_{eq,red} = -(1-\alpha)\widehat{p_b} < 0$. The result according to which α should reduce remains, but the magnitude of that reduction no longer only depends on the initial value of α. Furthermore, the consumption of green goods increases to offset the reduction in brown good consumption (irrespective of the parameter values) as the direct effect of the tax on aggregate consumption is neutralised by the redistribution.

A numerical illustration gives an idea of the scale of the preference shock required and therefore makes it possible to verify whether it is realistic to consider using a change in preferences to do away with a carbon tax. In the initial situation, we assume that $\omega = 0.9$, which means that the goods consumed are, by value, 90% brown goods, and $\frac{p_g}{p_b} = 1.2$: green goods are 20% more expensive than brown goods. Furthermore, by positing $\sigma = 4$, which corresponds to estimates of the elasticity of substitution between the two types of goods as shown in the literature, this gives $\alpha \approx 0.6$ in the initial situation and the following results (Table).

While, in the absence of redistribution, the preference shock seems unrealistic in the short term, the tax redistribution, which greatly reduces the scope of the effect on brown good consumption, reduces the preference shock required to just 4%, which seems more practicable. However, the same result can be interpreted very differently: if we want the same reduction in brown good consumption with redistribution of the tax revenue as without that redistribution, a higher level of tax on brown goods is required (in our numerical example, the increase in the price of the brown good must be multiplied by 3.25) and the necessary preference shock is also higher here (also multiplied by 3.25 in our example).

The shocks modelled thus far have only covered two goods, with one consuming more energy than the other. However, it is, in essence, the use of durable goods (cars, electrical household goods, housing) that is associated with high energy usage levels and these goods tend to accumulate over time. What is more, only taking two goods into consideration reduces the possible ways in which sufficiency can be interpreted. We therefore suggest extending the analysis to three goods (energy, durable goods and non-durable goods) and adopting a dynamic, general-equilibrium approach.

1.2. Dynamic Preference Shock Simulations

In order to assess the macroeconomic impacts of energy sufficiency, in particular on consumption of all goods, we simulate different shocks to preference parameters. The model used is that proposed by Henriet *et al.* (2014), the specifications of which are presented in Box 1. It was recalibrated in 2020 with a household carbon tax of €44.6 per tCO_2eq and adapted in line with the margin in order to create shocks to the preference parameters. The shocks enable us to report on structural and dimensional sufficiency on the one hand and usage and cooperative sufficiency on the other. The terminology associated with the various types of sufficiency is taken from négaWatt as defined in the introduction. In order to compare the impacts, the size of these shocks is calibrated such that the effect on household energy consumption after adjustments is the same, quantitatively, as with a carbon tax shock in 2019 compatible with the level proposed in

7. *In effect:* $\widehat{C_b} = -(\omega + \sigma(1-\omega))\widehat{p_b} + \sigma(1-\omega)\frac{1}{1-\alpha}\widehat{\alpha} + \hat{I}$ *and* $\widehat{C_g} = -(1-\sigma)\omega\widehat{p_b} - \sigma\omega\frac{1}{1-\alpha}\widehat{\alpha} + \hat{I}$, *with* $\hat{I} = \omega\widehat{p_b}$.

Table – **Preference shocks required to induce the same consumption reduction of brown goods as a 10% carbon tax**

Shock	Without redistribution		With redistribution	
	$\widehat{p_b} = 10\%$	$\widehat{\alpha}_{eq} = -13\%$	$\widehat{p_b} = 10\%$	$\widehat{\alpha}_{eq,red} = -4\%$
$\widehat{C_b}$ (%)	−13	−13	−4	−4
$\widehat{C_g}$ (%)	27	117	40	36
α final	0.6	0.52	0.6	0.58
ω final	0.87	0.72	0.87	0.86

Reading note: Without redistribution of revenue from a 10% carbon tax on brown goods, a 13% preference shock is required to reach a comparable reduction in consumption of brown goods (−13%).* With redistribution of revenue from the tax, this shock is lower (−4%), as is the reduction in consumption of brown goods (−4%).
* The fact that $\widehat{C_b}$ is equal to $\widehat{\alpha}_{eq}$ here is a coincidence resulting from the choice of parameter values.

Quinet (2019) and then increasing at a rate of 7.5% per year to reach €775 in 2050, which, compared with 2019, reduces household energy consumption by 28% by 2050 (see graph Var_{Em} in the Figure, after 40 periods).

1.2.1. Impacts of "Structural" and "Dimensional" Sufficiency (Adjustment of Parameter γ)

"Structural" sufficiency corresponds to a change in preferences brought about by changing how spatial aspects and/or activities are organised (for example, land planning leading to a reduction in the distances that people need to travel to commute to work or do their shopping) so as to reduce energy usage. Conversely, "dimensional" sufficiency reflects changes in preferences moving towards smaller sizes of durable consumer goods/investments (car, housing, phone or fridge, for example), thereby reducing energy usage. In both cases, sufficiency can be incorporated into the model by means of a higher weight of non-durable goods in the consumption mix, i.e. a larger parameter γ in equation (2).

"Structural" or "dimensional" sufficiency (smaller housing, less powerful cars, for example) therefore reduces the stock of durable goods held by households, which limits composite consumption (Figure). We firstly see an initial peak due to a strong, instantaneous shift towards non-durable goods, which raises the composite consumption defined by equation (2). This effect is only temporary as consumption of

Box 1 – **Specifications of the Model Proposed by Henriet *et al.* (2014)**

The model proposed in Henriet *et al.* (2014) was initially developed to determine the policies required to achieve the emission reduction targets in the absence of preference changes. It represents an open economy producing a generic good, which may be consumed or invested, and importing fossil fuels as its sole source of energy. Here, we have altered it marginally to allow for preference changes.

