N° 543 - 2024

Economie ET Statistique

Economics AND Statistics

Dossier

Environnement : les enjeux économiques du défi climatique

Varia

L'attachement aux animaux de compagnie

Thematic Section

Environment: The Economic Stakes of the Climate Challenge

Varia

Attachment to Pets

Insee

Economie ET Statistique

Economics AND Statistics

Conseil scientifique / Scientific Committee
Jacques LE CACHEUX, président (Université de Pau et des pays de l'Adour)
Frédérique BEC (Thema, CY Cergy Paris Université et CREST-ENSAE)
Flora BELLONE (Université Côte d'Azur et GREDEG-CNRS)
Céline BESSIERE (Université Paris-Dauphine, IRISSO, PSL Research University)
Jérôme BOURDIEU (École d'Économie de Paris)
Pierre CAHUC (Sciences Po)
Sandrine CAZES (OCDE)
Gilbert CETTE (NEOMA Business School)
Dominique GOUX (Insee)
Yannick L'HORTY (Université Gustave Eiffel - Erudite, TEPP)
Daniel OESCH (LINES et Institut des sciences sociales-Université de Lausanne)
Katheline SCHUBERT (École d'Économie de Paris, Université Paris I)
Louis-André VALLET (CNRS & Sorbonne Université - GEMASS)
François-Charles WOLFF (Université de Nantes)

Comité éditorial / Editorial Advisory Board
Luc ARRONDEL (École d'Économie de Paris)
Lucio BACCARO (Max Planck Institute for the Study of Societies et Département de Sociologie-Université de Genève)
Antoine BOZIO (Institut des politiques publiques/École d'Économie de Paris)
Clément CARBONNIER (Université Paris 8 Vincennes-Saint-Denis et LIEPP-Sciences Po)
Erwan GAUTIER (Banque de France)
Pauline GIVORD (Insee et CREST)
Florence JUSOT (Université Paris-Dauphine, Leda-Legos et Irdes)
François LEGENDRE (Erudite/Université Paris-Est)
Claire LOUPIAS (Université d'Evry Val d'Essonne)
Pierre PORA (Insee)
Ariell RESHEF (École d'Économie de Paris, Centre d'Économie de la Sorbonne et CEPII)
Thepthida SOPRASEUTH (Théma/Université de Cergy-Pontoise)

Directeur de la publication / Director of Publication:
Jean-Luc TAVERNIER
Rédactrice en chef / Editor in Chief:
Dominique GOUX
Assistante éditoriale / Editorial Assistant: Véronique EGLOFF
Traductions / Translations: RWS Language Solutions
Chiltern Park, Chalfont St. Peter, Bucks, SL9 9FG, Royaume-Uni
Maquette PAO / CAP: LUMINESS
1, rue du Docteur-Sauvé, BP3, 53101 Mayenne, France
Impression / Printing: PARAGON TRANSACTION
39 rue des Rivières Saint-Agnan, 58200 Cosne-Cours-sur-Loire, France

La revue est en accès libre sur le site **www.insee.fr**. Il est possible de s'abonner aux avis de parution sur le site. La revue peut être achetée sur le site **www.insee.fr**, rubrique « Services / Acheter nos publications ».

The journal is available in open access on the Insee website **www.insee.fr.** Publication alerts can be subscribed online. The printed version of the journal (in French) can be purchased on the Insee website **www.insee.fr**.

© Insee Institut national de la statistique et des études économiques
88, avenue Verdier - CS 70058 - 92541 Montrouge Cedex
Tél : +33 (0)1 87 69 50 00

Economie et Statistique / Economics and Statistics
Issue 543 – 2024

ENVIRONMENT: THE ECONOMIC STAKES OF THE CLIMATE CHALLENGE

SOCIETY

The views or opinions expressed by the authors engage only themselves,
and neither the institutions they work with, nor INSEE.

Costs and Co-Benefits of Climate Transition Policies: How Accurately Will They Be Measured by Standard of Living and Well-Being Indicators?

Didier Blanchet* and Craig Pesme*

Abstract – The aim of the climate transition is to minimise the long-term losses of well-being that would result from inaction. However, the necessary policies are likely to incur costs in the short and medium term. Standard of living indicators will serve their intended purpose if they accurately reflect these costs. Nevertheless, some of them may be underestimated, resulting in a greater impact than suggested by conventional indicators. Conversely, the well-being cost of the transition could be lower if non-monetary co-benefits emerge quickly enough and/or if preferences shift: reduced access to polluting goods has a different impact depending on whether the intrinsic taste for these goods remains strong or declines. While these questions are relevant to various contexts, the climate transition offers an opportunity to examine them in greater depth.

JEL: C43, E01, E31, I31
Keywords: climate transition, standards of living, well-being

* *Chaire Mesures de l'économie, Paris School of Economics.* Correspondence: *didier.blanchet@icloud.com*

This text is taken from a contribution, written together with Aude Pommeret, to the research conducted by the mission led by Jean Pisani-Ferry and Selma Mahfouz on the economic implications of climate action (Blanchet et al.*, 2023). This contribution has benefited from their feedback, as well as comments from Anne Épaulard, Mathilde Viennot, Xavier Timbeau, Nicolas Carnot and Mathieu Lequien. It was largely based on research conducted with Marc Fleurbaey as part of the "Measurement in Economics" Chair at the Paris School of Economics, funded by INSEE, Société Générale, Candriam and QuantCube. This article has also benefited from numerous discussions with Étienne Debauche, and comments from the two reviewers. The opinions expressed are the authors' own.*

Received in July 2023, accepted in May 2024. Translated from "Coûts et co-bénéfices des politiques de transition climatique : comment seront-ils retracés par les indicateurs de niveau de vie et de bien-être ?".
The opinions and analyses presented in this article are those of the author(s) and do not necessarily reflect their institutions' or INSEE's views.

Citation: Blanchet, D. & Pesme, C. (2024). Costs and Co-Benefits of Climate Transition Policies: How Accurately Will They Be Measured by Standard of Living and Well-Being Indicators? *Economie et Statistique / Economics and Statistics*, 543, 3–20. doi: 10.24187/ecostat.2024.543.2116

The consideration of environmental issues is often criticised as a weak point in monetary approaches to living conditions (Gadrey & Jany-Catrice, 2016; Laurent & Le Cacheux, 2016), whether in the highly aggregated approach of national accounts or in more microeconomic approaches that also examine the distribution of living standards across households. For national accounts, a recurring request is to enrich them with sustainability indicators, allowing to assess, beyond GDP, whether sufficient efforts are being made to ensure that future well-being levels will be at least equivalent to current ones. This is a complex undertaking, as it addresses a subject that is simultaneously prospective, multi-dimensional and global. Prospective, because it involves assessing the impact of current decisions and actions on future living conditions. Multi-dimensional, as these actions and decisions cover a large number of areas: greenhouse gas emissions and climate action are currently prominent, but the issue of sustainability is much broader. Global, since the sustainability of living conditions in a given country depends on the actions and decisions of all countries, and therefore cannot be measured by accounts for each country in isolation. This explains the slow progress in this area, in spite of some advances (Germain & Lellouch, 2020).

However, there is one aspect of the climate transition that the current statistical system should be able to cover more easily: calculating its local and real-time costs as it progresses. This topic has long been neglected due to the prevalent belief that these costs could be kept to a minimum, a view that is increasingly falling out of favour (Pisani & Mahfouz, 2023). While the climate transition aims to increase well-being in the long term compared to a reference scenario without climate policy, short-term costs are expected, due to the phasing out of highly energy-intensive production and consumption practices that have driven past growth. When measuring these costs, national accounts and income and price statistics should be expected to fulfill their usual role. They have been used to quantify how reliance on fossil fuels and poor environmental practices have facilitated the rise in living standards. They should also be equally capable of measuring the impact that the consumption restrictions necessary for greening would have on living standards.

But are these measures guaranteed to be exhaustive? Conversely, is there a risk of overlooking elements that could offset these costs, if the transition brings non-monetary co-benefits with sufficiently rapid local effects, without needing to wait for the expected long-term global benefits? This transition could also be accompanied by a greening of preferences, which should also be taken into account as such a phenomenon would reduce the impact on well-being from decreasing the consumption of carbon-intensive goods.

This article does not claim to be exhaustive but explores several of these issues. None of them are entirely specific to the climate transition, but the transition provides an opportunity to examine them in greater depth or from a new perspective. The article will start by analysing how the transition could impact the monetary living standards of households, a question also addressed by Dees *et al.* (2023). It will focus on three different vectors of decarbonisation: a green version of the classic process of creative destruction, taxation on carbon-intensive goods, and regulations restricting their consumption. The current method for calculating purchasing power will, in theory, account for the first two types of greening, but not necessarily for the third. This limitation arises from measurement instruments based on income and prices, which fail to take into consideration other factors that can limit consumption opportunities for given levels of income and prices.

As a direct extension of this first observation, other questions may arise concerning indicators related to additional aspects of real income, such as the volume/price decomposition of public services that households benefit from, given that these services will also need to be decarbonised (The Shift Project, 2023), and the devaluation of carbon-intensive assets held by households. These issues are not explored further in this article; we refer interested readers to the report on which this article is based (Blanchet *et al.*, 2023). The second section will therefore move directly onto the issue of the non-monetary co-benefits of the transition. The consideration of non-monetary elements of well-being is a classic subject, and we will review the available options for addressing it. The issue of greening preferences has received much less attention and presents particularly challenging conceptual problems. We will explore this in the third section.

1. Green Transition and Purchasing Power of Disposable Income

The first step is to determine which of the usual statistical indicators would be best suited for

capturing the net costs of the climate transition. It is common to focus on the impact on GDP: can greening be compatible with continued GDP growth or will it necessarily lead to a significant slowdown or even a reversal? This first section will instead focus on another indicator used in national accounts, namely the gross disposable income (GDI) of households, and its counterpart measured by social statistics, their standard of living. Both of them can be considered either as average values, for an individual deemed to be representative, or in terms of dispersion across different household types.

With a few differences, these two indicators represent the total primary income of households, which mostly consists of labor income and, for some, capital income. All taxes and contributions paid by households are deducted from this income, while monetary benefits received are added. The resulting figure is then deflated by a chain-weighted price index: price variations for different goods and services are weighted according to their share in the household budget, with updates made for changes in these shares over time. Finally, the purchasing power of income, or standard of living, is adjusted to account for household size and the economies of scale that result from it.

Whether from a macro or micro perspective, this article will aim to compare these indicators with a stylised theoretical representation of consumer utility. Such a comparison cannot be ruled out on the basis that GDI or living standards are not intended to measure well-being. This defensive argument is often used to dismiss their criticism or that of GDP. It is true that none of these indicators are intended to provide a comprehensive measure of well-being, and it is always worth keeping this in mind. However, they are assumed to capture a key component of this well-being: the utility that is derived from income and the consumption it enables. It might be argued, in return, that this utility cannot be quantified in an unequivocal way and that the comparison is therefore meaningless, but this counterargument is also invalid. Although standard of living indicators cannot be expected to directly correspond to a cardinal measure of utility - which we know to be relative - their messages should still be as consistent as possible with *ordinal* preferences. There would indeed be a significant problem if measures of standard of living suggested an improvement between two periods t and t' while, all else being equal, households in period t' would prefer to return to their nominal income and price levels of period t. Such a risk can never be completely eliminated, but it is important to ensure that the green transition does not exacerbate it.

1.1. Growth and Renewal of Goods: The Standard Case of Creative Destruction

In order to fully understand this risk of contradictory messages, it is useful to first revisit what typically allows us to ignore it. If this risk does not immediately come to mind, it is because we often envision a growth scenario where the consumption of goods and services increases in all dimensions, and we assume that having more of all these goods and services is inherently preferable.

In reality, growth is never completely of this type, as it always goes hand-in-hand with the renewal of goods: the consumption of new goods spreads and grows as they replace goods for which consumption reduces until they disappear completely. Growth is therefore a process of addition and subtraction. However, it has most frequently taken the form of a spontaneous creative destruction process driven by the price decrease of new goods, rather than by an increase in the price of existing goods. In such cases, it is reasonable to assume that consumers benefit from this process, and that the additions outweigh the subtractions. The improvement in living standards could even be underestimated due to the difficulty of accurately measuring the contribution of new goods when they are first introduced to the market. It is only once they are fully integrated into the price index that statisticians can measure how their falling prices improve living standards.

This usual line of thinking is illustrated by a first simulation of a three-good model that will be used throughout this article. It considers a generic good 0 and two goods, 1 and 2, between which growth will generate a replacement effect (Box 1 and Figure I). The simulation is based on an initial situation in which good 2 may exist but can only be marketed at a price unacceptable to the consumer, i.e. higher than the reservation price, beyond which the demand for the good is zero. We then assume that a technological shock causes its price to drop significantly below the reservation price at a given time $t_1 = 25$,[1] leading to an immediate jump in both production and demand. After this initial surge, production continues to benefit from ongoing technical progress, resulting in further price reductions and increased consumption until time $t_2 = 100$.

1. This date could also be interpreted as the date at which good 2 is introduced into the basket of consumer goods used to calculate the price index.

Box 1 – **A Model Made Up of Three Goods**

Throughout the article, our discussions will be based on a model made up of three goods: two goods between which the replacement phenomenon will take place, with prices p_1 and p_2 and which are consumed in quantities q_1 and q_2, and an aggregate of all other goods consumed in quantity q_0. For the greening scenarios, good 2 will be the green good and good 1 the polluting ('brown') good. Preferences are represented by a nested CES (Constant Elasticity of Substitution) function, which will be maximised under the budgetary constraint $R = q_0 + p_1 q_1 + p_2 q_2$ and, in some simulations, a regulatory cap $\overline{q_1}$ on the consumption of good 1. Goods 1 and 2 are combined in a first CES, while a second CES combines them with good q_0. Incompressible minimum consumption or usage terms B_0 and B are added to this second CES. They can also take negative values, in which case the good 0 or the composite good are non-essential, i.e. it is possible to not consume them at all. The overall utility function $U(q_0, q_1, q_2)$ is expressed as follows:

$$\left[a_0 \left(q_0 - B_0\right)^{\frac{\sigma_0 - 1}{\sigma_0}} + \left(1 - a_0\right) \left(\left(a q_1^{\frac{\sigma-1}{\sigma}} + \left(1-a\right) q_2^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} - B \right)^{\frac{\sigma_0 - 1}{\sigma_0}} \right]^{\frac{\sigma_0}{\sigma_0 - 1}} \quad (1)$$

In all simulations, except the last one where preferences are unstable, the parameter values for this function are assumed to be fixed with values $a_0 = 0.25, a = 0.55, B_0 = 1, B = -1, \sigma_0 = 0.5$ and $\sigma = 2$.

What relationship should we expect to find between this representation of utility and standard of living indicators?

Generally speaking, the relationship can only be exact in the specific case of a homogeneous function U of degree 1. In this case, it is possible to write $U = \sum_i U_i' q_i$, from which we can derive the form $U = \lambda \sum_i p_i q_i$ and $dU/U = \sum_i p_i dq_i / \sum_i p_i q_i$, which reflects the variation in volume at current prices. In this case, the chain-linking of these variations would reproduce the change in U between any two dates.

When the utility function can be expressed as $V = g\left(U(q)\right)$, where g is any monotone function and the same homogeneity of degree 1 of U is maintained, this scalar equivalence is lost, but there is still consistency between the measurement of the standard of living and ordinal preferences: in this case, an increase in income deflated by a chain-weighted price index still corresponds to an increase in both U and V, all else being equal. This case is that of "homothetic" preferences, in which an equal increase in all of the quantities consumed has the same effect on well-being, regardless of the initial consumption structure.

This result no longer holds up if such a homotheticity property is not satisfied, which will be the case for specification (1). For example, if the saturation of satisfaction is reached more quickly for a particular good, the gain in well-being is not the same if we double all consumption from a state in which the good in question is already being extensively consumed and from a state in which it is rarely consumed. This will be the case if B and/or B_0 are not equal to zero. In this case, a discrepancy may arise between preferences and the standard of living measurement with a chain-weighted price index, one manifestation of which is the issue of path dependence - the fact that the comparison of standards of living between two dates t and t' depends on the path taken between the two periods (see Blanchet & Fleurbaey (2022) for a more detailed description of this). However, it is still useful to check that the extent of such discrepancies remains limited. This is the approach that will be taken in this article.

With this point in mind, the use of this very simple model may give rise to three further objections, but of unequal significance:

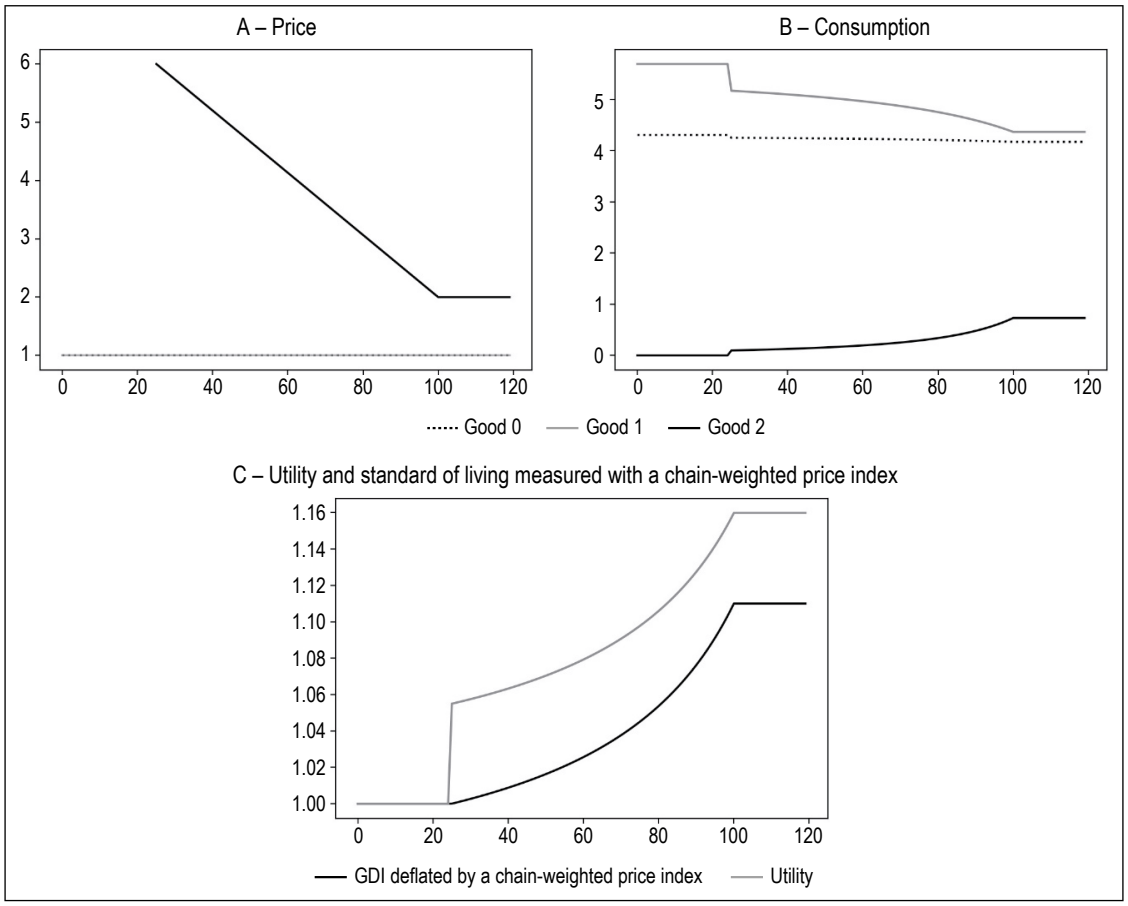
- The first is that it only seems to concern a representative agent, with all of the well-known limitations that come with this concept (Kirman, 1992). Indeed, given that green or brown goods may often be indivisible (electric versus non-electric car), our simulations will more likely represent a phenomenon of increasing adoption expressed in terms of average weighting in the basket of an aggregated "household" agent. However, the qualitative insights from this model remain translatable to the micro level and would apply directly to divisible goods: the number of car trips rather than car ownership, lowering home temperature rather than changing the heating system, or reductions in any other consumption category with high greenhouse gas content. Everything presented can therefore be used for evaluating the redistributive effects of climate policies, in the spirit of Douenne (2022) and analyses in terms of inflation inequality (Jaravel, 2021).
- The second objection is the fact that reasoning is done in partial equilibrium. This second limitation would indeed be very problematic if we wanted to offer a comprehensive prediction of the effects of different greening policies. For example, the greening of preferences that will be studied at the end of the article would have general-equilibrium effects on supply and demand and therefore on income and prices. These effects would need to be simulated if we wanted to provide a comprehensive forecast of their overall impact on well-being. However, the objective of this article is more limited. Assuming that the balances of these effects on income, prices and consumption patterns will be directly observed by the statistician, the only question raised is whether the usual standard of living indicators will synthesize them in a way that will properly reflect their impact on the utility of household(s). This question essentially boils down to whether or not the nominal income deflators are valid, which will be illustrated by projections with constant nominal incomes. Only one feedback element will be simulated, in the case of taxation: the effect on nominal income of a recycling of the tax revenue.
- The final limitation is that it neglects intertemporal effects. Whether individual or representative, the consumers we model choose their consumption pattern on each date based on current prices or constraints without considering their future trends and without having the ability to smooth their response to those trends. This approach is clearly just

➔

Box 1 – *(contd.)*

a simplified vision of a reality that is made more complex by the effects of anticipation and other intertemporal reasoning, particularly when the greening involves durable goods, with electric cars once again serving as the standard example: the higher purchase cost may be partially offset by cheaper running costs, although the ability to benefit from such compensation depends on financial assets, current resources or borrowing capacity, and potentially the resale value of the good. Here, the price of the good should be considered as an indicator of average usage costs over the service life of the good, taking all these elements into account. When the green good is more expensive, it indicates that its lower energy consumption or lower maintenance costs would not be sufficient to offset the higher purchase cost or the cost of the debt required for its purchase. A more explicit modeling of these intertemporal effects has not been attempted in this preliminary overview.