We only show the specifications used on the household side, as they will be directly affected by these preference changes. These are essentially "nested" CES functions, which provide an overview of the combination of:

(i) "Durable" goods, (D), i.e., goods that are consumed over a certain period, and which require energy, for example cars or fridges, and energy (E). This combination provides a service (Z):

$$Z_t = \left(\nu D_{t-1}^{\frac{\varepsilon}{\varepsilon-1}} + (1-\nu)(A_t^e E_t)^{\frac{\varepsilon}{\varepsilon-1}} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (1)$$

with $D_{t-1} = (1-\delta)D_{t-2} + X_{t-1}$, where X_t is the investment in durable goods, ν is the weight of the consumption of durable goods in the service consumption Z, and A^e is technical progress in the form of energy efficiency.

(ii) The service Z and the consumption of "non-durable" goods (N), i.e., goods that are consumed immediately, which contribute to a composite consumption C:

$$C_t = \left(\gamma N_t^{\frac{\omega}{\omega-1}} + (1-\gamma) Z_t^{\frac{\omega}{\omega-1}} \right)^{\frac{\omega}{\omega-1}}, \quad (2)$$

where γ is the weight of the consumption of non-durable goods in the composite consumption C.

The utility is a concave function of C:

$$U(N_t, D_{t-1}, E_{h,t}) = U(C_t). \quad (3)$$

Durable goods D accumulate and depreciate at a rate δ of 9% per year, which equates to an average lifetime of 11 years. The CES function that links these durable goods and energy E has a substitution elasticity ε = 0.5. This means that the consumption ratio varies by 0.5% where the iso-utility gradient varies by 1%, and therefore gives an indication of the degree of substitutability between these two consumptions. It also incorporates technical progress in the form of energy efficiency A^e which is assumed to grow at a rate of 2% per year.

Finally, the energy price follows a Hotelling rule, i.e., it increases at the interest rate, and the model is calibrated for France.

We assume that the same homogeneous good is used for investment in durable goods, X_t, and for consumption of non-durable goods N_t; their carbon intensity is therefore the same. Changes in preferences reduce greenhouse gas emissions because they lead to substitutions between durable goods and energy on the one hand, and non-durable goods and durable goods services (which use energy) on the other. Without changing preferences, the only way to reduce fossil fuel consumption while also keeping production constant is to increase energy efficiency. This is done via technical progress, which limits the amount of fossil fuel required. As the rate of energy-saving technical progress is faster than the rate of labour-saving technical progress, with no public policy intervention or other shock, Henriet *et al.* (2014) show that the use of fossil fuels gradually reduces, although at a slow rate (0.4% per year). With this approach, a 75% energy reduction target would be unattainable (i.e., it would take 347 years to achieve).

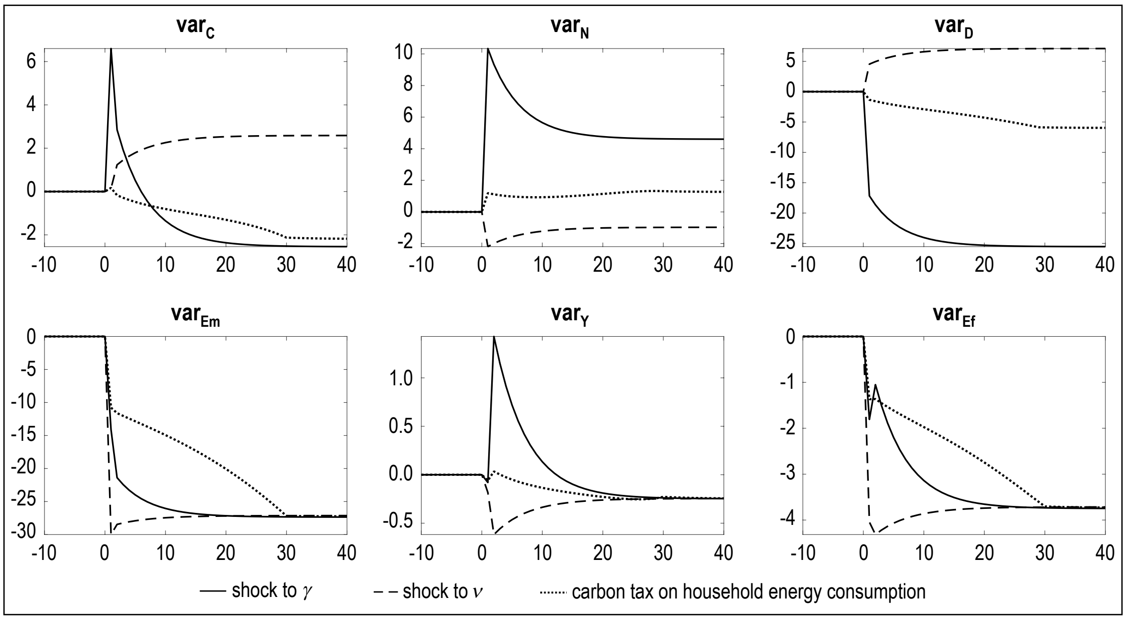
non-durable goods stabilises at a higher level than before the shock (but below the peak level), which, however, is not sufficient to offset the significant reduction in consumption of durable goods, and therefore the associated services. Indeed, the CES specification suggests that the substitution between durable and non-durable goods is not perfect, such that there is ultimately a sustained reduction in composite consumption. With this type of change in preferences, and within the model used (specifications and values for parameters), energy sufficiency is accompanied by "overall sufficiency", i.e. a reduction in overall consumption.

1.2.2. Impacts of "Usage" and "Cooperative" Sufficiency (Adjustment of Parameter ν*)*

"Usage" sufficiency refers to changing the way equipment is used in order to reduce energy consumption on the basis of new social norms or better information, which implies that any wastage previously took place unconsciously. "Cooperative" sufficiency is based on the pooling of equipment and its usage (car sharing, shared housing or workspaces). It may result from developments in terms of the supply of shared services. These two types of sufficiency are incorporated into the model by lowering the weight of energy in durable goods' services, i.e. an increase in parameter ν which corresponds to a higher weight of durable goods in the services provided by those goods, or a lower weight of energy in the services provided by those goods in equation (1).

This change in relative weights between durable goods and energy (reduction in heating, for example) has effects that are almost symmetrical to those obtained when γ changes. An increase in ν raises consumption of durable goods and reduces that of non-durable goods (although to a lesser extent), as these two types of goods are not fully substitutable: this reduces household energy consumption but without reducing total consumption. This effect is similar to a rebound effect, but does not go as far as to cause a backfire effect, as the shock is calibrated so as to reproduce the reduction in household energy consumption seen with the tax: journeys previously split between trains and cars become journeys undertaken solely by car, thanks to car sharing, for example, with the total effect still leading to a reduction in energy consumption. This rebound effect may also affect another of the goods within composite good D_t. This good may have a lower environmental quality, but once again the total effect is to reduce energy consumption as the shock is calibrated so as to reproduce the reduction in household energy consumption seen with the tax. This therefore

Figure – **Effects of preference shocks and the tax shock**



Reading note: *Ef* represents the energy consumption of companies and *Em* that of households. *C*,*N*,*D* and *Y* represent, respectively, the composite good for consumption (which aggregates *N* and *D*), the consumption of non-durable goods, that of durable goods, and production. The shock γ corresponds to an increase in the weight of non-durable goods in the consumption mix, while the shock ν represents a drop in the weight of energy in the services of durable goods. The x-axis shows the time (in years) and the y-axis the percentage of deviation from the baseline without the shock: for example, following a shock to ν (calibrated to produce the same reduction in household energy consumption as the tax in the long term), aggregate consumption *C* increases by over 6% at the moment at which the shock happens compared with the baseline, and falls more than 2% below this in the long term.
Sources: Authors' calculations.

represents a way of reducing energy consumption without limiting total household consumption. This gives us a situation of energy sufficiency, not one of "overall sufficiency". For this reason, where a change in preferences results from a regulation, that regulation will probably be more widely accepted than structural or dimensional sufficiency.

1.2.3. Comparisons with the Tax Effect

This exercise is similar to that carried out as part of the "Quinet tax variant"[8] in Henriet *et al.* (2014) – but the carbon tax is higher here and only relates to household energy consumption. Tax revenue is redistributed in the form of transfers to households, which makes it possible to observe the effect on marginal conditions associated with the price signal, but neutralises the income effect. This redistribution absorbs the shock to a large extent.

From the perspective of microeconomic theory (i.e. optimisation of utility subject to the budget constraint), varying the tax involves pivoting the budget constraint line of households for given iso-utility curves, while the sufficiency considered above (brought about by adjusting the weights of the various types of goods in the utility) consists of pivoting the iso-utility curves for a given budget constraint.

The simulations show that both qualitatively and quantitatively, the carbon tax has an intermediate or average effect between that of the shocks towards "structural" or "dimensional" sufficiency and that of the shocks towards "usage" or " cooperative" sufficiency, which suggests the mechanisms in place differ from changes in preferences. In particular, the effects on GDP and total consumption during the transition are very different. On the one hand, the negative shock to the relative weight of energy raises composite consumption but brings about a downturn during the transition due to the impact it has on companies (here, we see in particular that energy consumption drops significantly). On the other hand, the positive shock to the relative weight of non-durable goods (to the detriment of services provided through the combination of durable goods and energy) reduces composite consumption as the negative impact on durable goods prevails, without having as great an impact as the previous shock on the growth in GDP, which is sustained by the production of non-durable goods. Conversely, the long-term effects on GDP, once the transition has been achieved, are similar,[9] irrespective of whether a tax has been imposed or one of the preference shocks has taken place. This is due to the fact that companies are only affected by the adjustment to energy consumption Ef. However, the latter reacts to the change in energy price brought about by the reduced household demand, which is ultimately assumed to be the same in all three cases.

1.2.4. Impacts on Well-Being and Other Specifications for Preferences

The behavioural change brought about by a carbon tax results from the introduction of an additional constraint; therefore, the tax will in all cases reduce household well-being. Conversely, there is no constraint in the case of a change in preferences, and when we measure the effect of the behavioural change in the light of final preferences, there is in all cases an increase in well-being. This choice is not trivial.[10] In the following section, we will see that if we consider preferences to have changed because internalities (i.e. behavioural biases) have been corrected by nudges, using final preferences amounts to a measurement based on "real" preferences, making it therefore quite natural to proceed in this way.

Changes in supply could be considered via a change in minimum individual consumption by adjusting the "need" portion of consumption, as the provision of public transport or cycle routes, for example, reduces that need or the minimum consumption of individual automobile transport. This would require the use of Stone-Geary preferences, in which consumption is limited by a minimum level in the utility function. This would also make it possible to move away from the assumption of homothetic preferences (which is present with the CES functions used above), which imply an increase in direct household energy consumption that is proportional to income (i.e. the Engel curves that represent consumption as a function of income are linear). Indeed, the empirical literature shows that this is not the case for energy. In particular, direct household energy consumption increases significantly less than proportionally to income in developed countries (Caron & Fally, 2022), based on non-homothetic preferences (Comin *et al.*, 2021), and there is no identifiable satiety

8. *In reference to the "Quinet 2" commission, see Quinet (2019).*
9. *Here, we can say that, in the case of the usage or cooperative sufficiency shock, household consumption increases, while production falls. We should bear in mind that the simulated model is a general-equilibrium open-economy model and that there is therefore a gap between household consumption and production due to energy imports and business investment.*
10. *See Blanchet* et al. *(2014): when preferences change, individuals, with their final preferences, naturally prefer their new choice rather than the situation in which they found themselves at the start, but this does not mean that they feel better or worse than they felt at the start with their initial preferences, and, in the light of their initial preferences, the initial situation is preferred.*

threshold that would justify non-monotone preferences (for example, quadratic, with the possibility of a disutility resulting from overconsumption).

Having examined the consequences of changes in preferences, we now need to identify the channels that will enable those preferences to change in order to implement relevant policies and measure the costs associated with those changes in preferences. Assuming that preferences are immutable is equivalent to overestimating the cost of the transition; conversely, assuming that they can change immediately and without cost would lead to an underestimation. Before examining the reasons behind changes in preferences in section 3, we will use the next section to analyse behavioural biases and the effects we can expect if these are reduced.