Figure I – **The new good effect: the standard case**



Reading note: Good 2 appears on the market at date 25 thanks to an innovation that brings its price significantly below its reservation price. It is therefore immediately adopted to a significant degree, resulting in a fall in the consumption of good 1, and also favouring the consumption of good 0. These changes have an immediate effect on the consumer's well-being that is not reflected in their real gross disposable income. The latter nevertheless does reflect the increase in well-being from the subsequent reduction in the price of good 2 until date 100. If goods 1 and 2 were perfectly substitutable ($\sigma \to \infty$), the model would have simulated a full and immediate switch from good 1 to good 2 as soon as the price ratio of the two goods exceeds the ratio of the services they provide $a/(1-a)$. In this case, deflation by chain-weighted prices would accurately account for all the impacts on the consumer's standard of living: no impact while the price of good 2 remains above the price at which the switch takes place, a completely neutral change during the switch, followed by an increase in well-being linked to the subsequent fall in its price, which is captured well by our indicators. The only possible source of bias is the late introduction of good 2 into the basket of consumer goods taken into consideration by statisticians.
Sources: Authors' calculations.

In such a scenario, there is an initial positive impact on utility, as defined by equation (1) in the box, that is not measured by nominal income deflated by the chained price index. This limitation is well-known when it comes to measuring prices and volumes: it is impossible to assess the initial impact of a new good the first time it appears in the consumer basket, when its first appearance occurs at a non-marginal level. However, the subsequent process in which the reduction of the price of the good leads to a further increase in its consumption

is well captured and is indeed a process of growth in which the gain induced by the growing consumption of good 2 outweighs the decreasing consumption of good 1.

The underestimation of the impact of new goods highlighted by this initial simulation has been extensively discussed in debates about measuring the effects of new ICT (information and communication technologies) or the digital economy.[2] This issue arises either when dealing with goods that provide innovative services and immediately capture significant market shares as soon as they are introduced, or when their inclusion in the price index is delayed until their market share begins to rise significantly. It is possible that a similar underestimation could apply to the greening process, particularly for green technologies that are becoming increasingly competitive compared to polluting technologies. However, a significant difference is expected with this optimistic version of the process of creative destruction. The reason is that green goods typically do not offer new services but rather serve as alternatives to existing polluting goods, often at a higher initial cost. It is this initial extra cost that may justify public intervention aimed at reducing the consumption of polluting goods. How these costs are reflected in measures of the standard of living will depend on the method used to achieve this greening.

Setting aside, at this stage, the case of voluntary sufficiency resulting from a change in preferences, we will consider the two most frequently discussed options of "forced" greening. The first scenario involves the implementation of a tax on good 1, now assumed to be the polluting good (henceforth called the 'brown' good), with or without redistribution of the collected funds. The second scenario consists of a quantitative constraint on its consumption, which is often preferred when taxation faces too much resistance.

1.2. Forced Replacement Through Taxation or Regulation

If the incentive for greening takes the form of a Pigouvian tax, we remain within a framework governed by price signals. Unlike the situation we previously simulated, in which the price of good 2 decreased, the price signal now consists in an increase in the price of the brown good. The expected impact is therefore a reduction in living standards, even if there is some redistribution of tax revenues, due to the deadweight loss effect. The fact that redistribution does not avoid welfare losses is particularly easy to understand in the extreme case where the tax entirely eliminates the consumption of the brown good: there would be no additional tax revenue to redistribute, while utility and the standard of living would obviously decline.

The impact of such a tax is simulated with and without this redistribution of its revenue (Figure II). Of course, this assessment does not take into account the utility gains that are expected to arise both in the long term and at a level broader than that of the local consumer. The goal of the tax is indeed to improve the state of the world in the long term by taking into account externalities that are not reflected in market prices. However, the focus here is on measuring the effect of the tax on the utility of a consumer who does not directly benefit from this improvement, or who is unaware of it. This effect is fairly well captured by the standard of living indicator. The slight discrepancy observed can be attributed to the non-homogeneity of the utility function, which causes a slight drift in the chained price index, but this bias is not significant in our case.

What would happen then if, rather than taxing the brown good, the same consumption trajectory was achieved by a regulatory measure that reduces the consumption of the brown good by the same amount, but without any price signal? The overall consumption trend is identical to that under the taxation scenario with revenue recycling, as nominal income remains unchanged and allows for the same consumption shift possibilities towards the green good and the all-purpose good. Utility therefore evolves in the same manner, still downwards, but this time without any measured decrease in real income (Figure III). Although there is a change in the weighting of the goods making up the price index, it does not affect the index in the absence of price changes, even though the increasingly restrictive nature of the regulation leads to the same continuous decline in utility that would occur with a price increase.

Overall, while a significant proportion of the effects of the transition on nominal income and its purchasing power are likely to be relatively well captured by national accounts – specifically those stemming from variations in nominal income or prices – some negative impacts may be missed. These are the effects not automatically and fully converted into income and price

2. *See, for example, Aghion* et al. *(2018) and, for literature reviews, Ahmad & Scheyer (2016) or Blanchet* et al. *(2018).*

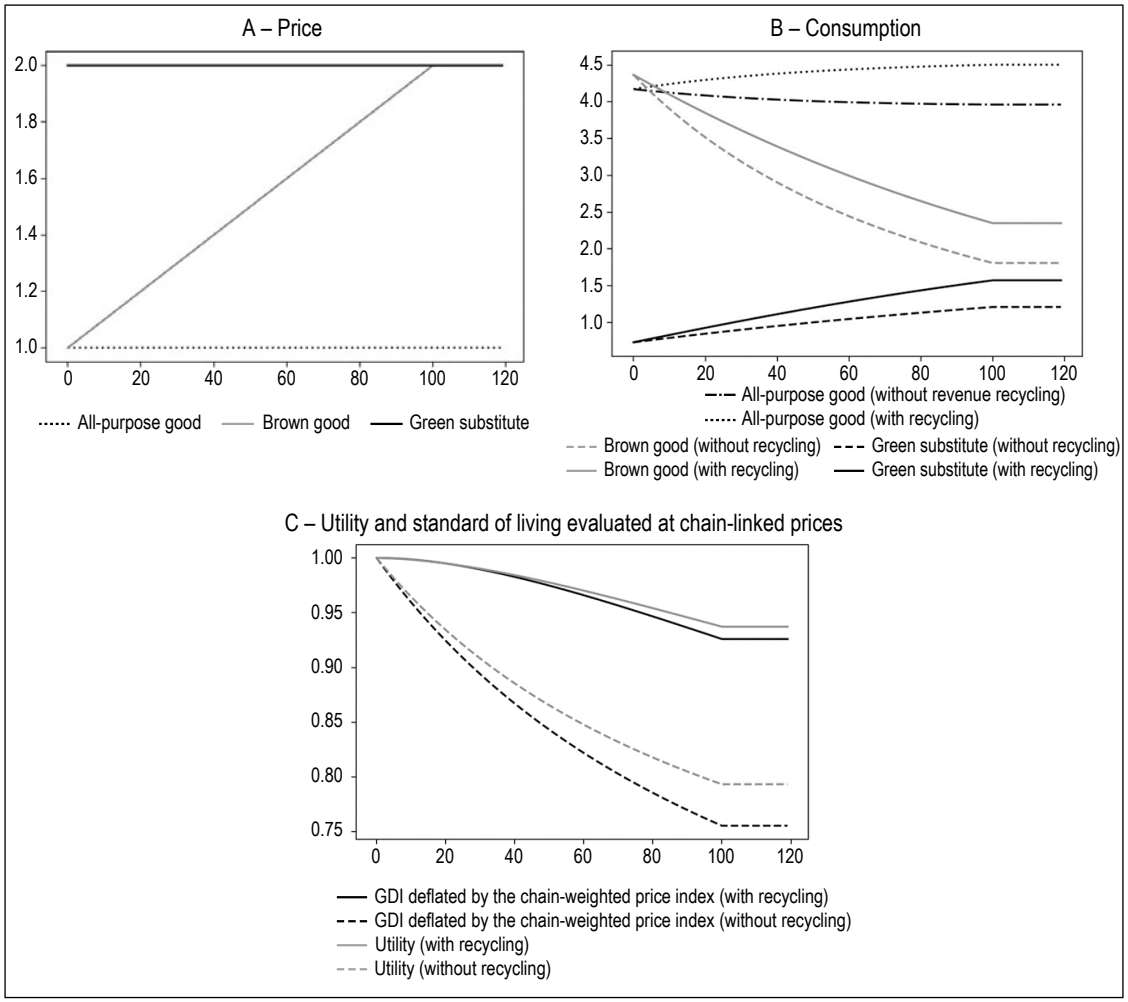
signals. This issue touches on a classic critique of measuring standards of living: the impact of non-discretionary consumption or mandatory expenditures, which limit the possibilities of consuming other goods. Purchasing requirements and bans are two facets of this problem. A more systematic approach to measuring living standards would incorporate these by calculating the income losses equivalent to such restrictions, assuming constant prices (Box 2). Although systematic application of these calculations in routine production may be difficult, we should at least be clear about what the measurement ignores at both macro and micro levels. Just as one might expect inequality in exposure to the effects of taxation or other sources of price modifications, inequality in the impacts of regulatory measures should also be taken into account.

2. Non-Monetary Co-Benefits

The list of effects that were discussed in this first overview appears rather negative. While income and price statistics should spontaneously capture anything occurring via these two variables, they risk missing the effects of regulatory constraints. This limitation should be given special attention: underestimating the costs to households could result in poor anticipation of resistance to change and to inadequately sizing the measures needed to make the transition more bearable.

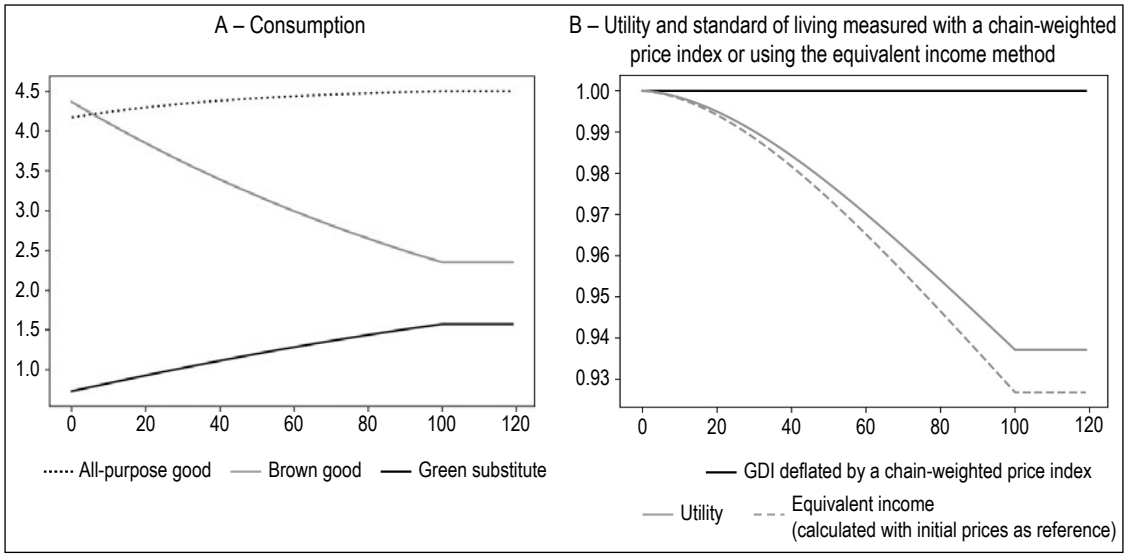
However, could other factors play in the opposite direction? There are two aspects to this question. The first involves highlighting the possible non-monetary effects of the transition, some of which could be favourable. It is necessary to list these effects and to assess to what extent they might offset the monetary costs.

Figure II – **Impact of the taxation of the brown good on standard of living and well-being**



Reading note: The price of the green good (good 2) does not benefit from any advances in greening technology. Greening results from an increasing tax on the brown good (good 1) with or without redistribution of the tax revenue. The redistribution of tax revenue does not prevent a decline in utility, though the decline is of course smaller than if redistribution had not taken place. Income deflated by the chain-weighted price index takes account of this decrease in utility and of the fact that it is more marked in the absence of redistribution, even if the equivalence is only approximate given the non-homothetic nature of the utility function.
Sources: Authors' calculations.

Figure III – **Impact of a regulatory constraint on the consumption of the brown good**

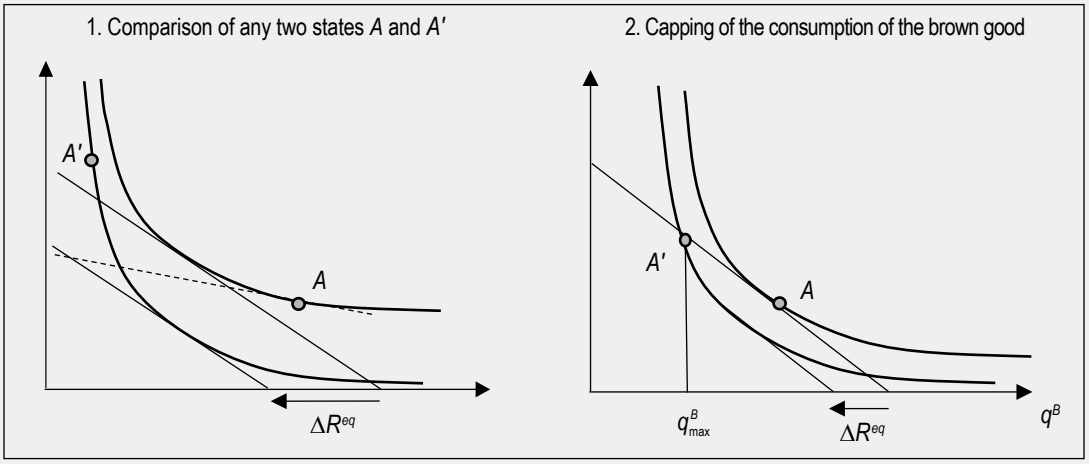


Reading note: The same reduction in consumption of the brown good is achieved by limiting its consumption via a regulatory measure. This results in a shift in consumption towards the green good, but also towards the other good. This forced change in the consumption structure leads to a fall in utility that is equal to that which would result from a Pigouvian tax with revenue being fully redistributed to households. However, no effect on real GDI is recorded, since neither nominal income nor prices are changed. On the contrary, evaluating the impact of the consumption constraint using the equivalent income method (Box 2) does capture the decline in utility, although there is a discrepancy due to the non-homotheticity of preferences.
Sources: Authors' calculations.

Box 2 – **Monetary Evaluation of The Impact of a Regulatory Constraint**

From a theoretical point of view, the evaluation of a monetary equivalent of a regulatory constraint can be viewed as a specific application of the concept of equivalent income. Equivalent income provides a scalar ranking of consumption options that is consistent with ordinal preferences. It consists in associating each utility isoquant with the minimum income level required to achieve that level of utility under a given reference price system (Figure A.1). Each reference price system corresponds to a set of parallel budget lines in the goods space. Utility isoquants are then cardinalised by the position of the line tangent to them. This position can be measured, for example, by the intersection point of this line with the horizontal axis, which corresponds to considering the associated good as the numeraire. This approach allows for comparing the utilities associated with two arbitrary points A and A'. This comparison will be consistent with ordinal preferences, which is something that is not always guaranteed by standard of living indicators which use chained prices or, even more so, fixed base-year prices. For example, in this figure, point A' would be considered better than point A if one uses base prices corresponding to the point A situation – since it lies above the corresponding budget line (dashed line) – although it is on a lower isoquant. Chain-weighting reduces this risk of erroneous classification, but not completely, as the comparison of standards of living between points A and A' may depend on the path taken to move from one to the other (path dependence).

Figure A – **Equivalent income: general principle and application to a regulatory constraint**



This equivalent income method applies directly to cases where the switch from A to A' does not result from a change in →

Box 2 – *(contd.)*

income or relative prices but rather from a cap on the consumption of the good on the x-axis. The impact can be measured by using the price system that the individual actually experiences as the reference price system (Figure A.2). The constraint forces the individual to reduce their consumption of the brown good below what they would do ordinarily on the basis of income and prices alone. This results in a shift towards consuming the other good, assuming the individual exhausts their budget, but that shift would not be sufficient to keep utility unchanged, especially if the two goods are not easily substitutable. The variation in equivalent income accounts for this.

This approach resembles another form of equivalence calculations for different climate policy instruments, that of the carbon price equivalent used by the IMF (Black *et al.*, 2022). Economy-wide carbon price equivalents (ECPE) correspond to the level of carbon tax that would result in the same reduction in emissions as the policy or policies under consideration, which could therefore involve the introduction of standards or constraints. Although the two approaches may overlap, they should not be confused. In the carbon price equivalent approach, two policies are considered to be equivalent if they lead to the same reduction in emissions. In this article, we use equivalent income to determine whether these policies have the same effect on well-being. Two policies can be simultaneously equivalent in both meanings of the word if they both lead to the same mix of brown, green and generic consumption: indeed, in this case, the same reduction in emissions would correspond exactly to the same variation in utility. However, this overlap is not guaranteed. For example, a non-recycled tax and a constraint that both lead to the same reduction in brown consumption would be equivalent according to the ECPE, but not in terms of the effect on well-being, since the non-recycling of the tax revenue would generate a negative income effect for the consumption of all goods. Generally speaking, the lack of overlap may therefore offer a criterion for choosing between the various options for decarbonisation: the policy that is the least detrimental to well-being must be prioritised for a given environmental impact. Moreover, from a social well-being perspective that takes inequalities into account, an additional difference would be the fact that the various options do not affect everyone in the same way: the same overall reduction in emissions can be achieved with varying degrees of equality.

The second aspect concerns the possibility that the transition may be accompanied by changes in preferences: everything discussed so far has been based on the implicit assumption of stability in preferences for polluting and green goods. Yet, an additional vector of greening is voluntary sufficiency (Pommeret *et al.*, 2023; Oliu-Barton *et al*., 2024), meaning a change in preferences in favour of green goods or even towards reduced overall consumption.

These two aspects partially overlap: preferences may shift in a way that reduces the importance of polluting goods while increasing the weighting of green goods, and that also gives more weight to the non-monetary co-benefits of the transition. For the sake of clarity, we will separate these two topics, starting with the evaluation of the non-monetary impacts of the transition if preferences were to remain stable. In doing so, we do not claim to provide a systematic inventory of these co-benefits but will limit ourselves to a few methodological observations.