2. Behavioural Biases and Nudges

Where a behavioural bias is present, demand does not reflect agents' preferences. The literature clearly shows that "biases do not enter into the experienced utility, but do affect choices, creating a gap between marginal utility and price." (List *et al.,* 2022). Farhi & Gabaix (2020) also specify that, where behavioural biases are at play, demand is not obtained based on utility maximisation. If, for example, that bias is the reason behind excess energy consumption, reducing it may lead to sufficiency (while also increasing well-being, which is itself defined as a function of preferences). Box 2 draws on the approach put forward by List *et al.* (2022) to present the mechanisms brought about by these behavioural biases. The dissemination of information (via communication campaigns or educational programmes, for example) and nudges seek precisely to reduce these biases. According to Thaler & Sunstein (2008), nudges seek to modify "the way people behave in a predictable way, without taking away options or significantly changing their economic incentives". To qualify as a nudge, an action must also be easy to implement and inexpensive.

Nudges make it possible to correct behavioural biases (internalities) without imposing significant material costs, while also changing the underlying "choice architecture", for example by changing the default option so as to benefit from people's general tendency to passively accept the values proposed. The dissemination of information can also serve to correct behavioural biases at a lower cost. Furthermore, these types of actions clash with conventional political tools in the sense that they are considered to be replacements for (rather than complementary to) a carbon tax policy, for example.

Numerous nudges take the following general form: they consist in making the benefits of behavioural changes more easily accessible, by simplifying decision-making processes (Benartzi *et al.*, 2017), thanks, for example, to labels, or by reframing choices. While the cost of nudges is assumed to be fairly low, it is often difficult to assess it accurately. For this reason, it is not explicitly taken into consideration when assessing effectiveness. Instead, the strategy consists of assessing the benefits of a nudge, which gives an order of magnitude for the maximum acceptable cost to implement that nudge. In particular, it is worth considering implementing nudges whose benefits are substantial. According to List *et al.* (2022), as part of a similar model extended to incorporate the heterogeneity of behavioural biases, this is the case in certain contexts (e.g. cigarette consumption), but not in others (e.g. the energy market). Therefore, reducing behavioural bias may require action of a different nature, depending on the goods in question.

While actions such as 1) nudges or the dissemination of information and 2) taxes can both lead to changes in behaviour, they each have their own unique comparative advantage. The comparative advantage of nudges and the dissemination of information lies in reducing the heterogeneity of a behavioural bias, while that of taxes lies in the internalisation of externalities (List *et al.*, 2022). Furthermore, nudges and the dissemination of information often have no political cost, whereas taxes, as we have seen with the *Gilets Jaunes* movement, may lead to social discontent.

The economic effectiveness of an action (nudge, information or tax) is assessed by comparing the effects on well-being with the economic cost of the action. The impact-cost ratios for nudge actions and conventional political tools (tax and other financial incentives) show that nudges are often more cost effective than conventional actions (Benartzi *et al.*, 2017). More specifically, List *et al.* (2022) show analytically that, the greater the standard error of the behavioural bias across the population, the greater the relative effectiveness of the nudges due to the fact that the behavioural bias is corrected by the nudge. Conversely, the effectiveness of these actions falls with the average size of the externality to be corrected by means of a conventional action (Box 2). Finally, this theory is empirically confirmed based on more than 300 observations of nudges and price interventions.

Box 2 – **Sufficiency Seen as a Reduction in a Behavioural Bias as Per List *et al.* (2022)**

Two sources of friction matter when it comes to the consumers' decision-making: the first, known as an "internality", comes from a behavioural bias (which, for example, leads consumers to eat too much meat) while the second is an externality (for example, pollution or greenhouse gas emissions). Using a simple model, we show that a reduction in behavioural bias is doubly beneficial for the consumer, as not only does it remove the internality but also reduces the externality (and thus limits the corrective tax).

Let's start with demand: for a quantity consumed q, we consider an increasing and concave function of personal benefit $V(q)$. As regards supply, this is characterised by a function of production with constant returns and marginal cost c. In a competitive equilibrium, the price of the consumer good is then $p=c$.

Internality (behavioural bias). We now incorporate an internality b, also known as a behavioural bias, into the consumer's decision. A non-zero value of b means that consumers systematically misperceive the benefits of a marginal consumption unit. These perception errors may, for example, be possible co-benefits that the consumer is unaware of, or may more generally reflect their lack of information about the product or about the consequences of consuming it (e.g., wastage, good or bad impacts on health, etc.).

Hence, to maximise their utility consumers do not choose a consumption level q satisfying $V'(q)=p$, but instead such that $V'(q)+b=p$. This therefore involves an over- or underconsumption dependent on whether $b>0$ or $b<0$, respectively. Reducing the behavioural bias leads to sufficiency in the former case (a), which may take place via nudges, for example, or via education and/or information, or even by modifying social norms.

Externality (and tax to internalise it). We will now consider the case in which the consumer good produces an externality, and in which a Pigouvian tax is implemented to correct it. The size of the marginal externality is referred to as ξ and assumed to be constant. Companies are assumed to be competitive, so the price is $p=c+t$ where t represents the above-mentioned tax. Unlike with the internality, the externality does not affect choices but is directly incorporated into the function of social well-being. This function includes the well-being of the consumer, the company, the state, and the externality, as follows:

$$W(q,t)=\left[V(q)-(p+t)q\right]+\left[pq-cq\right]+\left[tq\right]-\xi q=V(q)-cq-\xi q.$$

The allocation q_1 which maximises social well-being (i.e., satisfying $V'(q_1)=c+\xi$) takes into consideration the externality but not the internality. Conversely, q_2, the consumer's optimum allocation is guided by both the tax and their behavioural bias (i.e., satisfying $V'(q_2)=p+t-b$). We will note here that the two approaches match if and only if $t=\xi+b$. If $b>0$, reducing the value of the behavioural bias therefore makes it possible to reduce the tax required to reach the optimum level.

Conclusion. When the behavioural bias is positive, its reduction is therefore twice beneficial for the consumer: on the one hand, this makes it possible to increase well-being by reconciling the chosen allocation with the optimum allocation; on the other hand, this makes it possible to reduce the Pigouvian tax, which must otherwise correct both the externality and the internality.