First of all, regarding the list of these non-monetary effects, it should be mentioned again that our focus is on the issue of current standard of living and well-being. Therefore, we are only considering co-benefits that have sufficiently immediate effects to counterbalance the equally immediate costs. The longer-term benefits fall under the issue of sustainability. In addition, the non-monetary effects of the transition are not all necessarily co-benefits; some may actually exacerbate costs. Positive impacts include immediate gains in terms of health, leisure and the improvement of our living environment. Many negative effects can nevertheless also be anticipated. For example, restructuring caused by the transition to greener production will result in a mix of job losses and job creation, potentially leading to periods of unemployment and/or transitions to different types of work (Hentzgen *et al.*, 2023). Changing jobs can have an impact on well-being that goes beyond the effects on income; this is even more true for those who experience unemployment, since the loss of well-being associated with being unemployed is greater than the difference between previous wages and unemployment benefits. Another example is the potential need for increased housing density as part of a shift towards greater sufficiency. While income per consumption unit could view this positively due to larger economies of scale from shared living arrangements, it would not align with actual well-being: the historical trend towards reduced cohabitation suggests that individuals are willing to sacrifice purchasing power for the benefits of living alone, which they may be forced to give up.

From a methodological point of view, regardless of whether these non-monetary effects are positive or negative, the issue remains the same: how to integrate them with monetary indicators? This is the topic traditionally addressed in the

« beyond GDP » literature, which proposes four options for incorporating these non-monetary factors into the measurement of well-being, as previously outlined in Blanchet & Fleurbaey (2020).

The first approach is the use of dashboards, which entails presenting a range of indicators that shed light on various aspects of living conditions and well-being, without attempting to aggregate them. For instance, in their comparative analysis of various avenues for achieving greener consumption with potential positive effects on well-being, Creutzig *et al.* (2022) order these effects according to the categories of the Sustainable Development Goals currently promoted by the United Nations. However, the problem with this approach is the sheer volume of information it generates and the difficulty in prioritising it. Synthesised information is also required. And, in the end, when these dashboards are used to make trade-offs between policies with different effects on different aspects of well-being, these decisions ultimately rely on some form of implicit aggregation and non-transparent hierarchies of these dimensions.

The second approach is that of composite indices. It has to be mentioned given its long-standing prominence in the search for alternatives to GDP. It employs a number of techniques to statistically make comparable things that are not inherently so, and then aggregates them into a single index according to conventional rules. The method is considered to be transparent since the aggregation rules are based on fairly basic arithmetic. Its limitation lies in the fact that the resulting relative valuations may not reflect individual preferences or relevant social choices, since they are the uncontrolled result of a purely statistical aggregation rule.

Conversely, full respect of individual preferences appears to be an advantage of the third approach, namely the measurement of subjective well-being. It eliminates the need to formulate principles for aggregating different components of well-being, relying instead on what individuals report about their overall well-being, using a cardinal approach. Individuals indicate how favourable they perceive their living conditions to be, typically by scoring their perceived overall well-being on a scale of 0 to 10, without needing to make their personal weighting of different well-being dimensions explicit. The appeal of this method lies in the fact that it directly leads to the end result, while also allowing to account for the unequal distribution of subjective well-being. This is something that composite indicators based on macro data are unable to do. Even when they try to include inequalities measured across different dimensions, composite indicators fail to capture the cumulative impact of deprivations when they are correlated across axes. These advantages make the method particularly useful for addressing many questions, and it is a natural candidate for assessing the "all-encompassing" impact of climate transition (Perona, 2022).

However, relying on declared well-being poses the problem of the relativity of the scales on which individuals assess their situation. The fact that an individual A could feel less happy than another despite having the same circumstances is certainly interesting to measure. However, problems arise when this leads to inconsistencies with ordinal preferences, which is precisely what we are trying to avoid. For example, an individual A might prefer their current situation over that of another individual A', yet rate their own well-being less favourably than A' if they are naturally more demanding than A'. It would be manifestly wrong to conclude that a society predominantly composed of individuals of type A is worse-off than if it were primarily composed of individuals of type A'. The method risks producing results that conflict with the actual ordinal preferences of individuals.

This problem is addressed by the fourth type of approach, which has already been introduced in Box 2 in the context of calculating a monetary equivalent for the rationing of the polluting good. The method of equivalent income allows for a monetary translation of anything that affects the ability to generate utility from income, with prices and rationing constraints being just specific cases. The situation where utility is affected by both prices and one or more non-monetary factors is discussed in Box 3. The approach involves setting reference values for prices as well as for the non-monetary factor(s), and then calculating the income that would allow achieving the current level of utility in the hypothetical situation in which the individual is exposed to these reference values rather than their current values. For instance, if an individual with income R is in a poor state of health H and if a good state of health H^{ref} is taken as reference, his equivalent income R^{eq} will be the amount that would guarantee the equality $U\left(R^{eq}, H^{ref}\right) = U\left(R, H\right)$. This income would be lower the worse the health state H is, while it would increase if an improvement in the environment leads to better health. This method provides a monetary valuation

of this improvement, consistent with ordinal preferences related to health and monetary living standards. It is rooted in the tradition of cost-benefit analysis.

However, the problem that this method poses lies in its implementation. A number of techniques or combinations of techniques are possible: relying on preferences revealed through behaviours; using contingent valuation techniques, i.e. directly asking individuals how much they would be willing to pay or receive for specific changes in their situation or environment; or combining objective data with subjective satisfaction measurements presented earlier. The idea is to measure how individuals are willing to trade off material factors against other aspects of their living conditions by empirically analysing how these factors impact subjective well-being. This can be done through surveys that combine direct measures of perceived well-being with objective components. Utility function calibrations from existing literature may also be used.

The cost of implementing these different techniques makes it difficult to imagine applying them for routine production of measures. Among the practical applications of this approach, one notable example is the work by Serres & Murtin (2014), who attempt to calculate the extent to which increased life expectancy associated with a reduction in local pollution – resulting from decreasing greenhouse gas emissions – could offset the economic costs of these reductions. They find that the compensation is only partial, but this does not exhaust the topic, as their focus is limited to just one of the co-benefits of the transition.

3. Transition and Well-Being with Changing Preferences

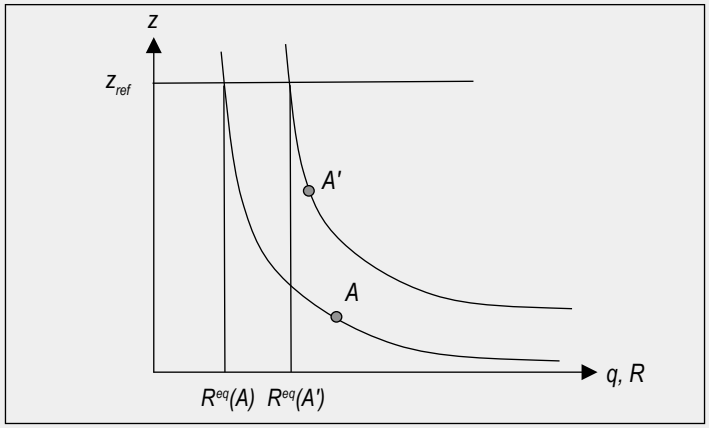
Even without co-benefits such as those described in the previous section, the cost of the transition in terms of perceived standard of living or well-being could still be reduced if this transition is accompanied and/or driven by a greening

Box 3 – **Equivalent Income Applied to Non-Monetary Co-Benefits**

To maintain the possibility of a two-dimensional representation, we consider that preferences are governed entirely by the capacity of income R to purchase a composite all-purpose good q and a single non-monetary co-benefit described by the variable z: this could be, for example, the state of the environment or the state of health as affected by the state of the environment. If we use the composite good as the numeraire, this method just needs a reference value z_{ref} for the variable z. The equivalent incomes associated with the states A and A' correspond to the x-coordinates of the points at which the isoquants and the horizontal $z = z_{ref}$ intersect.

In this example, there is a decrease in income between state A and state A', but it is more than offset by the increase in variable z.

Figure B – **Equivalent income when well-being depends on a market good and a non-monetary factor**



It should be noted that, in practice, some of the effects on well-being associated with improvements in the state of health may already be measured by some of our usual indicators via the associated reduction in healthcare expenditure. Gross disposable income should indeed capture any reductions in health insurance spending if these lead to a reduction in taxes that finance them. However, the effect of a reduction of medical expenses paid by households, which would free up income for other expenses, would only be taken into account with an approach in terms of discretionary income treating these medical expenses as constrained spending. Finally, the so-called "adjusted" disposable income approach, which integrates the monetary equivalent of individualised transfers, would, in principle, miss all of these effects, since the decrease in taxes would be completely offset by the decrease in health benefits.

of preferences. If the consumption of meat or air travel dramatically decreases simply because individuals spontaneously stop eating meat and travelling by plane, their well-being will not be negatively affected, regardless of what happens in terms of prices or regulations.

But how can one quantify the dampening effect brought about by such changes in preferences? Attempting to measure the cost of living or real income growth in the context of changing preferences is like trying to compare the size of different objects using an elastic ruler that expands or contracts as you move from one object to the next. There does not seem to be any solution to this problem, which is undoubtedly why, until recently, it was largely ignored by the literature (Samuelson & Swamy, 1974; Balk, 1989), in spite of the fact that past growth has clearly been accompanied by radical changes in preferences.

The COVID-19 crisis provided a first reason to stop ignoring this subject: it drastically changed preferences concerning different types of goods and services, with some goods suddenly becoming essential, while others became dispensable (Baqaee & Farhi, 2020; Baqaee & Burstein, 2021; Blanchet & Fleurbaey, 2022). This raised two questions: how can standard statistical indicators that implicitly rely on the stability of preferences be interpreted in such a context and which actual measures of utility or well-being can we try to compare them with? These two questions are even more critical in the context of the green transition, since changes in preferences are no longer an exogenous disruptive factor that we can afford to ignore, for lack of a better option. In the green transition context, we indeed expect them to play an active role (Konc *et al.*, 2021; Mattauch *et al.*, 2022a; Mattauch *et al.*, 2022b) and policies (including sufficiency) are being considered to encourage them. Continuing to ignore them is a position that is increasingly untenable. But how can they be taken into account?

The two approaches that we have just put forward for handling non-monetary co-benefits – the measurement of subjective well-being and the equivalent income method – each offer a solution to this issue and both are worth considering.

One could choose to rely on the subjective measurement of well-being. For example, if there is taxation, it would be reasonable to assume that the subjective indicator would incorporate both the negative impact of the tax and the fact that individuals quickly learns to put its effects into perspective or to derive information about the consequences of climate change and integrate this into their preferences. More generally, one could even say that the very nature of these subjective indicators allows them to take account of all possible ways in which preferences may change. This is how we are accustomed to interpreting the most well-known of their stylised messages, the Easterlin paradox (1974), which states that beyond a certain stage of development, economic growth has only a minor impact on subjective well-being. One possible explanation of this paradox is that needs and aspirations increase as material living conditions improve, and that it is the gap between living conditions and those aspirations that determines declared well-being. This is not necessarily a change in ordinal preferences, but at the very least a change in the way they are translated into cardinal terms.

If such an explanation of the Easterlin effect is correct, it could play out in the opposite direction along a green transition path: the scenario of chosen sufficiency would involve a slow-down or even a decline in consumption at the same time as growth slows down or declines, thereby limiting the fall in subjective well-being. This calls for a keen examination of how these subjective indicators would behave along a transition trajectory with changing preferences.

We can also investigate what would say standard of living indicators calculated according to the equivalent income method introduced earlier.

First of all, what can we say about the impact of these changes in preferences on the usual standard of living indicator, calculated as nominal income deflated by a chained price index, given that statisticians will continue to calculate it anyway? If preferences remain constant, the tax generates a substitution effect that mitigates some of the impact that would have occurred if substitution were not an option. In principle, that impact is taken into consideration by the chained index, although path dependence introduced by chain-weighting can still be an issue, even with constant preferences. The greening of preferences would strengthen this substitution effect, adding a second factor to moderate the effects of the tax, but at the same time introducing a second path dependence issue. Consider an initial state A with brown preferences, a final state A' with greener preferences, a tax increase between these two periods, and two different scenarios for the trajectory of preferences: one where their greening occurs

before the tax increase and another where the greening follows the tax increase. It is clear that the message conveyed by the chain-weighted indices would not be the same in these two scenarios: in the first case, the increase in the price of the brown good would be reflected in the price index with a weight that will already have begun to decrease, whereas this would not be the case in the second scenario. The fall in the standard of living would therefore be deemed to be smaller along the first trajectory than along the second, even though both trajectories have the same starting and ending points.

Thus, while the standard indicator may not necessarily be silent on a potential moderating effect of the change in preferences, its message will be partial and unstable.

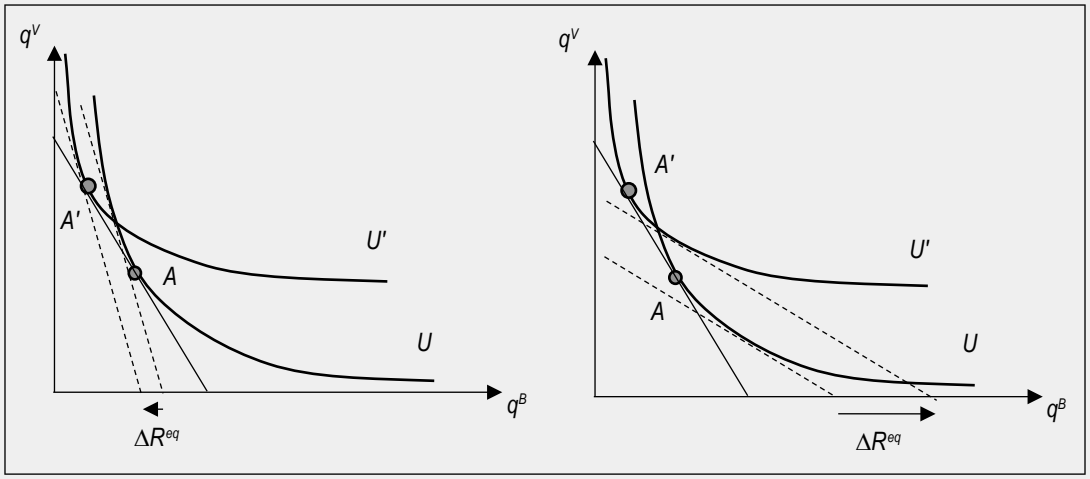
Would the equivalent income method help to circumvent this problem? From a technical point of view, there is nothing preventing its implementation, as it does not require considering individuals with identical preferences (Fleurbaey & Tadenuma, 2014). There is no need to assess how each individual would feel with preferences that are not their own. Instead, it is on the basis of their own preferences that they assess the hypothetical level of income that would make them indifferent between their current state and a situation in which they would be faced with the price system that has been chosen for reference. Comparisons are then made based on these equivalent incomes, whether they are interpersonal comparisons between two individuals living at the same time or comparisons over time for the same individual with two successive preference systems.

Uncertainty about the final message is not entirely resolved however, but it takes a different form: the result of the comparison will depend on the chosen reference price system. That dependence is shown in Box 4 and can be illustrated by one last simulation from the model used throughout this article (Figure IV). This simulation also allows for a comparison with the evolution of standard of living indicators measured with a chain-weighted price index, in the context of one of the two scenarios of the simulations in Figure III: the introduction of a tax without recycling its revenue - which arguably represents the least favourable situation

Box 4 – **Equivalent Income with Variable Preferences**

We consider a green good and a brown good coupled with a change in preferences in favour of the former, assuming for now that income and prices remain unchanged (Figure C). Initial and final preferences are represented by the functions U and U'. The change in preferences leads to a shift from point A to point A'. The classification of these two points using the equivalent income method depends on the reference price system: point A appears above point A' with the reference prices in the left-hand figure and below it with the reference prices in the right-hand figure. This indeterminacy may appear unsolvable, but it is simply a reflection of the fundamental indeterminacy resulting from the change in preferences: A is preferred over A' for an individual with the initial preferences, and A' is preferred over A for an individual with the final preferences. In cases where prices remain the same in both states, these prices can be used as reference prices, in which case the two states will be judged equivalent. This is ethically relevant: two individuals with different preferences but having the same income at given prices are considered to be equally well off, even if their consumption choices differ.

Figure C – **Effect of a change in preferences, at given prices and income, depending on the chosen reference price system**



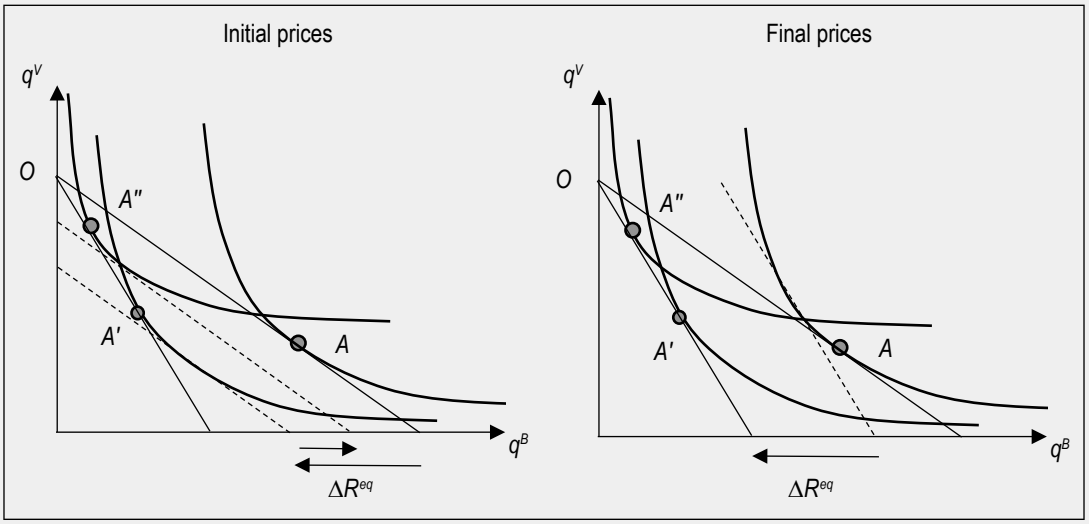
➔

Box 4 – *(contd.)*

This solution is no longer possible when the change in preferences is accompanied by a change in prices. This would be the case in particular if the greening of preferences goes hand-in-hand with the introduction of a tax on the brown good. Consider a two-stage process (Figure D) in which the tax first pivots the budgetary constraint and leads to a shift from point A to point A' with preferences remaining unchanged, after which a change in preferences results in a shift to a point A'' without any change to the budget line.

If final prices are used as the reference prices (right-hand figure), the transition phase from point A' to point A'' has no effect on the equivalent income and only the decrease in the equivalent income between point A and point A' would be observed. In other words, the compensatory effect of the preference change is not accounted for. On the contrary, some compensation is measured if initial prices are chosen as reference (left-hand figure), resulting in a back-and-forth movement that remains partial on the figure but would be complete if the change in preferences were such that, ultimately, the individual entirely forgoes the brown good.

Figure D – **Effect of environmental taxation on equivalent income with variable preferences, with reference prices equal to the initial prices or final prices**



We have focused here on a pure change in preferences, that necessarily goes in the direction of greener behaviour. This calls for three remarks:

- This type of greening should be differentiated from that which would result from a pure income effect with no change in preferences, which would be the case if environmental quality were a superior good to which consumers attached greater importance the higher their income. In this case, we would remain within the framework of a fixed-preference analysis. However, this scenario still encounters challenges due to the non-homothetic nature of preferences, complicating the interpretation in terms of utility of real volume or standard of living indicators.
- The preferences considered here as a standard of well-being are the true preferences of the households, which must be distinguished from so-called behavioural preferences, which are those revealed by consumers' actual choices (Fahri & Gabaix, 2020). A discrepancy arises between the two when individuals fail to internalise all the consequences (for themselves) of their choices, typically due to a lack of information. If true preferences are stable and only behavioural preferences change, for example as a result of a nudge that corrects the discrepancy between the two, we remain within a framework of fixed preferences, and the effect of the nudge is generally positive. For further reading, see Pommeret *et al*. (2023).
- As for the change in true preferences, it can occur spontaneously, influenced by communication campaigns or driven by peer effects. It may also result from the introduction of taxes or regulatory changes that increase awareness of environmental issues, thus enhancing their effectiveness (Konc *et al*., 2021). However, opposite reactions may also be observed, where taxation or constraints lead to a rejection phenomenon (Ehret *et al*., 2022).