(a) Reducing the behavioural bias should be understood as reducing b *in absolute terms (i.e., reducing it if* $b>0$*, and increasing it otherwise). Hence, sufficiency is only achieved when* $b>0$ *as the behavioural bias in this case leads to overconsumption.*

Carlsson *et al.* (2021) take this even further by suggesting that nudges be used even in the absence of behavioural bias, simply with a view to correcting an externality, in particular where a Pigouvian tax is insufficient. Here, we can use the term "green nudges". These exploit the limited rationality of agents when making decisions so as to guide their behaviour towards a socially optimum decision, but one which may not necessarily be in the interest of those agents. We can also make the following distinction: on the one hand, "purely green nudges", which involve emphasising a default choice, for example by simplifying information (labels), or via reminders and the design of the physical environment (style of bins, ease of reaching them). On the other hand, "moral green nudges" are, for example, based on the notion of green social status, where consumption signals an environmentally friendly action (see Sexton & Sexton, 2014 who explain, in this way, the willingness to pay a higher price for a Toyota Prius, or more recently Boon-Falleur *et al.*, 2022).

3. The Reasons Behind Changes in Preferences

To measure the macroeconomic impact, we need to understand how public policies will affect the preferences of individuals. Firstly, there is an interaction between "standard" climate policies and the preferences of agents. Secondly, policies for "collective" sufficiency (land planning, a sustainable food policy, labour organisation, etc.) will also reconsider social norms and individual needs, which will change how individuals consume.

The main aim of this section is therefore to understand the impact of climate and sufficiency policies on agent preferences (real preferences, rather than nudges, which we will look at in the next section). This impact may come via three channels: awareness of a certain number of co-benefits; change due to environmental policies; and direct action to change preferences so as to promote environmental awareness, for example the dissemination of information.

3.1. Taking Co-benefits Into Consideration

If climate policies bring about changes in preferences in favour of behaviours that generates fewer emissions, achieving climate goals will then be less costly. This change in preferences may be explicit (individuals prefer using less energy, all other things being equal) or implicit, through the existence of co-benefits, i.e. additional positive impacts on well-being, not explicitly modelled in the preferences (individuals identify new links between reducing energy consumption and well-being, and incorporate these into their consumption choices). If, conversely, there is a substitution effect between virtuous actions and the acceptability of a carbon tax (the implementation of a tax relieving us of the responsibility to make any efforts elsewhere), climate policy will be more complicated.

The existence of co-benefits may change preferences as modelled, where the modelling is simplified and does not incorporate all aspects of well-being. For example, developing bicycle use for commuting not only reduces energy consumption, but also improves health by increasing active mobility. While the utility function of the model does not explicitly incorporate an appetite for health, it is the individual's awareness of reduced energy consumption that this co-benefit will change, guiding them towards greater sufficiency.

The IPCC report (2022) and the article by Creutzig *et al.* (2022) show the benefits of a strategy targeting energy demand rather than supply. In effect, such a strategy brings about more synergies and co-benefits between the Sustainable Development Goals (SDGs) defined by the United Nations than crowding-out effects among these goals. For example, increasing the density of towns and cities will also allow for significant improvements in access to health, mobility, education and social security. Using a literature analysis, Creutzig *et al.* (2022) show that, of 306 proposed measures for reducing energy consumption through demand, 79% have a positive impact on well-being, and only 3% have a negative effect. These positive effects help to reduce the total cost of climate policies for society. To assess the overall effect of a mitigation strategy on the aspects of well-being represented in the SDGs, the authors calculate a ratio between (*i*) the created "synergies", i.e. the beneficial effects on well-being (through channels other than reducing climate change), and (*ii*) the crowding-out effects, i.e. the deteriorations in well-being caused. The comparison between the ratios for the mitigation strategies targeting demand and those targeting supply shows that the former is more beneficial from an SDG-compliance perspective, in particular in the industrial and construction sectors. Among the measures considered to be in favour of sufficiency, for example, active mobility (cycling and walking) has the widest beneficial effects, with no negative effect identified. Furthermore, the biggest benefits are seen in the areas of air quality, health, food, mobility, economic stability and water, with relatively high confidence levels given the methodologies used in the various articles considered.

In conclusion, the co-benefits of measures seeking to reduce energy consumption are likely to work towards sufficiency and bring about more virtuous behaviours than that anticipated based on stable preferences that do not take these co-benefits into consideration.

3.2. Interactions Between Conventional Environmental Policies and Preferences

The cost of climate policies will be smaller than envisaged if, endogenously, public environmental policies (including non-climate policies per se, for example, education, information or communication policies) guide agents' preferences towards less carbon-intensive consumption (all other things being equal, in particular price). Conventional climate policies target a long period over which preferences have the time to change due to the policy itself (Mattauch *et al.*, 2022).

Conventional macroeconomic models assume that the consumption choices made by agents result from stable preferences. However, as environment and social setting change the structure of individuals' choices (and thereby their final choices), public policies will have an effect on economic institutions and, therefore, through cultural transmission and their impact on a specific social group, on agent preferences. Individuals adopt new habits as a result of public policy (examples include wearing seat belts or ski helmets), including that relating to the carbon tax. The example from British Columbia in Canada (Rivers *et al.*, 2015) shows that a carbon tax can lead to much lower short-term fuel demand than could be expected with an equivalent increase in the market price of fuel. Furthermore, an empirical analysis of the implementation of a carbon tax and VAT on transportation fuel in Sweden (Andersson, 2019) shows that the elasticity of demand for fuel in relation to the carbon tax is three times greater than the price elasticity.[11] These two outcomes can be explained by an increased awareness of climate change.

Changes in preferences also have consequences for the acceptability of conventional environmental policies: by directly modifying individuals' preferences, a much more stringent environmental policy could be introduced and accepted ex post, whereas it would have been widely contested ex ante (and, in particular, voted down). The opposite may also be true, in the case of a crowding-out effect between changes in preferences and conventional environmental policy. The implementation of a carbon tax may reduce incentives to "small actions" to reduce emissions (Goeschl & Perino, 2012). Reciprocally, the adoption of virtuous behaviours or the implementation of a nudge may reduce support for the carbon tax (Hagmann *et al.*, 2019).

3.3. Policies Targeting Sufficiency

We now consider policies primarily seeking to modify preferences. The rationale behind such policies comes firstly from the observation that "small actions" and legal orders imposing individual accountability will not be enough to sufficiently reduce our greenhouse gas emissions. According to the consultancy firm Carbone 4, individual compliances represent between 25% and 30% of the effort needed to reduce greenhouse gas emissions sufficiently to meet the Paris Agreement (Dugast & Soyeux, 2019). Secondly, even if this is not universally agreed, we expect a synergy between sufficiency policies and conventional policies.

A large proportion of climate policies targeting sufficiency will need to take the form of collective mechanisms, namely changes to collective organisation that will facilitate behavioural changes (see, for example, the reports from the French High Council on Climate, in particular HCC, 2021). Here, for example, we are referring to urban planning (cycle lanes, public transport network), relocating services to town/city centres, deploying super-fast broadband to improve remote working and reduce travel, etc. Furthermore, the dissemination of information can help to change behaviour and improve the effectiveness of choices. This assumes that there is a market failure (incomplete information) leading to a sub-optimal situation, for example, excess consumption, which would, in that case, be corrected. For example, a study conducted by Larcom *et al.* (2017) shows that a London Underground strike, which forced numerous users to take new routes led to lasting behavioural changes and improved network efficiency. This can be explained in two ways: either these users were not taking the most efficient route, with research costs not being sufficient to explain their behaviour; or they used other means of transport and increased their mobility capital, and, in this way, caused a reduction in the cost of alternative options to the Underground (Kaufmann *et al.*, 2004). However, there is no consensus in the empirical literature regarding the effect of information on energy consumption. For example, the effect of labels on consumption choices is sometimes mitigated (see fridge example in Houde, 2018). By way of example, an experiment conducted by Aydin *et al.* (2018) revealed that information campaigns led to a 20% reduction in energy consumption in homes; whereas other studies in the transport sector found no effect in terms of the energy performance of the vehicles purchased (Allcott & Knittel, 2019).

Finally, much of what relates to individual behaviour is, in reality, anchored in a collective dimension, the influence of which is such that individuals find themselves guided or obliged to behave in a certain way. What we may think to be an individual choice may in fact be the result of collective organisation (finding accommodation in a multiple-occupancy building rather than a single-family home, using public transport, etc.) and the proportion of agency that each individual has, their free will or room for manoeuvre, is in reality very unequally distributed across society (Otto *et al.*, 2020). Policies that relate to these collective organisations will therefore have an impact on individual preferences. The impact of peer behaviour (peer effects) on the choices made by individuals was highlighted in the case of car purchases (Grinblatt *et al.*, 2008), installation of solar panels (Bollinger *et al.*, 2020; Gillingham & Bollinger, 2021, or Baranzini *et al.*, 2017) and economical use of water (Bollinger *et al.*, 2020). Lobbies and interest

11. We may suspect that individuals rightly interpret an increase in carbon taxation as being permanent and an increase in the pre-tax price as being temporary, which is why they adapt more to the former than to the latter.

groups may also have an impact in favour of or against a behavioural change. Sufficiency awareness campaigns will change how consumers view their environment (their connection with food and organic production, for example), make them reflect on their habits (their choice of transport, for example), and change the way in which they will compare themselves to other segments of society by, in particular, changing the carbon intensity of symbolic markers of material success (Brispierre *et al.*, 2013). It should be noted that sufficiency policies on the supply side (changing the supply of goods, services, their distribution or the way they are provided) will also have an impact on individuals' preferences, especially in the long term, by changing markers of social success towards simpler lifestyles (Coulangeon *et al.*, 2023).

However, the collective dimension of individual preferences should not overshadow the necessary consideration of inequalities (in terms of land, income, etc.) in order not to over- or underestimate the changes in preferences (Marcus *et al.*, 2023). Indeed, taking inequalities into consideration may have several opposing effects. On the one hand, as emissions from the wealthiest individuals are highest (Cayla *et al.*, 2020), a change in their preferences will have a greater impact on reducing greenhouse gas emissions than that of the poorest. On the other hand, the high-consumption model that sufficiency policies seek to move away from is highly symbolic, in particular among the working classes, for whom some forms of high-emission consumption (cars, holidays in the sun, purchasing a detached house) are strong markers of social and material success (Halbwachs, 1938), whereby "to consume is to be part of society". Therefore, there may be many difficulties in achieving changes in a particular part of the population, which would increase the time needed for preferences to change. Furthermore, the collective mechanisms found in (social) groups stop preference changes from spreading where legal orders or sufficiency policies are not differentiated appropriately (Coulangeon *et al.*, 2023). Indeed, the symbolic barriers between social strata are very strong and behaviours seen as virtuous in certain strata can, conversely, serve as deterrents in others. For example, while a preference change resulting from some sufficiency policy may be facilitated among the upper classes thanks to the social benefit that this brings ("I don't fly any more, not because I can't but because I have the luxury of choosing not to"), it may, on the contrary, be slowed down among the working classes as a response to this freedom of choice ("you represent the urban elite who have the choice", see the *Gilets Jaunes* movement).

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The potential contribution that sufficiency can make to reduced greenhouse gas emissions warrants our consideration of the ways in which this can be implemented to bring individuals to effectively adopt less energy-intensive behaviours. In this article, we have explored the different avenues that could lead to improved energy sufficiency.

We first modelled energy sufficiency resulting from exogenous shocks to the relative weights of durable goods, the energy to use those goods, or even non-durable goods, in the consumers' preferences. Simulating these shocks to achieve the same reduction in household energy consumption has shown a high level of heterogeneity in terms of GDP impact and total consumption during the transition. The decision to incentivize one shock or another via public policies could be guided by considerations such as acceptability (here, total consumption is prioritised by creating a negative shock to the relative weight of energy in the consumer's preferences) or GDP growth (here, the energy reduction is be limited by prioritising a positive shock to the relative weights of non-durable goods).