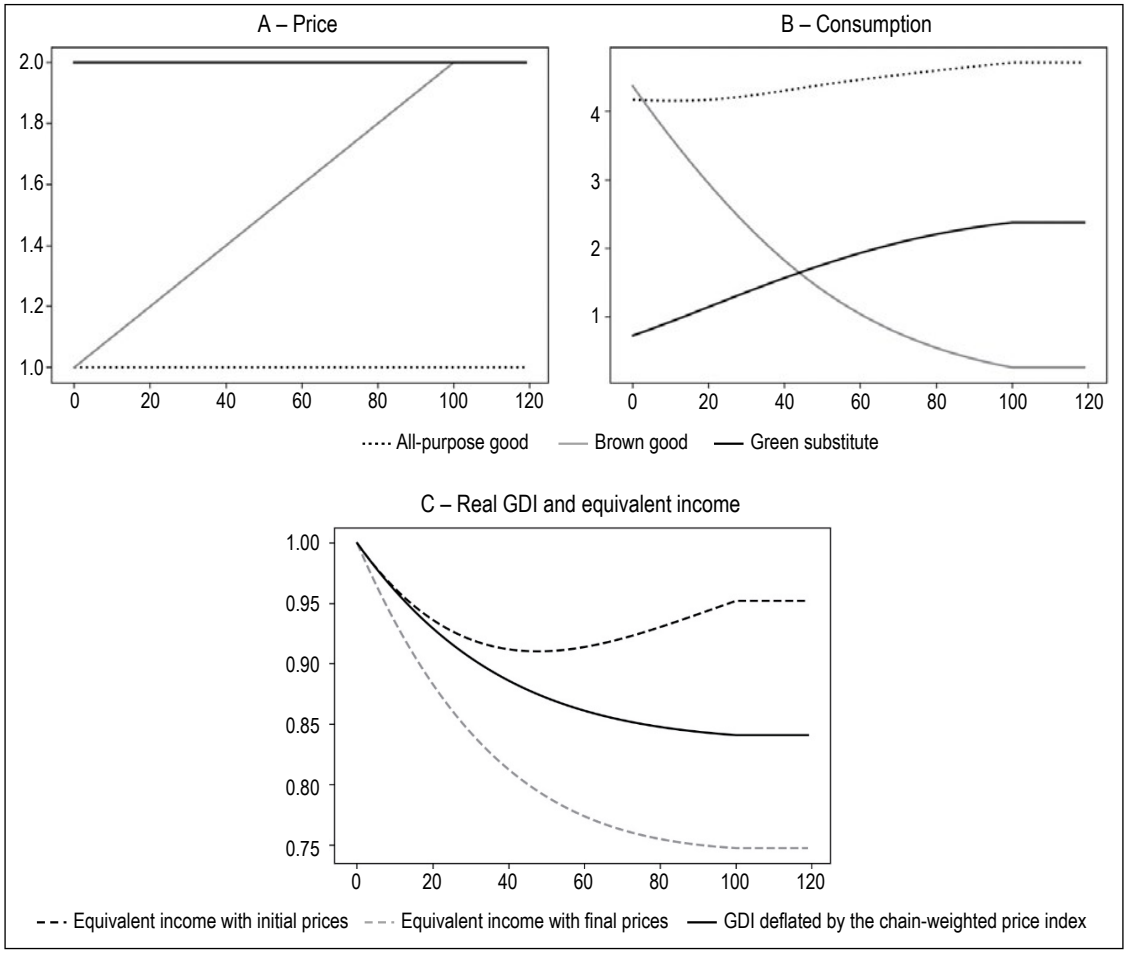
for consumers - coupled with preferences that become greener as the tax increases. The change in preferences involves a joint change of parameters B and a of the utility function from -1 to -2 and 0.55 to 0.25, respectively, between 0 and 100. The fall in B indicates a reduced need to consume the service provided by both the green and the brown good (for example, reduced need to travel by car, regardless of whether that car is electric or not) and the fall in a means that, in order to produce this service, an increasing preference is assigned to good number 2, which is considered to be the green good.

We compare the evolution in income deflated by a chain-weighted price index with two versions of equivalent income, one that takes initial prices as reference and the other based on the current prices at each date as reference (Figure IV-C). It can be noted that, unsurprisingly, the decrease in deflated income is less than in the case of taxation with fixed preferences shown in Figure II. This is because the weight of the taxed good in the index decreases faster than it would with fixed preferences, resulting in a smaller deterioration in living standards, but this offsetting will differ depending on whether the change in preferences occurs before or after the tax is introduced.

The equivalent income approach avoids this form of path dependence since, at each date, it only involves current preferences, regardless of the way they have evolved since the start of the process. However, the outcome depends on the prices used as reference.

- When the reference prices are those of the initial period (upper trajectory), the equivalent income evolves under the influence of two contradictory forces: the tax increase logically reduces equivalent income, but the change in preferences has a positive impact since it allows the consumer to move away from a good that has become expensive compared to its price in the reference system, namely the initial price without the tax. Here, this second effect prevails over the first, since the equivalent income changes its slope as soon as preferences start to become greener. At the end of the transition, the equivalent income remains below its initial value, but, in the limit case where the consumer becomes fully "green" and does not wish to consume the brown good at all, even at its initial price, their equivalent income would return to its initial value since they would have become completely indifferent to the price of the no longer desired brown good.

Figure IV – **Scenario involving the taxation of the brown good (without recycling of the tax revenue) coupled with a greening of preferences**



Reading note: Based on the same initial values as in the stable case, the parameters *B* and *a* shift (in a linear manner) from −1 to −2 and 0.55 to 0.25 between 0 and 100. The decrease in the consumption of the brown good is more marked than in the simulation depicted in Figure II with an identical tax trajectory and without recycling. The impact on equivalent income is evaluated by taking either the initial prices or the current prices as the reference prices.

- If one follows the other convention of using current prices as the reference system (lower trajectory), the effect of the change in preferences is fully neutralised in terms of current equivalent income, since it is equal to current income by definition. However, at each period, the change in reference prices leads to updating the value of the initial equivalent income, which increases because the initial situation appears retrospectively more advantageous as the reference price of the brown good increases: compared to the price after tax, brown consumption was initially being implicitly subsidised. As a result, when compared to an initial equivalent income that is increasing, the current equivalent income appears to be in continuous decline.

In the end, there are two different and complementary points of view on the changes at play, which bracket the evolution of real income deflated by a chained price index. One perspective suggests a compensation of costs by changes in preferences, although this viewpoint cannot be entirely privileged either. The measurement of the evolution in standards of living was already affected by unavoidable perspective effects with non-homothetic but stable preferences; this problem can only be amplified when dealing with unstable preferences.

* *
*

Overall, replicating the question asked by Ahmad & Schreyer (2016) on consequences, for national accounts, of the digitalisation and the increasing dematerialisation of the economy, can we say that these accounts are perfectly "up to the challenge" of a relevant statistical monitoring of the greening of the economy? What about the broader set of measures for living standards, both on average and at a disaggregated level?

In some respects, the questions raised are easier to answer than those posed by the new production models of the digital economy. The challenge for accountants was the increasingly dematerialised nature of goods and services offered to consumers, and for some of them, the blurring or total disappearance of price signals, with the development of new forms of free or pseudo-free goods and services. In the case of the costs of the climate transition, we return to the more familiar territory of productions and consumptions for which there are physical definitions – liters of fuel oil or petrol, kilowatt-hours, consumption of more or less carbon-intensive foods – and for which we are able to apply unit prices, which is an area in which we know, in principle, how to properly define the volume/price decomposition. Upon first analysis, the toolbox available to national accountants and its extensions at the microeconomic level should therefore provide the basic instruments to account for a significant part of the costs of the transition for households who will bear them.

Nevertheless, even on purely economic grounds, several points may require additional information or new conceptual reflections, whether these points tend towards increasing costs – mainly quantitative rationing – or reducing costs – changes in preferences and the problem that they pose for quantifying standards of living. Looking beyond the strictly economic scope, the issue is compounded by the need to account for a certain number of favourable non-monetary effects of the transition, those that would arise sufficiently rapidly and would directly benefit the individuals who will bear the main costs of this transition. Finally, it should be emphasised once again that the main reason for accepting these costs is the expected gain regarding the planet's future habitability: this extends beyond the measurement of the present and also beyond the territorial scope covered by national statistics, as the issue is global. This should not prevent national statistical systems from contributing to its understanding, and the quest for adequate sustainability indicators must continue. □

BIBLIOGRAPHY

Aghion, P., Bergeaud, A., Boppart, T. & Bunel, S. (2018). Firm Dynamics and Growth Measurement in France. *Journal of The European Economic Association*, 16(4), 933–956. https://doi.org/10.1093/jeea/jvy031

Ahmad, N. & Schreyer, P. (2016). Are GDP and Productivity Up to the Challenges of the Digital Economy? *International Productivity Monitor*, Centre for the Study of Living Standards, 30, 4–27. https://econpapers.repec.org/article/slsipmsls/v_3a30_3ay_3a2016_3a1.htm

Balk, B. M. (1989). Changing Consumer Preferences and the Cost-of-Living Index: Theory and Nonparametric Expressions. *Journal of Economics*, 50, 157–169. https://doi.org/10.1007/BF01239124

Baqaee, D. R. & Farhi, E. (2020). Nonlinear Production Networks with an Application to the COVID-19 crisis. NBER, *Working Paper* N° 27281. https://doi.org/10.3386/w27281

Baqaee, D. R. & Burstein, A. (2021). Welfare and Output with Income Effects and Taste Shocks. NBER, *Working Paper* N° 28754. https://doi.org/10.3386/w28754

Black, S., Minnett, D., Parry, I., Roaf, J. & Zhunussova, K. (2022). A Framework for Comparing Climate Mitigation Effort Across Countries. IMF, Working Paper N° 2022/254. https://www.imf.org/en/Publications/WP/Issues/2022/12/16/A-Framework-for-Comparing-Climate-Mitigation-Policies-Across-Countries-527049

Blanchet, D., Khder, M.-B., Leclair, M., Lee, R., Poncet, H. & Ragache, N. (2018). La croissance est-elle sous-estimée ? *L'Économie Française - Comptes et dossiers édition 2018*, Insee, coll. *Références*, pp. 59–79. https://www.insee.fr/fr/statistiques/3614240?sommaire=3614262

Blanchet, D. & Fleurbaey, M. (2020). Construire des indicateurs de la croissance inclusive et de sa soutenabilité : que peuvent offrir les comptes nationaux et comment les compléter ? *Economie et Statistique / Economics and Statistics*, 517-518-519, 9–24. https://www.insee.fr/fr/statistiques/4770120?sommaire=4770254

Blanchet, D. & Fleurbaey, M. (2022). Valeurs, volumes et partages volume-prix : sur quelques questions (re) soulevées par la crise sanitaire. *Economie et Statistique / Economics and Statistics*, 532-33, 71–88. https://doi.org/10.24187/ecostat.2022.532.2072

Blanchet, D., Pesme, C. & Pommeret, A. (2023). Les incidences économiques de l'action pour le climat : rapport thématique bien-être. France Stratégie. 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

Creutzig, F., Niamir, L., Bai, X., Callaghan, M., Cullen, J., Díaz-José, J., Figueroa, M., Grubler, A., Lamb, W. F., Leip, A., Masanet, E., Mata, É., Mattauch, L., Minx, J. C., . . . Ürge-Vorsatz, D. (2021). Demand-side solutions to climate change mitigation consistent with high levels of well-being. *Nature Climate Change*, 12(1), 36–46. https://doi.org/10.1038/s41558-021-01219-y

Dees, S., Bellevrat, E., de Gaye, A., Geerolf, F., Lequien, M., Schweizer, R., Tettaravou, A. & Wegner, O. (2023). Les incidences économiques de l'action pour le climat : rapport thématique inflation. France Stratégie. https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2023-les_incidences_economiques_de_laction_pour_le_climat-thematique-inflation.pdf

Douenne, T. (2020). The Vertical and Horizontal Distributive Effects of Energy Taxes: A Case Study of a French Policy. *The Energy Journal*, 41(3), 231–254. http://dx.doi.org/10.13140/RG.2.2.24881.07529

Easterlin, R. A. (1974). Does Economic Growth Improve the Human Lot? In: P.A. David and M. W. Reder, eds., *Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz*, Academic Press. https://doi.org/10.1016/B978-0-12-205050-3.50008-7

Ehret, S., Constantino, S. M., Weber, E. U., Efferson, C. & Vogt, S. (2022). Group identities can undermine social tipping after intervention. *Nature Human Behaviour*, 6, 1669–1679. https://doi.org/10.1038/s41562-022-01440-5

Fahri, E. & Gabaix, X. (2020). Optimal Taxation with Behavioral Agents. *American Economic Review*, 110(1), 298–336. https://www.aeaweb.org/articles?id=10.1257/aer.20151079

Fleurbaey, M. & Tadenuma, K. (2014). Universal Social Orderings: An Integrated Theory of Policy Evaluation, Inter-Society Comparisons, and Interpersonal Comparisons. *The Review of Economic Studies*, 81, 1071–1101. https://doi.org/10.1093/restud/rdu006

Gadrey, J. & Jany-Catrice, F. (2016). *Les nouveaux indicateurs de richesse*. Quatrième édition. Paris: La Découverte. https://www.editionsladecouverte.fr/les_nouveaux_indicateurs_de_richesse-9782707190635

Germain, J.-M. & Lellouch, T. (2020). Coût social du réchauffement climatique et indicateurs de soutenabilité : leçons d'une application à la France. *Economie et Statistique / Economics and Statistics*, 517-518-519, 81–102. https://doi.org/10.24187/ecostat.2020.517t.2024

Hentzgen, C., Orand, M., Cousin, C., Lê, J., Villedieu, P., Janelli, R., Garner, H. & Jolly, C. (2023). Les incidences économiques de l'action pour le climat : rapport thématique marché du travail. France Stratégie. https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2023-les_incidences_economiques_de_laction_pour_le_climat-thematique-marche_du_travail.pdf

Jaravel, X. (2021). Inflation inequality: Measurement, Causes, and Policy Implications. *Annual Review of Economics*, 13, 599–629. https://doi.org/10.1146/annurev-economics-091520-082042

Kirman, A. (1992). Whom or what does the representative agent represent? *Journal of Economic Perspectives*, 6(2), 117–136. https://doi.org/10.1257/jep.6.2.117

Konc, T., Savin, I. & van den Bergh, J. C. (2021). The social multiplier of environmental policy: Application to carbon taxation. *Journal of Environmental Economics and Management,* 105, 102396. https://doi.org/10.1016/j.jeem.2020.102396

Laurent, E. & Le Cacheux, J. (2016). *Un nouveau monde économique : mesurer le bien-être et la soutenabilité au XXIe siècle*. Paris: Odile Jacob. https://www.odilejacob.fr/catalogue/sciences-humaines/economie-et-finance/un-nouveau-monde-economique_9782738132901.php

Mattauch, L., Hepburn, C., Spuler, F. & Stern, N. (2022a). The Economics of Climate Change with Endogenous Preferences. *Resource and Energy Economics*, 69, 101312. https://doi.org/10.1016/j.reseneeco.2022.101312

Mattauch, L., Stern, N. & Konc, T. (2022b). For climate economics, preferences can and should be treated as endogenous. *VoxEU*.
https://cepr.org/voxeu/columns/climate-economics-preferences-can-and-should-be-treated-endogenous

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 : rapport thématique enjeux redistributifs. France Stratégie.
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

Oliu-Barton, M., Pommeret, A., Robinet, A., Schubert, K. & Viennot, M. (2024). Chosen Energy Sufficiency: Preference Shocks and Behavioural Biases. *Economie et Statistique / Economics and Statistics*, 543, 21–37. https://doi.org/10.24187/ecostat.2024.543.2117

Perona, M. (2022). De l'éco-anxiété à la transition heureuse. *Note de l'observatoire du bien-être* N° 2022-09. https://www.cepremap.fr/2022/06/note-de-lobservatoire-du-bien-etre-n2022-09-de-leco-anxiete-a-la-transition-heureuse/

Pisani, J. & Mahfouz, S. (2023). Les incidences économiques de l'action pour le climat. France Stratégie. Rapport à la Première Ministre.
https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/2023-incidences-economiques-rapport-pisani-5juin.pdf

Pommeret, A., Oliu-Barton, M., Robinet, A., Viennot, M. & Schubert, K. (2023). Les incidences économiques de l'action pour le climat : rapport thématique sobriété. France Stratégie.
https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2023-les_incidences_economiques_de_laction_pour_le_climat-thematique-sobriete.pdf

Samuelson, P. A. & Swamy, S. (1974). Invariant economic index numbers and canonical duality: Survey and synthesis. *The American Economic Review*, 64(4), 566–593.
https://EconPapers.repec.org/RePEc:aea:aecrev:v:64:y:1974:i:4:p:566-93

de Serres, A. & Murtin, F. (2016). Your Money or Your Life: Green Growth Policies and Welfare in 2050. *Environmental & Resource Economics*, 63(3), 571–590. https://doi.org/10.1007/s10640-014-9849-x

The Shift Project (2023). Décarbonons la santé pour soigner durablement. Rapport final v2.
https://theshiftproject.org/wp-content/uploads/2023/04/180423-TSP-PTEF-Synthese-Sante_v2.pdf

Chosen Energy Sufficiency: Preference Shocks and Behavioural Biases

Miquel Oliu-Barton*, Aude Pommeret, Alice Robinet***, Katheline Schubert**** and Mathilde Viennot*****

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

* *Paris Dauphine University and France Stratégie;* ** *IREGE of Savoie Mont Blanc University, France Stratégie;* *** *France Stratégie;* **** *Paris 1 Panthéon-Sorbonne University and Paris School of Economics (PSE).* Correspondence: *aude.pommeret@univ-smb.fr*

This article uses to a large extent the "Sobriété" report on sufficiency from the Pisani-Ferry and Mahfouz commission.

Received in July 2023, accepted in March 2024. Translated from: "La sobriété énergétique choisie : chocs de préférences et biais comportementaux".
The opinions and analyses presented in this article are those of the author(s) and do not necessarily reflect their institutions' or INSEE's views.

Citation: Oliu-Barton, M., Pommeret, A., Robinet, A., Schubert, K. & Viennot, M. (2024). Chosen Energy Sufficiency: Preference Shocks and Behavioural Biases. *Economie et Statistique / Economics and Statistics*, 543, 21–37. doi: 10.24187/ecostat.2024.543.2117

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:

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

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

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 $\hat{\alpha}_{eq}$ leading to the same reduction in consumption of the brown good as brought about by a price policy:

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

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

As $0 < \alpha < 1$, $0 < \omega < 1$ and $\widehat{p_b} > 0$, then $\hat{\alpha}_{eq} < 0$. 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]

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

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

and $\hat{\alpha}_{eq,red} = -(1-\alpha)\widehat{p_b} < 0$. 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:* $\widehat{C_b} = -(\omega + \sigma(1-\omega))\widehat{p_b} + \sigma(1-\omega)\frac{1}{1-\alpha}\hat{\alpha} + \hat{I}$ *and* $\widehat{C_g} = -(1-\sigma)\omega\widehat{p_b} - \sigma\omega\frac{1}{1-\alpha}\hat{\alpha} + \hat{I}$, *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	
	$\widehat{p_b} = 10\%$	$\hat{\alpha}_{eq} = -13\%$	$\widehat{p_b} = 10\%$	$\hat{\alpha}_{eq,red} = -4\%$
$\widehat{C_b}$ (%)	−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 $\hat{\alpha}_{eq}$ 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):

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

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:

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

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:

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

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).