Highlighting and offering an improved assessment of the potential co-benefits are interesting avenues to explore as regards changing preferences. These avenues primarily require more research into endogenous changes in preferences and their inclusion in climate transition modelling. Furthermore, nudges, while they do not remove the externality, do make it possible to reduce behavioural biases or to create new ones that favour emissions reduction, and are also generally less costly, namely at the political level.

The fact that energy sufficiency can be chosen, and therefore does not require restrictions to be placed on individuals, must not be a pretext for forgetting the social and economic justice associated with decarbonising the economy. This argument is, in particular, put forward by Schubert (2023), who specifies that: "[…] pricing policies [and] voluntary behaviour […] must be seen within a social context of reducing inequalities" ☐

BIBLIOGRAPHY

Allcott, H. & Knittel, C. (2019). Are Consumers Poorly Informed about Fuel Economy? Evidence from Two Experiments. *American Economic Journal: Economic Policy*, 11(1), 1–37. https://doi.org/10.1257/pol.20170019

Andersson, J. J. (2019). Carbon taxes and CO_2 emissions: Sweden as a case study. *American Economic Journal: Economic Policy*, 11(4), 1–30. https://doi.org/10.1257/pol.20170144

Aydin, E., Brounen, D. & Kok, N. (2018). Information provision and energy consumption: Evidence from a field experiment. *Energy Economics*, 71, 403–410. https://doi.org/10.1016/j.eneco.2018.03.008

Baranzini, A., Carattini, S. & Peclat, M. (2017). What drives social contagion in the adoption of solar photovoltaic technology. Grantham Research Institute on Climate Change and the Environment*, Working Papers* N° 270.
https://www.lse.ac.uk/granthaminstitute/publication/what-drives-social-contagion-in-the-adoption-of-solar-photovoltaic-technology/

Benartzi, S., Beshears, J., Milkman, K. L., Sunstein, C. R., Thaler, R. H., Shankar, M., Tucker-Ray, W., Congdon, W. J. & Galing, S. (2017). Should Governments Invest More in Nudging? *Psychological Science*, 28(8), 1041–1055. https://doi.org/10.1177/0956797617702501

Blanchet, D., Pesme, C. & Pommeret, A. (2023). Les incidences économiques de l’action pour le climat – Bien-être. France Stratégie, Rapport thématique.
https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2023-les_incidences_economiques_de_laction_pour_le_climat-thematique-bien-etre.pdf

Bollinger, B., Burckhardt, J. & Gillingham, K. (2020). Peer Effects in Residential Water Conservation: Evidence from Migration. *American Economic Journal: Economic Policy*, 12(3), 107–133.
https://doi.org/10.1257/pol.20180559

Boon-Falleur, M., Grandin, A., Baumard, N. & Chevallier, C. (2022). Leveraging social cognition to promote effective climate change mitigation. *Nature Climate Change,* 12, 332–338.
https://doi.org/10.1038/s41558-022-01312-w

Brispierre, G., Beslay, C., Vacher, T. & Fouquet, J.-P. (2013). L’efficacité comportementale du suivi des consommations en matière d’économie d’énergie dépend des innovations sociales qui l’accompagnent. Synthèse de l’étude sociologique ADEME/GrDF sur les campagnes de sensibilisation aux économies d’énergie basées sur le suivi des consommations.
https://gbrisepierre.fr/wp-content/uploads/2019/11/GBS-Synthese-socio-campagnes-MDE-2013.pdf

Brunet, L. (2021). #Flygskam : le pouvoir de la honte de prendre l’avion pour gouverner le changement climatique. *Lien social et Politiques*, 86, 54–70. https://doi.org/10.7202/1079492ar

Carlsson, F., Graverty, C., Johansson-Stenmanz, O. & Kurz, V. (2021). The Use of Green Nudges as an Environmental Policy Instrument. *Review of Environmental Economics and Policy*, 15(2).
https://doi.org/10.1086/715524

Caron, J. & Fally, T. (2022). Per Capita Income, Consumption Patterns, and CO_2 Emissions. *Journal of the Association of Environmental and Resource Economists*, 9(2), 235–271. https://doi.org/10.1086/716727

Cayla, J.-M., Combet, E., de Lauretis, S., Nadaud, F. & Pottier, A. (2020). Qui émet du CO_2 ? Panorama critique des inégalités écologiques en France. *Revue de l’OFCE*, 169, 73–132.
https://doi.org/10.3917/reof.169.0073

Comin, D., Lashkari, D. & Mestieri, M. (2021). Structural Change with Long-run Income and Price Effects. *Econometrica*, 89(1), 311–374. https://doi.org/10.3982/ECTA16317

Coulangeon, P., Demoli, Y., Ginsburger, M. & Petev, I. (2023). *La Conversion écologique des Français – Contradictions et clivages*. Paris: PUF.

Creutzig F., Niamir, L., Bai, X., Callaghan, M., Cullen, J., Díaz-José, J., Figueroa, M., Grubler, A., Lamb, W. F., Leip, A., Masanet, E., … & Ürge-Vorsatz, D. (2022). Demand side solutions to climate change mitigation consistent with high levels of well-being. *Nature Climate Change*, 12, 36–46.
https://doi.org/10.1038/s41558-021-01219-y

Dillman, D. A., Rosa, E. A. & Dillman, J. J. (1983). Lifestyle and home energy conservation in the United States: the poor accept lifestyle cutbacks while the wealthy invest in conservation. *Journal of Economic Psychology*, 3(3-4), 299–315. https://doi.org/10.1016/0167-4870(83)90008-9

Dugast, C. & Soyeux, A. (2019). Faire sa part ? Pouvoir et responsabilité des individus, des entreprises et de l’État face à l’urgence climatique. Carbone 4, *Publication – juin*.
https://www.carbone4.com/publication-faire-sa-part

Farhi, E. & Gabaix, X. (2020). Optimal Taxation with Behavioral Agents. *American Economic Review*, 110(1), 298–336. https://doi.org/10.1257/aer.20151079

Giec (2022). Demand, Services and Social Aspects of Mitigation. In: *Climate Change 2022: Mitigation of Climate Change*, Ch. 5. IPCC, Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg3/