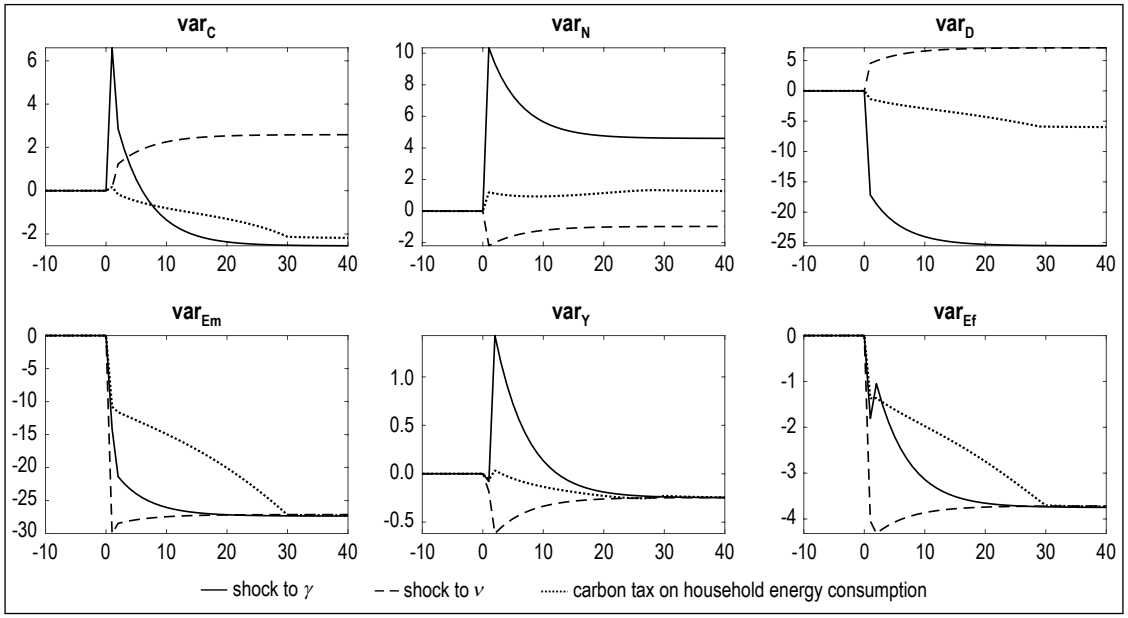
non-durable goods stabilises at a higher level than before the shock (but below the peak level), which, however, is not sufficient to offset the significant reduction in consumption of durable goods, and therefore the associated services. Indeed, the CES specification suggests that the substitution between 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).

* *
*

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.

Macroeconomic Impact of Climate Damage in France

Florian Jacquetin* and Gaël Callonnec*

Abstract – In order to assess the economic cost of climate inaction, we introduce the cost of the damage into the "ThreeME" macroeconomic model devised by ADEME (the French Agency for Ecological Transition). The traditional "Keynesian" framework of the model has been modified to take into account the risks weighing on certain sectors (agriculture and power generation) that would lead to pressures causing reductions in their production level. The damage includes not only chronic risks resulting from gradual changes, but also acute risks resulting from high intensity events of short duration, such as natural disasters. This damage is introduced in a "bottom-up" approach, i.e. at the level of both the supply and the demand of the stakeholders concerned. According to the simulations, compared to an anticipated and planned transition limiting global warming to 1.5°C by 2100, climate inaction could cost France almost 7 points of annual GDP by 2100.

JEL: Q54, Q43, O13, E12, E17
Keywords: macroeconomic modelling, climate change, cost of damage, physical risks and scenario analysis

* *Agence de la transition écologique.* Correspondence: *florian.jacquetin@gmail.com*

The authors would like to thank Hervé Gouëdard (ADEME), Mathieu Garnero (ADEME), Patrick Jolivet (ADEME) and Albertine Devillers (Corps des Mines) for their respective contributions, as well as the economists from the Banque de France, Thomas Allen, Stéphane Dees, Annabelle de Gaye and Noémie Lisack for sharing macroeconomic assumptions related to NGFS transition scenarios.

Received in June 2023, accepted in February 2024. Translated from : "Impact macroéconomique des dommages climatiques en France".
The opinions and analyses presented in this article are those of the author(s) and do not necessarily reflect their institutions' or INSEE's views.

Jacquetin, F. & Callonnec, G. (2024). Macroeconomic Impact of Climate Damage in France. *Economie et Statistique / Economics and Statistics*, 543, 39–64. doi: 10.24187/ecostat.2024.543.2118

Scenario analysis is a method favoured among governmental and international organisations to anticipate, plan for and estimate the consequences of many possible future climate conditions. However, this type of analysis suffers from a number of methodological limitations: in relation to the realism of the scenarios envisaged (political uncertainty), the future change in temperatures (climate uncertainty) and the associated economic consequences (impact uncertainty). In France, it is the SNBC (*Stratégie nationale bas-carbone* – National Low-Carbon Strategy), a roadmap towards decarbonisation which incorporates macroeconomic effects, that is used. According to this assessment (Callonnec & Cancé, 2022), the transition to a carbon-neutral society could boost national GDP by three to four points by 2050. This scenario, while still open to debate (ADEME, 2020), does not include the cost of climate change damage and does not allow an assessment of all the benefits of ambitious climate action.

In order to quantify the cost of damage, economists have been able to use so-called "macroenvironmental" models. This type of model combines a traditional macroeconomic model with a representation of the climate. Historically, the first macroenvironmental models were Integrated Assessment Models (IAMs). In 1992, American economist William Nordhaus developed the first version of the DICE (Dynamic Integrated Climate Economics) model, a general and intertemporal equilibrium model that incorporates both mitigation costs (i.e. actions, in particular political actions, aimed at reducing greenhouse gas emissions) and the cost of the damage. According to the initial simulations performed with this model, the optimal global decarbonisation trajectory would result in an exceeding 3°C of global warming, compared to the pre-industrial era, by 2100. That trajectory would have been associated with a carbon price of \$20/tCO_2 and a 15% drop in global emissions but, most importantly, the macroeconomic impacts would have been virtually insignificant. In view of the increased occurrences of intense climatic episodes in the world in recent years, such results now appear unrealistic.

Although highly controversial (Pindyck, 2017; Dietz *et al.*, 2020), this original work laid significant foundations for further academic research. This is the first time that a model combined traditional macroeconomic models with a representation of the climate (albeit one that was very simplified). The model links economic production to greenhouse gas emissions, then introduces concepts linked to climate dynamics (links between atmospheric and submarine emissions and concentrations), climate sensitivity (links between concentrations, radiative forcing[1] and temperature) and climate damage (link between temperature and economic losses), allowing for the hypothesis that there is a direct feedback loop between macroeconomics and climate.

This "top-down" approach is based in particular on a macroeconomic "damage function". First defined by Nordhaus, damage functions are mathematical functions linking temperature changes to a loss of aggregate Gross Domestic Product (GDP) globally (Box 1).

The calibration of this function has been the focus of academic work not only by Nordhaus (2016), but also by the research community (Howard & Sterner, 2017). While the first so-called "enumerative" estimates (which group together and calibrate impacts using sources

1. *Radiative forcing (W/m²) is the difference in power per unit area between solar radiation and terrestrial radiation in the stratosphere. It relies, in particular, on concentrations of greenhouse gases, which reflect part of the Earth's radiation.*

Box 1 – **Form(s) of a Damage Function**

In the "top-down" approach introduced by Nordhaus (1992), a damage function generally takes the form of a polynomial function $f(T)$. It separates national (or global depending on the geographical field) activity $Y_{theoretical}$, i.e., the activity that would occur in the absence of climate change, from a fraction dependent on T, which is the change in temperature since the pre-industrial era, and results in actual activity Y:

$$Y = \left(1 - f(T)\right) \times Y_{theoretical}$$

where: $f(T) = aT + bT^2$ (a and b are estimated or calibrated parameters) and $0 \leq f(T) \leq 1$

In the "bottom-up" approach introduced by multi-sectoral modelling, (so-called "sectoral") damage functions are applied at the level of one or more sectors and no longer directly affect the overall level of activity, but on certain parameters that influence supply and demand behaviours: level of productivity, rate of capital depreciation, demand for certain goods and services, etc.

with varying degrees of precision) led to highly uncertain results, the following functions were based on more sophisticated methods, including econometrics or damage simulation in calculable general equilibrium models. However, this work has led to extremely heterogeneous ranges of impacts, not only due to the diversity of the approaches, but also because of the different areas of damage chosen (Howard & Sterner, 2017). It is from among these approaches that the NGFS (Network for Greening the Financial System) selected macroeconomic damage in its first baseline scenarios (NGFS, 2020): two damage functions from meta-analyses carried out by Nordhaus & Moffat (2017) and Howard & Sterner (2017), and one from Kalkuhl & Wenz (2020) based on panel econometrics. Here too, heterogeneity prevails: for a global warming scenario of +3.5°C compared to the pre-industrial era, these functions respectively indicate 3, 10 and 15 GDP points of damage by 2100 globally.

A second methodology, a "bottom-up" methodology, gradually began to emerge in the 2000s. This approach no longer presents the impacts of climate change at the level of aggregate production alone, but it instead presents them across the entire value chain and all economic stakeholders, no longer describing the damage from climate change as a global risk, but as a set of specific events that impact on various stakeholders or sectors, on both the supply and the demand sides. The damage is then reflected through exogenous macroeconomic shocks, namely: the productivity of production factors and the rates of depreciation of capital, as well as the behaviour of demand for energy and for tourism services.

To that end, researchers used multi-sector models, adapted to identify shocks occurring on a sector by sector basis. In 2006, one of the first assessments was based on the static GTAP-EF model and assessed the long-term macroeconomic effects of the IPCC "B1" scenario on highly targeted consequences of climate change: tourism flows and sea-level rise. While the estimated macroeconomic effects remain limited, studies have highlighted interaction effects related to the simultaneous occurrence of multiple events and concluded that the cost of the damage should be assessed using a general equilibrium approach, so as to avoid restricting the analysis to direct costs only (Bigano *et al.*, 2006). Subsequently, Eboli *et al.* (2009) and Bosello (2012) extend this approach to dynamic multi-sector models and assessed the overall underlying damage in the IPCC scenarios, allowing for an assessment of the rise in macroeconomic costs over the century and the taking into account of closed model and feedback effects. The macroeconomic impacts of global warming estimated in the above-mentioned studies remain very low, or even positive for some European countries. Indeed, some European countries will benefit from the increase in tourist flows, as well as from the fact that some forms of damage harm foreign economies more and improve their competitiveness in terms of export prices (this is particularly the case with regard to falls in agricultural yields).

The European Commission has also adopted a similar approach in its GEM-E3 model, estimating damage for all EU countries based on a harmonised methodology and a broad climate and economic database. Its results still tended to underestimate the cost of climate change (a loss of 1.1 percentage points of GDP mainly related to labour productivity, sea level and agricultural yields). The primary difficulty, which was linked to the European-centred economic structure, was failing to take into account the indirect cost of damage occurring in the rest of the world and impacting on foreign trade (Ciscar Martinez *et al.,* 2014).

However, the researchers appear to believe that the "bottom-up" modelling approach (the main results of which, for Europe, are set out in the annexe) allows us to track, with precision and over time, how the effects of climate change would impact the economy, while taking into account feedback effects and second-round effects, such as changes in relative prices (Roson & Sartori, 2016). Finally, with new constraints on economic and financial stakeholders, some financial institutions have continued this work in order to anticipate the risks to their activity. Moody's rating agency has, for example, incorporated the cost of climate damage into its own macroeconomic model, but also underestimates the costs of climate change in northern countries, which would benefit from smaller falls in productivity, higher tourism flows and lower oil prices (Lafakis *et al.*, 2019).

After taking into account supply constraints in the "ThreeME" model (Section 1), the "bottom-up" damage functions are estimated using the data collected in the literature (Section 2). Once those functions are linked to the model (Section 3) and the aggregate cost of damage is estimated (Section 4), the macroeconomic consequences of a scenario of inaction are assessed in comparison

with the consequences of an orderly transition (Section 5).

1. Modification of the "ThreeME" Macroeconomic Model

The "ThreeME" model (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy[2]) is the tool used by ADEME to assess the cost of climate damage. It is a calculable general equilibrium model inspired by Keynesian economic theory (Reynès *et al*., 2021). Unlike so-called "Walrasian" models, its prices are not adjusted instantly to balance supply and demand in markets, which reflects the existence of macroeconomic imbalances and the possibility of Keynesian multiplier effects. In the "ThreeME" model, the supply of currency depends on the monetary policy which sets the interest rate, unlike in the Walrasian framework in which it is determined by the balance between the supply of and demand for capital. Thus, investments are financed by creating currency, without this necessarily leading to an increase in the interest rate, which would lead to a total wipeout of demand for investment from other sectors of the economy.

It includes 33 productive sectors (producing 28 commodities). In particular, the model is based on French national accounts data and aggregates sectors in accordance with existing classifications, specifically setting out 13 distinct energy sectors and four production factors, namely labour, capital, intermediate goods and energy. The "generalised CES" production function allows companies to minimise their costs by performing trade-offs between these factors, as well as between the different energies used and between domestic and imported products. Finally, the model calculates the energy requirements by means of a granular representation of the capital stock of households, which changes in accordance with transport and heating needs and the energy performance of the supply of property and vehicles.

The model has been used for a number of forecasting exercises. The French Ministry for the Ecological Transition used it to create macroeconomic scenarios for the SNBC (Callonnec & Cancé, 2022). Like the Mésange model (Bardaji *et al.*, 2017), it also makes it possible to measure the macroeconomic impact of fiscal and budgetary policies (Callonnec *et al.*, 2016) or to assess the impact of specific climate measures, such as hypotheses regarding the development of the electricity mix in France (ADEME, 2016). More recently, the model has been used in the estimation of the macroeconomic effects of a delayed transition scenario (Boitier *et al.*, 2023).

New financial and economic regulations (taxonomy, non-financial reporting and new requirements of supervisory authorities) and new institutional needs for climate scenarios, particularly in the financial sector (TCFD, 2017; NGFS, 2021; ECB, 2022), are driving the development of macroeconomic modelling to extend the applications of climate scenarios and to better measure all the "climate risks" that may arise during the transition period (Carney, 2015). These scenarios include transition risks, defined as potentially adverse consequences of decarbonising the economy (Boitier *et al.*, 2023), but do not generally include physical risks, the assessment of which remains subject to too many uncertainties and is still affected by the application of damage functions aggregated at global level (NGFS, 2021). The article proposes the application of "bottom-up" functions, in accordance with the literature mentioned in the introduction, together with an upstream change to the theoretical structure of the model to assess the cost of climate damage in France.

Several significant changes have been made to the model. At the outset, the model is based on a "neo-Keynesian" framework in which activity stems from the behaviour of economic stakeholders in terms of demand: consumption, investment and exports in particular. In order for the accounting framework to remain consistent, the model ensures that supply (production and imports) is adjusted to aggregate demand in each period: this is the "resources-uses" balance, which then makes it possible to reconstruct the main aggregates of the national accounts. This theoretical framework is similar to that of the Mésange model, co-developed by INSEE and the French Treasury (Bardaji *et al*., 2017), but it is not suitable for assessing the damage due to climate change because it has the following weaknesses:

- physical constraints on production: in the original version of ThreeME, the variation in production results solely from the change in domestic or external demand and possible exogenous shocks affecting production costs (prices of intermediate consumables, tax increases, etc.). Unlike neoclassical general equilibrium models, in which the quantities produced depend on the availability of production factors, neo-Keynesian models do

2. *There is an overview of the model on the website: www.threeme.org*

not adequately take into account the recessive effects that could result from a contraction in the quantity of production factors available. In addition, not all "real" factors of production are incorporated; for example, in the case of agriculture, the "land use" factor is not taken into account, although it is a factor that limits production;

- The determining factors of inflation: in ThreeME, inflation is mainly influenced by the prices of the factors ("cost-push inflation"), while on some markets, such as commodity or energy markets, inflation reacts and adjusts rapidly to direct imbalances in supply and demand ("demand-pull inflation").

The assumption that supply adjusts to demand within a relatively rigid price framework does not simulate the full impact of climate change. Physical risks would essentially come in two forms: direct damage to physical assets (through, for example, an increase in capital depreciation) and a disruption to the factors of production (through a decrease in the productivity of labour and capital). When either occurs, Keynesian models show two phenomena:

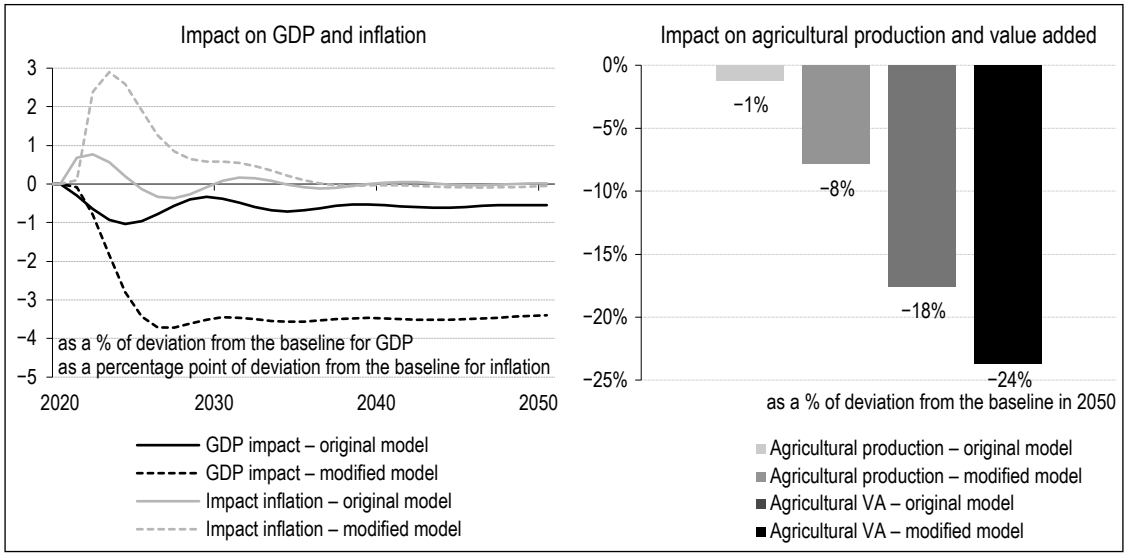
- first, unit costs of production are increasing and with the use of the factor itself having become more expensive, companies gradually pass on this increase to their sales prices (under the assumption that there is no long-term profit margin behaviour);
- second, demand for an "efficient" factor increases in order to compensate for the lower productivity of the factors already used and to satisfy demand. Increased investment and employment can have positive knock-on effects on activity, which may at least partially offset the direct recessionary effects of the shock to supply.

The latter effect is of little relevance in the agricultural sector (limited arable land) and the power generation sector (time needed for the installation of new capacities and dependence on certain climatic factors). It would be fanciful to think that additional investment or hiring could maintain the previous level of production.

As the simulations (Figure I) demonstrate, the traditional aggregated supply and demand framework ("original model") tends to minimise the costs of climate damage, not only because it allows for short-term adjustment of production (through job creation and additional investment), but also because price increases are smoothed due to adjustment times and nominal rigidities (the time it takes for the agricultural sector to incorporate the increase in production costs into its sales prices). This is why the modification of the agricultural sector is justified (cf. Box 1), which allows for production modelling that is correlated with actual yields and more realistic inflation in line with what is happening in the real economy ("modified model"), for example during summer drought periods.

In order to correct for these limitations, the levels of agricultural and energy production have been constrained. It is now not supply

Figure I – **Macroeconomic impact of an instant fall in agricultural yields of 10%**



Reading note: In the "original" ThreeME model (compared with the modified model), a decrease in agricultural yields of 10% leads to a fall in agricultural production of 1% (compared with 8%) in the long-term (in 2050).
Sources: The ThreeME model, according to the standard model (agricultural sector supply and demand equilibrium by volumes) or the modified version (price equilibrium).

that adjusts to demand in the context of relatively rigid short-term prices, but demand that adjusts to supply through greater price flexibility (Box 2). In the event of a reduction in domestic production, imports increase to meet at least part of the short-term demand that can no longer be met by domestic producers. This limits the rise in market prices and the drop in consumption. Given that these products are considered to be essential, demand is rather inelastic. However, it is declining due to higher prices. Under the assumption of a sharp contraction of world agricultural production, we could find ourselves in a scenario in which per capita food consumption would not be sufficient to avoid malnutrition in part of the population. The impact of scarcity on population growth[3] and labour productivity would then need to be taken into account. This last feedback loop has not yet been introduced into the model.

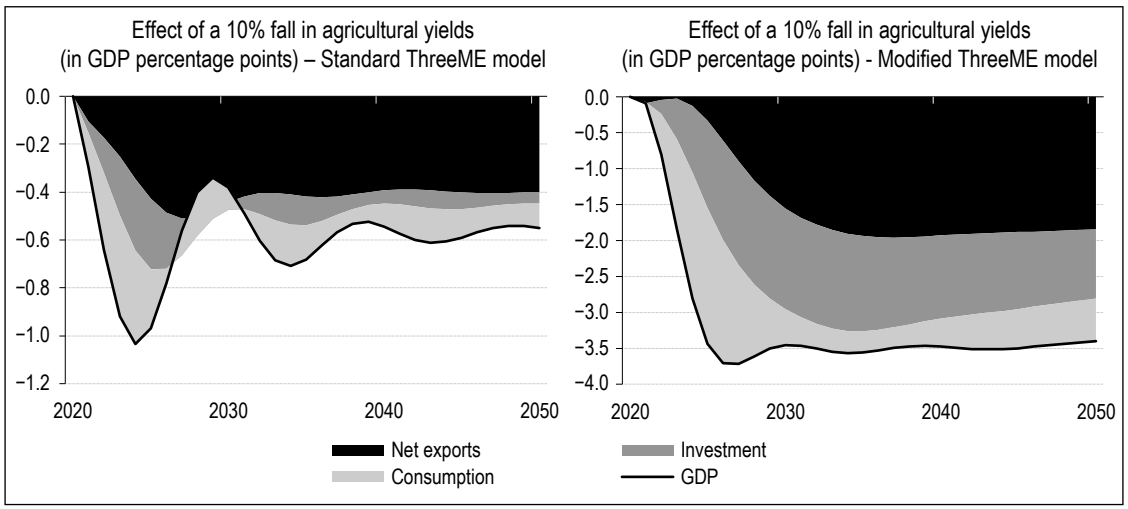
An instant and lasting fall in agricultural yields of 10% (i.e. a decrease in the productivity of each factor of production in the sector) is simulated and its effects are compared with the original model in order to confirm the new methodology (Figures I and II). Agricultural production falls instantly by 10% and the rise in the prices of agricultural products is sudden and abrupt. The overall inflationary effect is much higher in the new version of the model, as the adjustment is faster and is performed entirely through prices (and no longer through volumes). In the long term, declining activity and job losses limit wage growth and eventually reduce inflation. The rise in prices negatively impacts total consumption by stakeholders, who are forced to devote a larger share of their income to food at the expense of other goods and services. Ultimately, the drop in activity is much greater in the modified version. As also noted by Reilly *et al.* (2012) the macroeconomic effects are broader than the effects on agricultural production alone, as consumption is highly inelastic and requires factors of production to be partly reallocated to the agricultural sector in order to secure food demand first and foremost, at the expense of production in other sectors.

2. Estimation of a Damage Function in France

Using a "bottom-up" approach, ADEME economists have identified, both geographically and by sector, the costs of physical damage in France through an in-depth literature review, excluding at this stage non-monetary damage (impact on biodiversity), indirect effects of climate change (such as population displacement) and adaptation and reconstruction costs. The underlying monetary impacts in various global warming scenarios are extrapolated and sectoral damage functions are calibrated in accordance with traditional regressions. As for the assessment of acute risks, despite their unpredictability, they are extrapolated from historical inventories of natural disasters from the EM-DAT database (see below). Here we adopt a risk-based

3. In ThreeME, population growth is exogenous and is defined by using INSEE's estimate. It is around 0.4% per year. Food shortages could cause a rise in the mortality rate and a drop in the birth rate.

Figure II – **Effect of agricultural damage modelling on GDP**



Reading note: In the modified version of "ThreeME", an instantaneous 10% fall in agricultural yields reduces GDP by 3.5 points in the long term (including 2 points linked to exports), compared with 0.6 points (including 0.4 points linked to exports) in the standard version, in which prices are relatively rigid in the short term and evolve in line with production costs.
Sources: The ThreeME model, according to the standard model (agricultural sector supply and demand equilibrium by volumes) or the modified version (price equilibrium).

Box 2 – **The New Production and Inflation Dynamic in the Agricultural Sector**

In the usual Neo-Keynesian models, the production of the good Y_i adjusts to demand D_i and imports M_i, and the sale price is equal to a margin μ applied to the unit cost of production CU_i. People talk of "aggregate supply – aggregate demand" and "cost inflation" models:

$$Y_i + M_i = D_i$$
$$P_{Yi} = \mu CU_i = \mu\left(\alpha_{L,i}\, cl_{L,i} + \alpha_{K,i}\, ck_{K,i} + \alpha_{E,i}\, ce_{E,i} + \alpha_{mat,i}\, cmat_{mat,i}\right),$$

with $\alpha_{f,j}$: nominal remuneration of factor f in sector i and $cf_{f,j}$: unit cost of factor f in sector i.

This dynamic is changed for the agricultural sector. We introduce potential production Y_{pot} and potential imports M_{pot} of agricultural products that are in short supply and depend on the changes to the productivity of the factors, which is assumed to be exogenous:

$$\dot{Y}_{pot} = dlog\left(prog_{f_i}\right) + dlog\left(pop\right) \text{ and } \dot{M}_{pot} = dlog\left(prog_{f_i}\right) + dlog\left(pop\right).$$

The balance between supply and demand is no longer achieved by quantities but by prices. The equilibrium price $PY_{eq\,i}$ of domestically produced goods is equal to:

$$\boldsymbol{PY_{eqi}} Y_{pot_i} + Tax_i + Marg_i = PD_i.QD_i.$$

The equilibrium price $PM_{eq\,i}$ of imported goods is equal to:

$$\boldsymbol{PM_{eqi}} M_{pot_i} + Tax_i + Marg_i = PM_i.QM_i,$$

with QD as the demand for domestic products i (this is the sum of intermediate consumption and end consumption directed towards domestic producers), QM as the demand for products i directed towards the rest of the world, Tax as consumer taxes and $Marg$ as transport and trade margins.

The production price no longer depends on production costs but on the new equilibrium price:

$$P_{Yi} = \mu CU_i \text{ becomes: } \dot{P}_{Yi} = P\dot{Y}_{eqi}.$$

PM_i which was previously assumed to be exogenous becomes $P\dot{M}_i = P\dot{M}_{eqi}$.

End consumption CF is a function of population pop, income R and consumer prices P:

$$\dot{CF}_i = p\dot{o}p + \alpha\dot{R} - \beta\dot{P}_i \qquad (\alpha,\ \beta \text{ of the parameters}).$$

Intermediate consumption CI of agricultural products i by sectors j develops in the same way as the production of the sectors, but decreases relatively when their real prices $\left(\dot{P}_{ij} - \dot{P}_j\right)$ increase:

$$\dot{CI}_{ij} = \dot{Y}_j - \gamma\left(\dot{P}_{ij} - \dot{P}_j\right).$$

Imports M increase in the same way as demand D and decrease when their prices P_m rise faster than domestic prices P_i:

$$\dot{M}_i = \dot{D}_i + \gamma'\left(\dot{P}_i - \dot{P}_m\right).$$

Thus, demand adjusts to the level of potential supply through the increase in market prices. This specification simulates an effective decline in domestic agricultural production and yields, without an increase in sectoral investment and employment, and an increase in agricultural market prices, potentially exceeding the increase in unit production costs, which will have a crowding out effect on consumption of other products and a more negative effect on the trade balance.

approach and not a consequence-based one: it is nevertheless revealed that buildings and their occupants are exposed to a multiplicity of risks, as indicated by the forecasting studies carried out by ADEME (ADEME, 2022).

The main functions contributing to impacts are specified in Table 1. To our knowledge, this inventory takes into account most of the risks identified in international classifications (such as the European taxonomy) and makes a distinction between chronic risks and acute risks. Only the assessment of the acute risks remains incomplete. For example, forest fires, which are theoretically included in the history of natural disasters, are partially listed and their average cost (a few million euro) is likely underestimated,[4] especially

*4. ONERC (*Observatoire National sur les Effets du Réchauffement Climatique *– the French National Observatory on the Effects of Global Warming) (2009) estimates that the impact of climate change would be slightly positive for wood production until 2050, but would reverse by 2100 due to extreme events and the expansion of the Mediterranean forest.*

since non-monetary damage is not included in the assessment (adaptation to forest fires would cost France several billion euro per year). Other impacts related to natural disasters have also been investigated, though it has not been possible to obtain sufficiently detailed estimates to incorporate them into the damage, such as mountain risks and landslides; in theory, if all acute risks are taken into account in the inventory of natural disasters, the historical basis essentially reflects the monetary impacts of certain categories (floods, hurricanes, drought and periods of extreme temperatures). Moreover, it does not make it possible to model the future increase in the severity of such events. Finally, the effects of increased migration flows are not modelled.[5]

2.1. Chronic Risks

2.1.1. Productivity of Outdoor and Indoor Labour

It is estimated that labour productivity in some sectors will be significantly impacted, especially in outdoor working conditions (agriculture and construction) and in particular in southern European countries (Gosling *et al.*, 2018). In the absence of adaptation and under the worst impact models, outdoor labour productivity could decline by four percentage points by the end of the century in the case of high levels of global warming (two percentage points for indoor labour) (Figure III).

2.1.2. Agricultural Yields

On the basis of several simulation and projection approaches, it is established that wheat and corn crop yields are expected to decrease significantly in the face of temperature rises, without taking into account the effects of precipitation (Zhao *et al.*, 2017). Only the effects on production costs and prices are taken into account here. If producers are encouraged to increase their capacity to meet demand, they will eventually be able to cope with a reduction in available space. If opportunities for additional investment are limited, that could contribute to increasing the economic cost of global warming. Due to a lack of expertise on the subject, the possibilities of replacing the current crops with varieties that are more resistant to heat and water stress were not taken into account (Figure IV).

2.1.3. Sea Level

The European Commission's projections on the impact of sea level and damage it causes along the coast (effects of tides, waves and storm surges and flooding caused by marine submersion) indicate that France would be one of the European countries most affected economically by rising seas (Vousdoukas *et al.*, 2019). It is

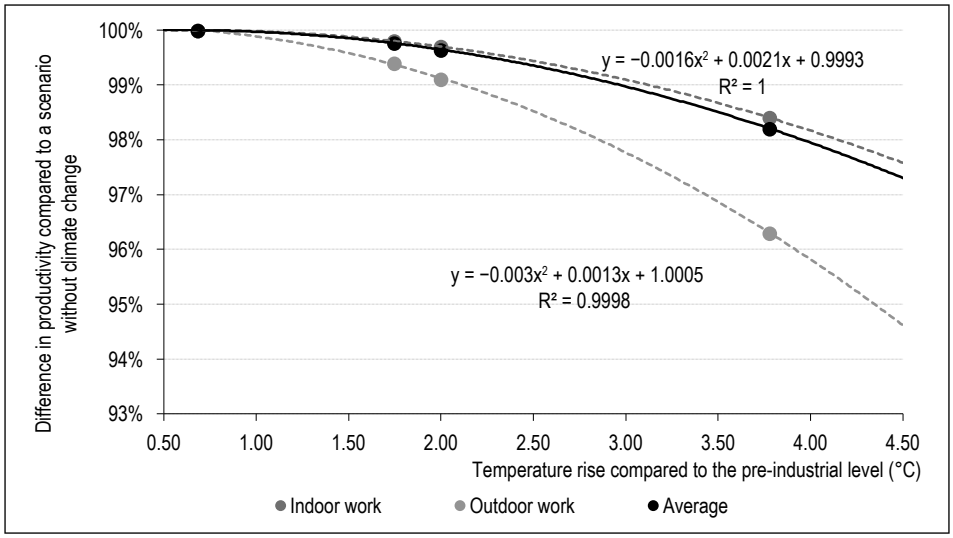
5. According to Missirian & Schlenker (2017), by the end of the century, the number of asylum applications would increase by 188% (66,000 additional applications per year) in the RCP 8.5 scenario.

Table 1 – **Selection of sectoral damage having a significant macroeconomic impact**

Sectoral damage functions	Macroeconomic shock	Sectors concerned
Hydroelectric generation capacities	Productivity of production factors	Power generation - hydraulic
Thermal generation capacities	Productivity of production factors	Power generation - thermal
Natural disasters	Depreciation rate	Residential and tertiary property
Supply chains	Global demand	The whole economy
Household energy demand	Energy consumption per m²	Household housing
Service energy demand	Company energy demand	The whole economy
Sea level rise	Depreciation rate	Residential and tertiary property
River flooding	Depreciation rate	Residential and tertiary property
Labour productivity - illnesses	Labour productivity	The whole economy
Productivity of outdoor work	Labour productivity	Agriculture, Forestry, Construction
Productivity of indoor work	Labour productivity	The whole economy (except outdoor work)
Agricultural and forestry yields	Productivity of production factors	Agriculture, Forestry
Wind turbine output	Productivity of production factors	Power generation - wind
Photovoltaic output	Productivity of production factors	Power generation - solar
Shrinkage and swelling of clay soils	Depreciation rate	Residential and tertiary property
Income from Tourism	Global demand	Private services

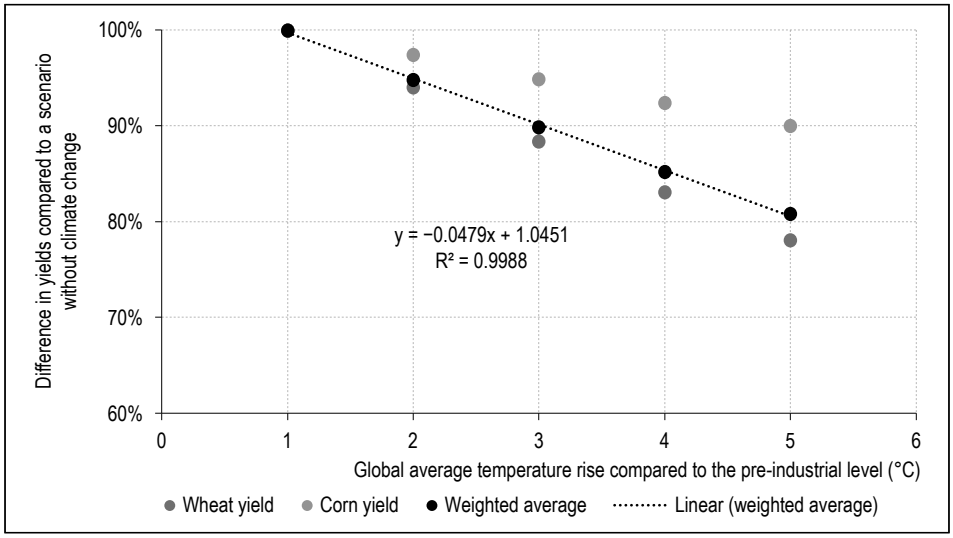
Reading note: Among the physical risks identified, sea level rise is assumed to influence, at the macroeconomic level, the rates of capital depreciation in the residential and tertiary property sector.
Sources: Jacquetin (2021).

Figure III – **Sectoral damage function – Labour productivity**



Sources: ADEME, based on Gosling *et al.* (2018).

Figure IV – **Sectoral damage function – Agricultural yields**



Sources: ADEME, based on Zhao *et al.* (2017).

thought that the annual damage caused would amount to between €5 billion and €10 billion by the end of the century according to the RCP 4.5 and RCP 8.5 scenarios (Figure V).

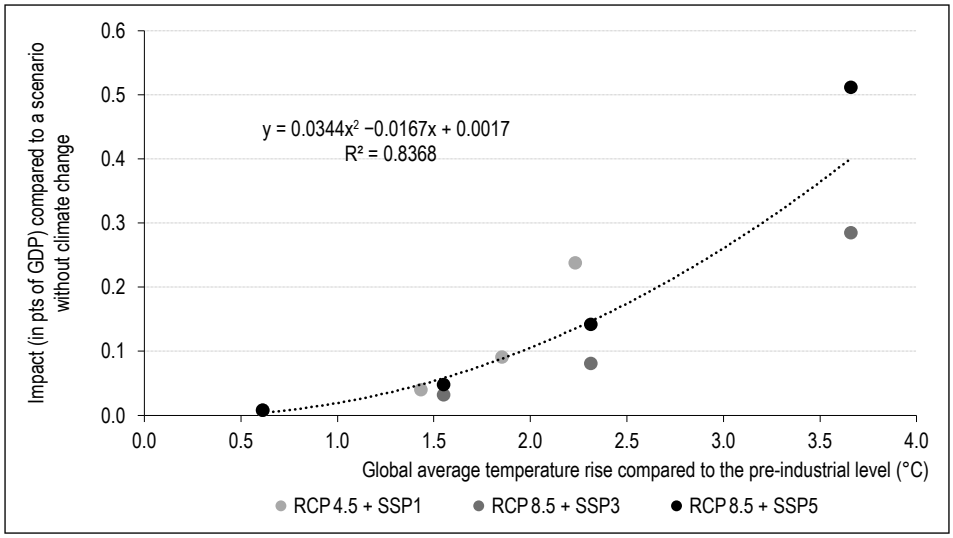
2.1.4. Changes in Heating and Air Conditioning Needs

Changes in temperature will have a major impact on the heating and air conditioning needs of the residential and tertiary sectors. Kitous & Després (2018) estimate the impact of temperature changes on residential demand for air conditioning and heating compared to a scenario where temperature does not increase after 2010. De Ciang & Sue Wing (2019) estimate the impact of temperature changes on other sectors. The impact on other sectors seems negligible in France, except for the impact on the commercial sector, which is estimated using a linear function. Using the relative weights of air conditioning and heating in residential demand for energy, and the share of residential and tertiary energy consumption, the average cost of the total demand for energy is estimated (Figure VI).

2.1.5. Power Generation

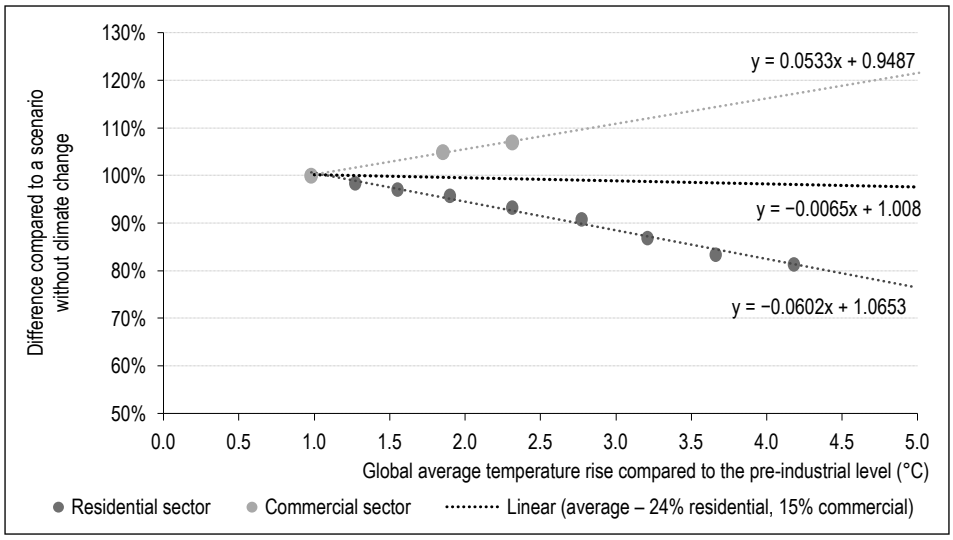
A function reflecting the change in output compared to the period 1971–2000 is estimated for four power generation technologies (solar, wind, hydroelectric and thermal) using Tobin *et al.* (2018). The impacts are more limited for

Figure V – **Sectoral damage function – Sea level**



Sources: ADEME, based on Vousdoukas *et al.* (2019).

Figure VI – **Sectoral damage function – Energy demand**



Sources: ADEME, based on Kitous & Després (2018) and Ciang & Sue Wing (2017).

the output of solar and wind power, which would be less than 10% in a scenario of inaction, while the output of hydroelectric and thermal power could decrease by 20% (Figure VII).