Gillingham, K. & Bollinger, B. (2021). Social Learning and Solar Photovoltaic Adoption. *Management Science*, 67(11), 7091–7112. https://doi.org/10.1287/mnsc.2020.3840

Goeschl, T. & Perino, G. (2012). Instrument Choice and Motivation: Evidence from a Climate Change Experiment. *Environmental and Resource Economics*, 52(2), 195–212. https://doi.org/10.1007/s10640-011-9524-4

Grinblatt, M., Keloharju, M. & Ikäheimo, S. (2008). Social Influence and Consumption: Evidence from the Automobile Purchases of Neighbors. *The Review of Economics and Statistics*, 90(4), 735–753. https://doi.org/10.2139/ssrn.995855

GRTgaz (2023). Actualisation des perspectives gazières pour l'hiver 2022-2023. https://www.grtgaz.com/medias/actualites/perspectives-systeme-gazier-hiver-janvier-2023

Grubler, A., Wilson, C., Bento, N., Boza-Kiss, B., Krey, V., McCollum, D. L., Rao, N. D., Riahi, K., Rogelj, J., De Stercke, S., Cullen, J., Frank, S., Fricko, O.,… & Valin, H. (2018). A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies. *Nature Energy*, 3(6), 515–527. https://doi.org/10.1038/s41560-018-0172-6

Hagmann, D., Ho, E. H. & Lowenstein, G. (2019). Nudging out support for a carbon tax. *Nature Climate Change*, 9, 484–489. https://doi.org/10.1038/s41558-019-0474-0

Halbwachs, M. (1938). *Morphologie sociale*. Paris: Armand Colin.

Harguess, J. M., Crespo, N. C. & Hong, M. Y. (2020). Strategies to reduce meat consumption: A systematic literature review of experimental studies. *Appetite*, 144(104478). https://doi.org/10.1016/j.appet.2019.104478

Haut Conseil pour le Climat, HCC (2021). Renforcer l'atténuation, engager l'adaptation. Rapport annuel, juin. https://www.hautconseilclimat.fr/publications/rapport-annuel-2021-renforcer-lattenuation-engager-ladaptation/

Henriet, F., Maggiar, N. & Schubert, K. (2014). A Stylized Applied Energy-Economy Model for France. *The Energy Journal*, 35(4). https://doi.org/10.5547/01956574.35.4.1

Houde, S. (2018). How consumers respond to product certification and the value of energy information. *The RAND Journal of Economics*, 49(2), 453–477. https://doi.org/10.1111/1756-2171.12231

Jungell-Michelsson, J. & Heikkuren, P. (2022). Sufficiency: A systematic literature review. *Ecological Economics*, 195(107380). https://doi.org/10.1016/j.ecolecon.2022.107380

Kaufmann, V., Bergman, M. M. & Joye, D. (2004). Motility: Mobility as capital. *International Journal of Urban and Regional Research*, 28(4),745–756. https://doi.org/10.1111/j.0309-1317.2004.00549.x

Larcom, S., Rauch, F. & Willems, T. (2017). The Benefits of Forced Experimentation: Striking Evidence from the London Underground Network. *The Quarterly Journal of Economics*, 132(4), 2019–2055. https://doi.org/10.1093/qje/qjx020

Leonard-Barton, D. (1981). Voluntary Simplicity Lifestyles and Energy Conservation. *Journal of Consumer Research*, 8(3), 243–252. https://doi.org/10.1086/208861

List, J., Rodemeier, M., Roy, S. & Sun, G. (2022). Judging Nudging: Understanding the Welfare Effects of Nudges Versus Taxes. *Framed Field Experiments*, 00765. http://dx.doi.org/10.2139/ssrn.4450082

Marcus, V., Combet, E., Ghersi, F., Hamdi-Cherif, M., Malliet, P., Lequien, M., Le Hir, B., Pinton, C. & Viennot, M. (2023). Les incidences économiques de l'action pour le climat – Enjeux distributifs. France Stratégie, Rapport thématique. https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2023-les_incidences_economiques_de_laction_pour_le_climat-thematique-enjeux_distributifs.pdf

Mattauch, L., Hepburn, C., Spuler, F. & Stern, N. (2022). The economics of climate change with endogenous preferences. *Resource and Energy Economics*, 101312. https://doi.org/10.1016/j.reseneeco.2022.101312

négaWatt (2016). Qu'est-ce que la sobriété ? *Fil d'argent*, 5, 11–13. https://negawatt.org/telechargement/Presse/1601_Fil-dargent_Qu-est-ce-que-la-sobriete.pdf

Otto, I. M., Wiedermann, M., Cremades, R., Donges, J. F., Auer, C. & Lucht, W. (2020). Human Agency in the Anthropocene. *Ecological Economics*, 167(106463). https://doi.org/10.1016/j.ecolecon.2019.106463

Quinet, A. (2019). La valeur de l'action pour le climat, une valeur tutélaire du carbone pour évaluer les investissements et les politiques publiques. France Stratégie, Rapport. https://www.strategie.gouv.fr/publications/de-laction-climat

Rivers, N. & Schaufele, B. (2015). Salience of carbon taxes in the gasoline market. *Journal of Environmental Economics and Management*, 74, 23–36. https://doi.org/10.1016/j.jeem.2015.07.002

RTE (2023). Bilan électrique 2022 : un système électrique français résilient face à la crise énergétique. Rte, Rapport. https://assets.rte-france.com/prod/public/2023-02/Bilan-electrique-2022-synthese.pdf

Sexton, S. E. & Sexton, A. L. (2014). Conspicuous conservation: The Prius halo and willingness to pay for environmental bona fides. *Journal of Environmental Economics and Management*, 67(3), 303–316. https://doi.org/10.1016/j.jeem.2013.11.004

Schubert, K. (2023). Sobriety. In: *Peace not Pollution: How Going Green Can Tackle Climate Change and Toxic Politics*. London: CEPR Press. https://cepr.org/chapters/sobriety/

Thaler, R. H. & Sunstein, C. R. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. New Haven, CT: Yale University Press.