2.1.6. Income from Tourism

The effects of climate change on winter tourism (ski resorts) and then on summer tourism are estimated in order to obtain the overall impact on income from tourism. It is estimated that the fall in demand for winter tourism is linked to a reduction in the number of overnight stays (Jacob *et al.*, 2018) and the number of people heading up the slopes (Spandre *et al.*, 2019). The rise in summer tourism is taken from Jacob *et al.* (2018) (Figure VIII).

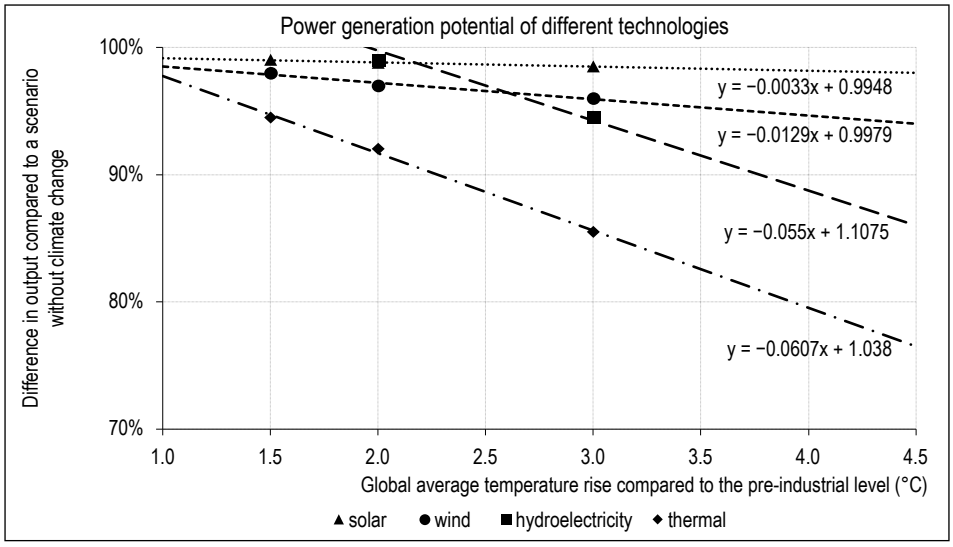
2.1.7. Shrinkage and Swelling of Clay Soils

Estimates of damage related to the shrinkage and swelling of clay soils are taken from Gourdier & Plat (2018). The increase in the cost of the damage depends first on the increase in the number of individual houses in risk areas and then on the increase in the scale and frequency of droughts (Figure IX).

2.1.8. Labour Productivity and Rise in Illnesses

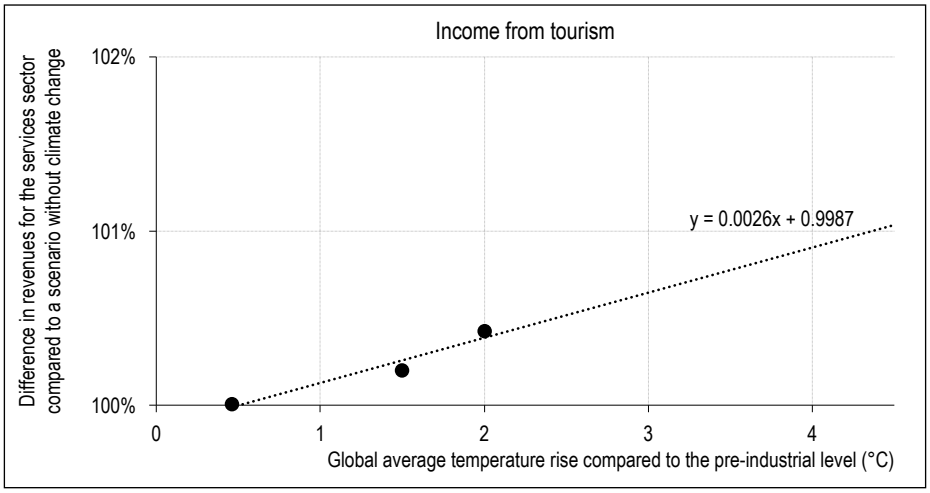
Paci (2014) assesses the impact of temperature rises on productivity at work in Europe (in terms of number of working days lost per capita) by assessing the relationship between

Figure VII – **Sectoral damage function – Power generation**



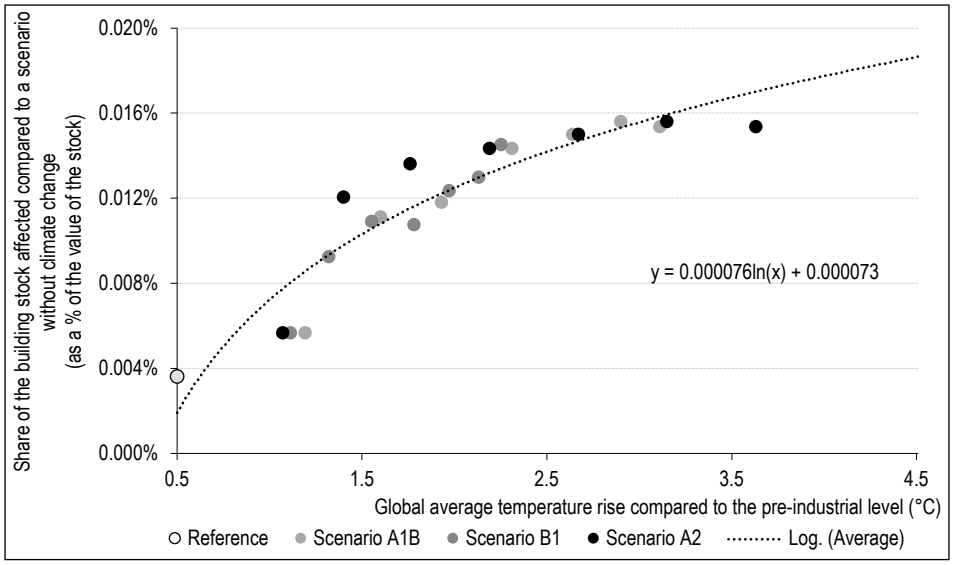
Sources: ADEME, based on Tobin *et al.* (2018).

Figure VIII – **Sectoral damage function – Tourism demand**



Sources: ADEME, based on Jacob *et al.* (2018) and Spandre *et al.* (2019).

Figure IX – **Sectoral damage function – Shrinkage and swelling of clay soils**



Sources: ADEME, based on Gourdier & Plat (2018).

temperature rises and number of working days lost through several phenomena: the increase in temperature-related morbidity and mortality (resurgence of cardiovascular and respiratory diseases), additional heat stress related to heat waves (mortality and morbidity) and the increase in food and water infections (salmonellosis and campylobacteriosis). It is assumed that the estimated per capita value for Europe is applicable to France as well (Figure X).

2.2. Acute Risks

2.2.1. Direct Costs in France

The International Disaster Database (EM-DAT) contains information on natural disasters and their economic costs (damage costs, insurance costs and reconstruction costs). Managed by the Centre for Research on the Epidemiology of Disasters (CRED, 2021) in Belgium, it is available for use in academic research and is one of the largest databases on extreme risks in the world. However, it displays information in a heterogeneous manner and remains subject to significant gaps (temporal and spatial coverage, missing indicators and estimates for certain categories of events, etc.).

It is thought that floods and hurricanes would have the most negative impact on the overall cost of extreme events in France (on average, $1 billion per hurricane and $0.8 billion per flood). Despite the increase in their intensity since 1990, there is still little detail on the cost of periods of extreme temperatures (only three events are recorded, including the heat wave of 2003 that cost $6.5 billion and the period of freezing temperatures in 2021 in the Rhône region). When all categories are combined, the most costly event recorded was the case of the extratropical cyclones Lothar and Martin in 1999, costing nearly $20 billion.

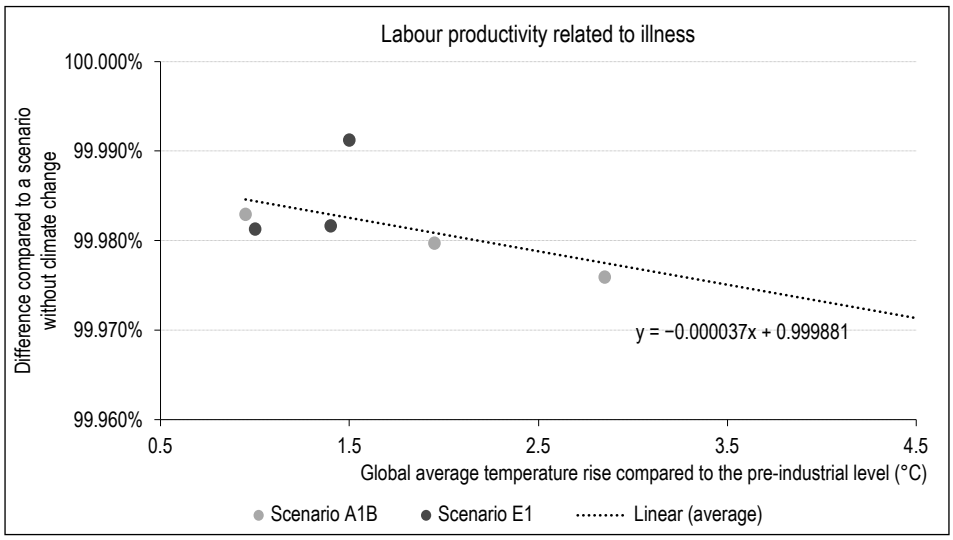
The available data make it possible to assess an upward trend in the number of natural disasters recorded and identified in the database as a function of changes in temperature (Figure XI). By imputing the average cost observed for these events (nearly €1 billion, Figure XI), it is possible to partially link the rise in temperatures since the pre-industrial era to the increase in the frequency of extreme physical risks.

This model remains very incomplete, as it does not account for the potential increase in severity of events in the future and does not examine the predominance of new categories of events to come, feedback loops or tipping points. Therefore, the long-term effects of natural disasters in a scenario of inaction would remain limited (around 1 percentage point of GDP per year in a scenario of inaction) and would represent only the average of the long-term cost.

2.2.2. Acute Risks in the Rest of the World

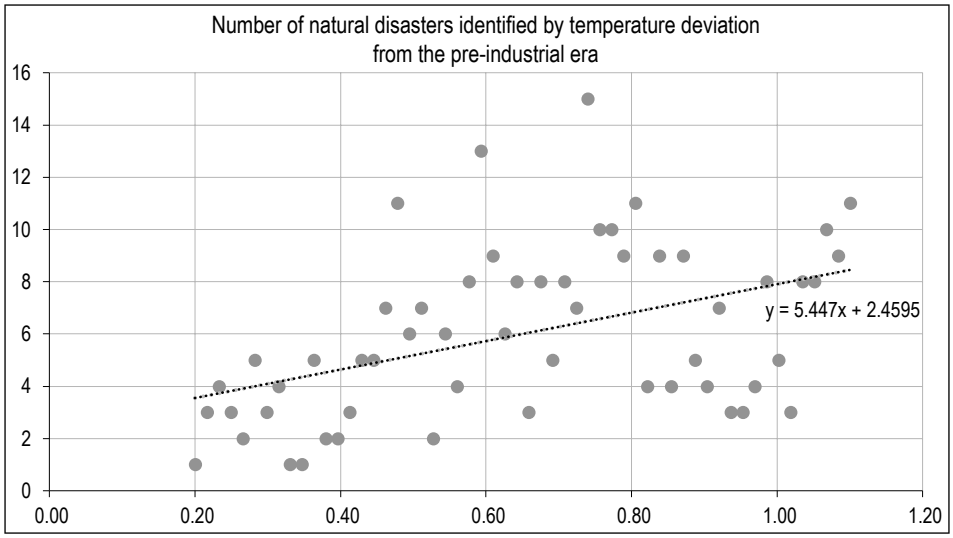
Climate risks will alter foreign economies and have a negative impact on their domestic demand (and therefore on demand for French goods and services) and their prices (and thus on inflation imported into France and relative price competitiveness). Finally, climate damage may also influence the financial environment (commodity prices, exchange rates and interest rates). The failure to take these effects into account has tended to minimise the costs of climate change, for example when the model is

Figure X – **Sectoral damage function – Illness**



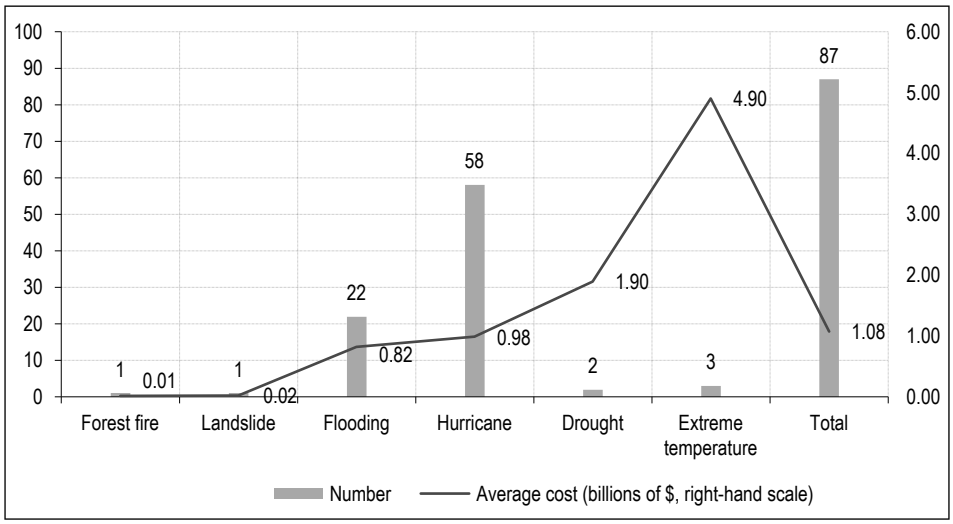
Sources: ADEME, based on Paci (2014).

Figure XI – **Sectoral damage function – Natural disasters in France**



Sources: EM-DAT (authors' calculations).

Figure XII – **Average cost of natural disasters in France by type of event**



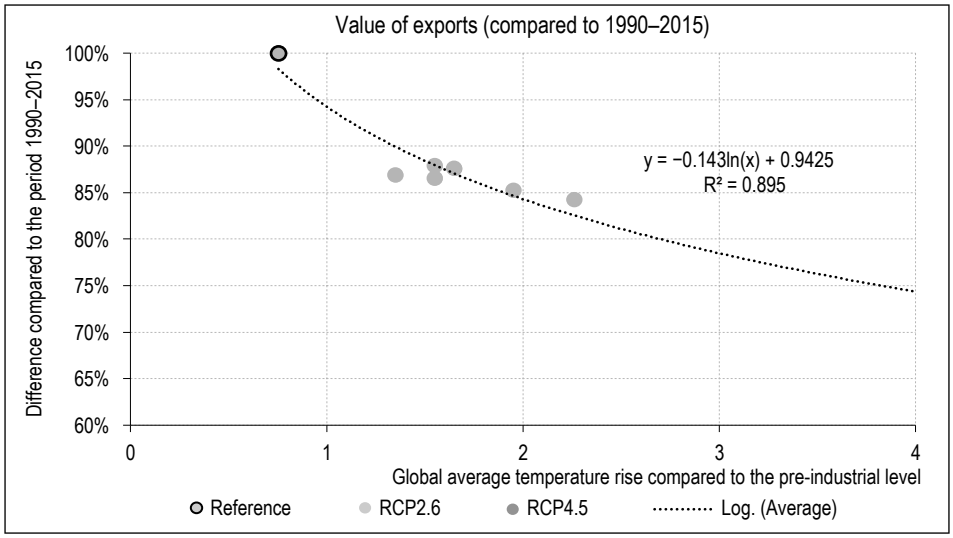
Sources: EM-DAT (authors' calculations).

centred on Europe (Ciscar Martinez *et al.*, 2014). However, some open-economy studies have been able to specifically assess future changes to regional trade flows linked to climate change. The OECD estimates, for example, that climate change combined with a scenario of inaction would have little impact on exports from the European Union and the United States up to 2060, but would have a greater negative impact on exports from Asian and African countries (Dellink *et al.*, 2017). In contrast, other studies examine potentially massive effects on the trade of EU countries. The latter hypothesis is the one that we favour in this study.

The effects on trade are estimated here on the basis of an econometric study linking the level of French exports to natural disaster indicators (Schleypen *et al.*, 2019). According to this model, the impact of extreme events on the supply chain would represent a major contribution to the cost of climate damage in France. They would correspond to the estimated economic consequences of disruptions to French supply chains caused by natural disasters abroad and the decline in external demand as a result of climate damage (Figure XIII). It underlines that the decline in exports observed is due to two mechanisms: the rising prices of resources for French companies – or the disruption of their supply – and falling demand for French companies when their customers are affected by natural disasters.

Aside from the clarity and rigour of their methodologies, the studies used were also selected

Figure XIII – **Sectoral damage function – Natural disasters worldwide**



Sources: ADEME, based on Schleypen *et al.* (2019).

because they assess the impact of risk by means of an economic indicator that can be used in a macroeconomic model and forecast the changes in that indicator in various temperature rise scenarios. However, it should be remembered that climate change impact studies can lead to highly heterogeneous results. While it is difficult to reconcile results over a wide range of fields, Table 2 compares our results (covering ten damage functions) with other recent estimates in the literature, most of which are identified by Delahais & Robinet (2023). France Assureurs (2021) estimated the cost, by 2050, of risks related to drought, floods, marine submersions and storms, and ONERC[6] (2009) forecast the costs associated with tourism, the shrinkage and swelling of clay soils, marine submersions and power generation.

3. Macroeconomic Modelling

3.1. Agricultural and Electrical Yields/ Labour Productivity

The fall in agricultural and forestry yields (cf. Figure IV) and electrical production (cf. Figure VII) is modelled as a fall in the productivity of all the factors of production $PROG_{f,s,t}$ (where f is either labour, capital, intermediate goods or energy) of the sector s concerned, in such a way as to reduce the total output of the sector by the same proportion. Falls in labour productivity linked, on the one hand, to the deterioration of working conditions both outdoors and indoors (cf. Figure III) and, on the other, to the increase in absenteeism related to health conditions (cf. Figure X), are modelled as shocks to the trend of labour productivity at the level of $PROG_{L,s,t}$ (but not to the other factors of production).

For the labour factor L in sector s and year t:

$$PROG_{L,s,t} = PROG\_CC_{L,s,t} \times PROG\_CC\_agri_{L,s,t} \times PROG\_CC\_elec_{L,s,t} \times PROG\_CC\_air_{L,s,t} \times PROG\_CC\_sickness_{L,s,t}$$

with

$$PROG\_CC\_agri_{L,s,t} = \begin{cases} \text{estimated function} & \text{if } s = agriculture \\ 1 & \text{if } s \neq agriculture \end{cases}$$

and

$$PROG\_CC\_elec_{L,s,t} = \begin{cases} \text{estimated function} & \\ & \text{if } s = power\ generation \\ 1 & \text{if } s \neq power\ generation. \end{cases}$$

$PROG\_CC\_air_{L,s,t}$ is the fall in labour productivity linked to indoor and outdoor working conditions,

$PROG\_CC\_sickness_{L,s,t}$ is the fall in labour productivity linked to the increase in absenteeism.

For the other factors f, $f \neq L$:

$$PROG_{f,s,t} = PROG\_CC_{f,s,t} \times PROG\_CC\_agri_{f,s,t} \times PROG\_CC\_elec_{f,s,t}$$

For all of the factors f:

$$PROG\_CC_{f,s,t} = PROG\_CC_{f,s,t-1} \times \left(1 + GR\_PROG_{f,s,t}\right)$$

where $GR\_PROG_{f,s,t}$ is the productivity gain for the factor f in sector s in year t.

6. Observatoire National sur les Effets du Réchauffement Climatique *(the French National Observatory on the Effects of Global Warming).*

Table 2 – **Comparison of the ten damage functions with other assessments**

Physical risks	Authors' assumption (+3.5°C)	Comparative impacts	Reference
Labour productivity	−2 percentage points of productivity	+0.96 of a percentage point of annual GDP lost in 2045–2055 +1.14 percentage points in 2060–2070	France Stratégie (2023) RCP 8.5 - 2050
Agricultural yields	−12% in global yields	−6.5 percentage points of grassland yields −3.2 percentage points of soft winter wheat yields −4.2 percentage points of winter barley yields	France Assureurs (2021) RCP 8.5 - 2050
Marine submersion	−0.3 of a percentage point of GDP *(sea level)*	+€6.5 billion in 2020–2050 or €200 million per year €15 to €35 billion in Languedoc-Roussillon or €200 to €400 million per year	France Assureurs (2021) RCP 8.5 - 2050 ONERC (2009) - 4°C
Energy demand	−2% energy demand	−8 TWh of heating energy demand in 2050 +8 TWh of air conditioning energy demand	RTE, France's Transmission System Operator (2022) RCP 8.5 - 2050
Power generation	In France Hydroelectricity: −5% Wind: −5% Thermal (including nuclear): −20% Solar: −2%	In Europe Hydroelectricity: +3% Wind: -0.2% Nuclear: −2% Thermal: +0.2% Solar: stable In France: Hydroelectricity: −15%	Tobin *et al.* (2018) RCP 8.5 - 2050 ONERC (2009) - 2050
Tourism (skiing)	−11% income from skiing (+2°C)	20 operable resorts in the Alps (out of 143) 55 operable resorts in the Alps	WWF France (2021) / +4°C ONERC (2009) / +4°C
Health	In Europe 7.6 million working days lost per year (2085)	In Europe +60,000 deaths per year +15,000 victims of respiratory illnesses	IPCC (2023) +3°C
Shrinkage and Swelling of Clay Soils	0.016% of clay soils	+€17.2 billion or €500 million per year +€1.3 billion per year	France Assureurs (2021) RCP 8.5 – 2050 ONERC (2021) / +4°C
River flooding	−0.15 of a percentage point of GDP *(domestic natural disasters)*	+€3.1 billion per year or €100 million per year	France Assureurs (2021) RCP 8.5 - 2050
Global demand	Directed towards France: −20%	Directed towards the EU: stable	Dellink *et al.* (2017) RCP 8.5 - 2060

Notes: The estimates are presented for specific years (e.g.: 2050) or for a given level of global warming (e.g.: +4°C). The effects of floods (France Assureurs) are compared with the cost of domestic natural disasters, while those of marine submersions (France Assureurs) are compared with the cost of rising sea levels. The RCP 8.5 scenario (Representative Concentration Pathway 8.5) is a scenario involving a change to the concentration of GHGs in the atmosphere, leading to an increase in radiative forcing to 8.5 W/m² in 2100.

3.2. Damage to Physical Assets

Damage from rising sea levels (cf. Figure V), the shrinkage and swelling of clay soils (cf. Figure IX) and natural disasters (cf. Figure XII) are modelled as an additional increase in the rate of depreciation of sectoral capital $K_{s,t}$, distributed across residential property $\delta'_{BUIL,k\,t}$ (for 69%, which is the proportion of French residential capital estimated by Eurostat) and tertiary property $\delta'_{s,t}$ (31%). Finally, the effect is deducted from permanent household income to take into account wealth losses and long-term Ricardian equivalence effects and will have a negative impact on current consumption C_t.

$$K_{s,t} = \left(1 - \delta'_{s,t}\right) K_{s,t-1} + I_{s,t}$$

$$\delta'_{s,t} = \delta_{t,s} + 0.31 \times \left(\delta_{t,sea} + \delta_{t,RGA} + \delta_{t,extreme}\right)$$

$$\delta'_{BUIL\,k,t} = \delta_{BUIL\,k,t} + 0.69 \times \left(\delta_{t,sea} + \delta_{t,RGA} + \delta_{t,extreme}\right)$$

$$C_t = c \times Revenue_t - 0.69 \times \left(\delta_{t,sea} + \delta_{t,RGA} + \delta_{t,extreme}\right) \times BUIL_t \times P_{BUIL}$$

3.3. Energy Demand

The change in energy demand (cf. Figure VI) is modelled as a variation in the energy need per m² $ENERperM^2$', which varies according to a coefficient $ENERperM^2\_CC$ which in turn depends on the variation in temperatures.

$$ENERperM^2{}' = ENERperM^2 \times ENERperM^2\_CC$$

A shock is introduced to the function of energy demand in the service sector $F_{E,spri}$:

$$d(\log(F'_{E,spri}) = d\left(\log\left(Y_{spri}\right)\right) - d\left(\log\left(PROG_{E,spri}\right)\right) + d\left(SUBST_{E,spri}\right)$$

$$F'_{E,spri} = F_{E,spri} \times ENER\_services\_CC$$

3.4. Global Trade

The effect of natural disasters in the rest of the world (cf. Figure XIII) and changes in tourist flows (cf. Figure VIII) are modelled as corrective factors for global demand for French goods and services WD'_t.

For each commodity c exported:

$$WD'_{c,t} = WD_{c,t} \times WD\_supplychain_t \times WD\_tourism_{c,t}$$

Where:

$$WD\_tourism_{c,t} = \begin{cases} \text{estimated function} & \text{if } c = Private\ services \\ 1 & \text{if } c \neq Private\ services \end{cases}$$

$WD\_supplychain_t$ is the fall in global demand caused by value chains and applies to all commodities exported.

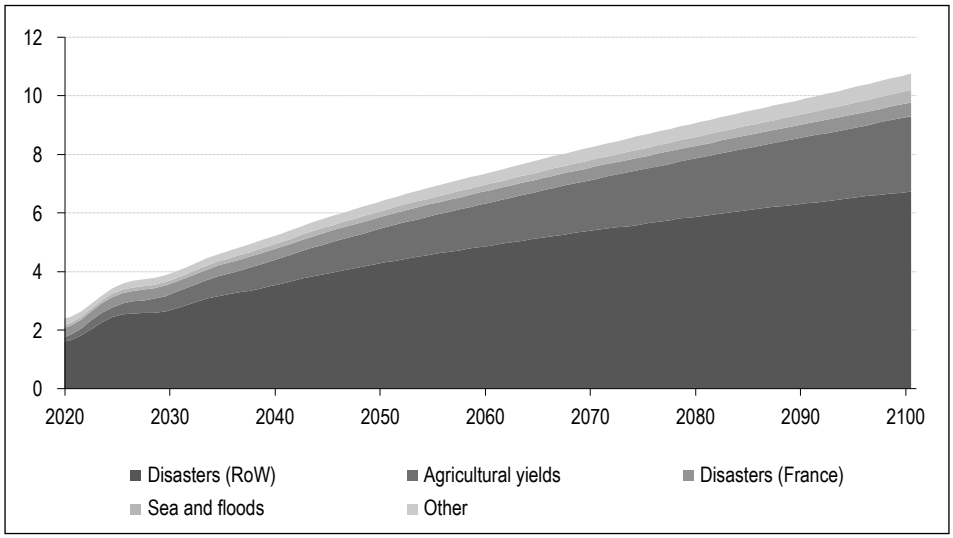
4. Assessment of the Cost of Macroeconomic Damage and Comparison with NGFS

By introducing these damage functions, calibrated for a warming scenario of +3.5°C by the end of the century (a scenario that is compatible with RCP 8.5[7]), it is possible to estimate the corresponding damage function at the aggregated level. If the temperature were to reach this level of warming, the damage of climate change could cost more than ten percentage points of annual activity compared to a scenario without climate change (Figure XIV). This counterfactual scenario is therefore fictitious, insofar as it does not include transition assumptions or costs of the damage. The contribution of the damage would be as follows:

- natural disasters occurring in the rest of the world (nearly six percentage points of activity);
- the fall in agricultural yields (three percentage points of activity);

7. *The RCP 8.5 scenario (Representative Concentration Pathway 8.5) is a scenario involving a change to the concentration of GHGs in the atmosphere, leading to an increase in radiative forcing to 8.5 W/m² in 2100.*

Figure XIV – **Macroeconomic damage function (as a % of GDP)**



Notes: Other risks include the shrinkage and swelling of clay soils, the change in energy output, the change in domestic energy demand, seasonal variations in tourism and the increase in absenteeism from work linked to the cost of illness.
Reading note: It is thought that global warming had already cost France nearly two percentage points of GDP in 2020 and would cost nearly ten percentage points of GDP in 2100 in a scenario of inaction, compared to a scenario without climate change.
Sources: ThreeME simulation combined with a global warming assumption of +3.5°C in 2100 compared to the pre-industrial era.

- direct costs of natural disasters in France (half a percentage point of activity);
- the rising sea level (half a percentage point of activity);
- finally, all other damage combined (half a percentage point of activity).

While this preponderance of trade effects is directly related to the estimate chosen outside the model and therefore remains subject to strong uncertainties, it is nevertheless consistent with the various estimates in the literature: most countries with a temperate climate could be significantly affected through trade and the risk of effects spreading (Lancesseur *et al.*, 2020).

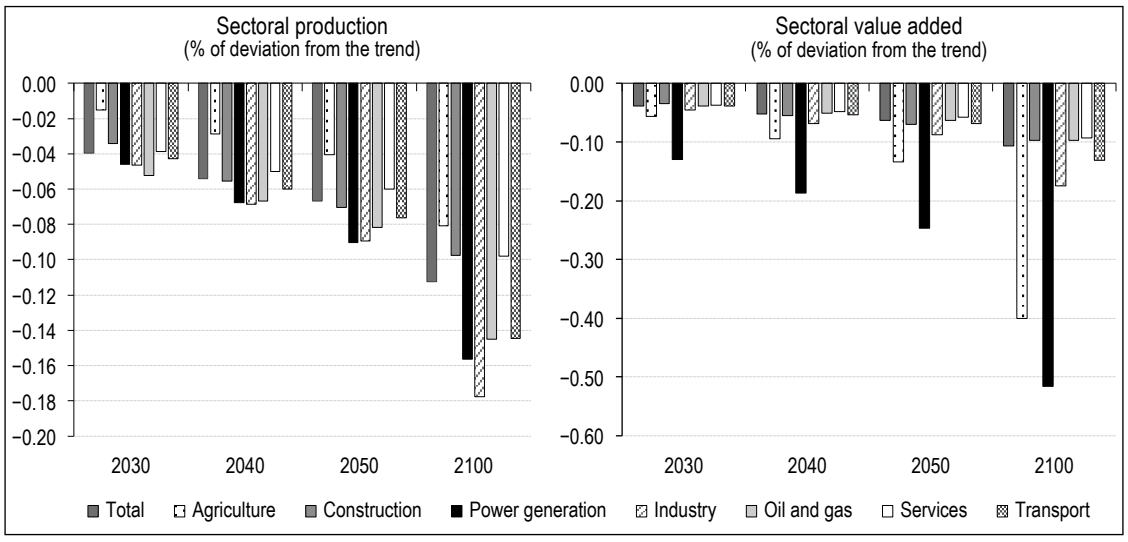
Looking at the details, activity in all economic sectors would be significantly affected (Figure XV), although the risks and effects are highly heterogeneous and have various causes. By their nature, the main sectors affected are primarily the exporting sectors (industry and services). In the absence of an adaptation policy, the agricultural sectors, as well as power generation and distribution, see their output fall at the same pace as technical performance. However, they are unable to pass on the full rise in production costs linked to inflation and therefore incur significant losses. For its part, construction is also impacted by economic decline, but benefits from the demand for repairs and reconstructions related to the damage caused to infrastructure by chronic risks and natural disasters. The fossil fuel distribution sector suffers due to the global fall in aggregate demand, and due to the reconstruction and development flows concerning old homes and buildings demolished and renovated to fit into less energy-intensive classes which, on paper, lowers the energy intensity of households.

Our estimate is currently in the high range of those in the literature. For example, the *Direction générale du Trésor* (French Treasury) identifies damage of between −2% and +5% of GDP in 2050 and between −6% and +10% in 2100 for a scenario of inaction (Lancesseur *et al.*, 2020), while macroeconomic modelling work shows very modest results (see Table A1 in the Appendix). By way of comparison, our estimate is related to damage functions that are referenced in the literature at global level and are applied in the first NGFS scenarios (NGFS, 2020). These functions are "top-down", polynomial and estimated at global level, unlike our function which is "bottom-up". The estimated impacts are among the highest identified by the NGFS (Figure XVI).

5. Application to a Scenario of Inaction

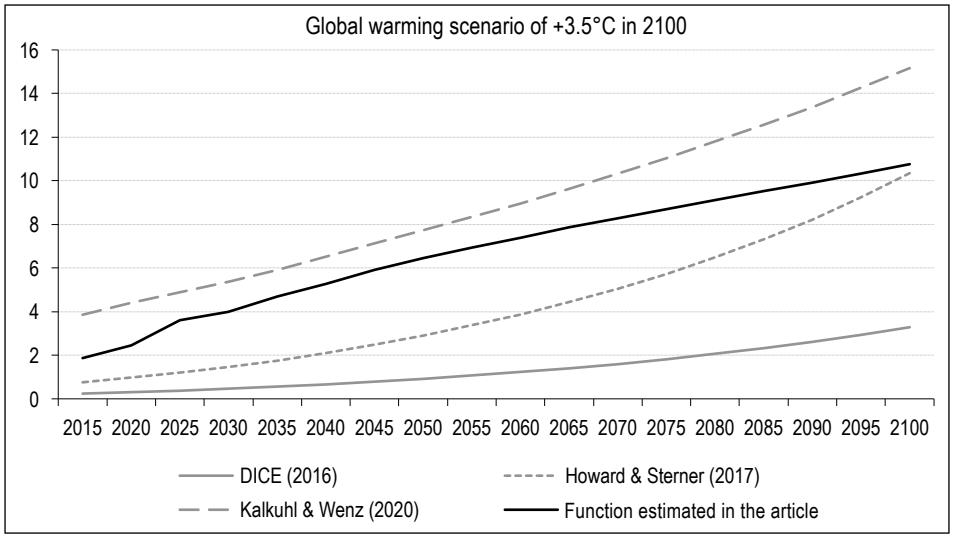
The sectoral specific damage functions proposed in Section 2 are now included in a traditional scenario analysis exercise. On this occasion, the simulation assesses the macroeconomic impact of a scenario of inaction compared to an orderly transition scenario, known as "Net Zero 2050" (NZ50). In order to construct these scenarios, conservative macroeconomic assumptions are applied from ADEME's work on transition risks (Boitier *et al.*, 2023) without, however, attempting to reproduce the granular nature of the climate policies assessed in the SNBC scenarios (Callonnec & Cancé, 2022).

Figure XV – **Sectoral impacts of climate change damage in a scenario of inaction**



Sources: ThreeME simulation combined with a global warming assumption of +3.5°C in 2100 compared to the pre-industrial era.

Figure XVI – **Comparison with other macroeconomic damage functions (as a % of GDP)**



Sources: NGFS database, Phase I (2020).

5.1. Shared Growth Path

Constant gains in productivity are assumed over the period, amounting to 1% per year in France and the rest of the world, which is the central assumption of the scenarios used by the *Conseil d'orientation des retraites* (2021) – French Pension Advisory Council. In the long-term, the national economy grows at the pace set by the Solow growth path (1956), which is defined by the sum of gains in productivity and changes in the labour force. Similarly, global demand grows at a similar pace, albeit slightly faster as a result of more dynamic population projections in the rest of the world.

5.2. Transition Assumptions

The assumptions adopted in the orderly transition scenario include:

- public action which translates into the linear and anticipated rise in real carbon prices up to $€_{2020}/900/tCO_2$ in 2050,[8] a level close to the shadow price of French carbon (France Stratégie, 2019),[9] with equitable income redistribution between companies and households (50/50);
- an energy mix that is consistent with NGFS assumptions and French climate strategies, anticipating a strong development of biofuel and biogas production, a phasing out of coal in power generation and a limited fall in the share of nuclear power in favour of renewable energies (wind and solar);
- the energy prices projected by the International Energy Agency (IEA, 2021), anticipating a modest rise in real fossil fuel prices (oil, natural gas and coal) linked with continued moderation of demand; a fall in demand for fossil fuels;
- foreign trade assumptions that are consistent with the NGFS scenarios, marked by a global phenomenon of relocation and a moderation of global demand toward France, as well as more dynamic inflation of foreign prices due to the lower carbon intensity of production in France.

5.3. Climate Assumptions

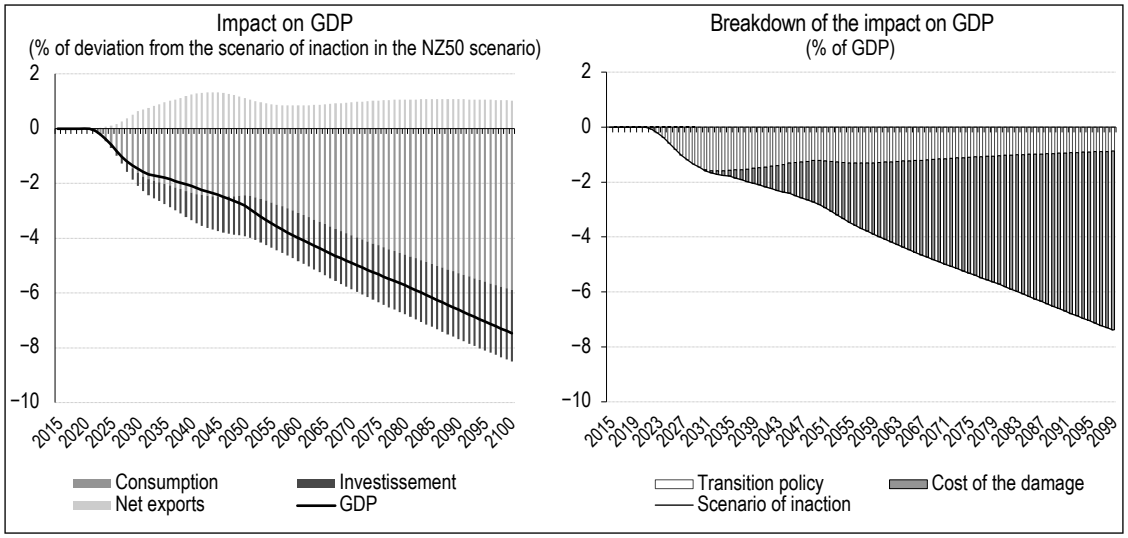
The temperature scenarios are derived from NGFS simulations based on the various integrated assessment models (in this case, the REMIND-MAgPIE model).[10] Since the ThreeME model is unable to produce climate scenarios itself, it remains dependent on the temperature trajectories associated with the NGFS narratives. These are therefore applied to the model "exogenously". The orderly transition scenario ensures that the temperature rise is limited to +1.5°C above its level in the pre-industrial era, while in the scenario of inaction, the global temperature rise is +3.5°C by the end of the century, as assumed by the NGFS "Hothouse World" scenario (NGFS, 2020).

8. In 2024, the carbon component (which is incorporated into domestic consumption taxes on fossil fuels and is proportional to their carbon content) was €44.6/tCO_2.

9. The shadow price of carbon represents the price per tonne of carbon equivalent (CO_2e) emitted and makes it possible to achieve the French targets in the fight against global warming. This value is used by the public authorities to guide public policy, particularly in the areas of investments, taxation and environmental regulation.

10. REMIND-MAgPIE is a so-called "IAM" that allows the assessment of the climate impact of policies aimed at fighting global warming on changes in temperatures (Luderer et al.*, 2015).*

Figure XVII – **Macroeconomic impact of the scenario of inaction**



Sources: Modified ThreeME model incorporating supply constraints and damage functions.

The scenario of inaction presupposes the absence of any new transition policy after 2022 and the energy mix being kept as it is today. The macroeconomic impact of political inaction is reflected in the absence of the benefits observed in the orderly transition scenario. However, the temperature trajectories diverge significantly from 2030 and the cost of the additional damage observed then gradually increases. By the end of the century, the scenario of inaction would cost nearly seven percentage points of GDP annually, of which one percentage point is linked to the freezing of transition policies and six percentage points are due to the costs of additional damage (Figure XVII and Figure XVIII).

Sectoral damage essentially follows the costs modelled in the creation of the damage function (Section 2) and represents nearly six percentage points of GDP. Due to its nature, the oil and gas sector broadly benefits and output in all other sectors falls (Figure XVII and Figure XVIII). The closed macroeconomic model allows for the modelling of negative spillover effects; for example, rising agricultural prices affect prices, wages, export competitiveness and employment, which has a negative impact on activity and income and affects other sectors. Moreover, since food is an unavoidable form of consumption, rising agricultural prices force household consumption away from other sectors.

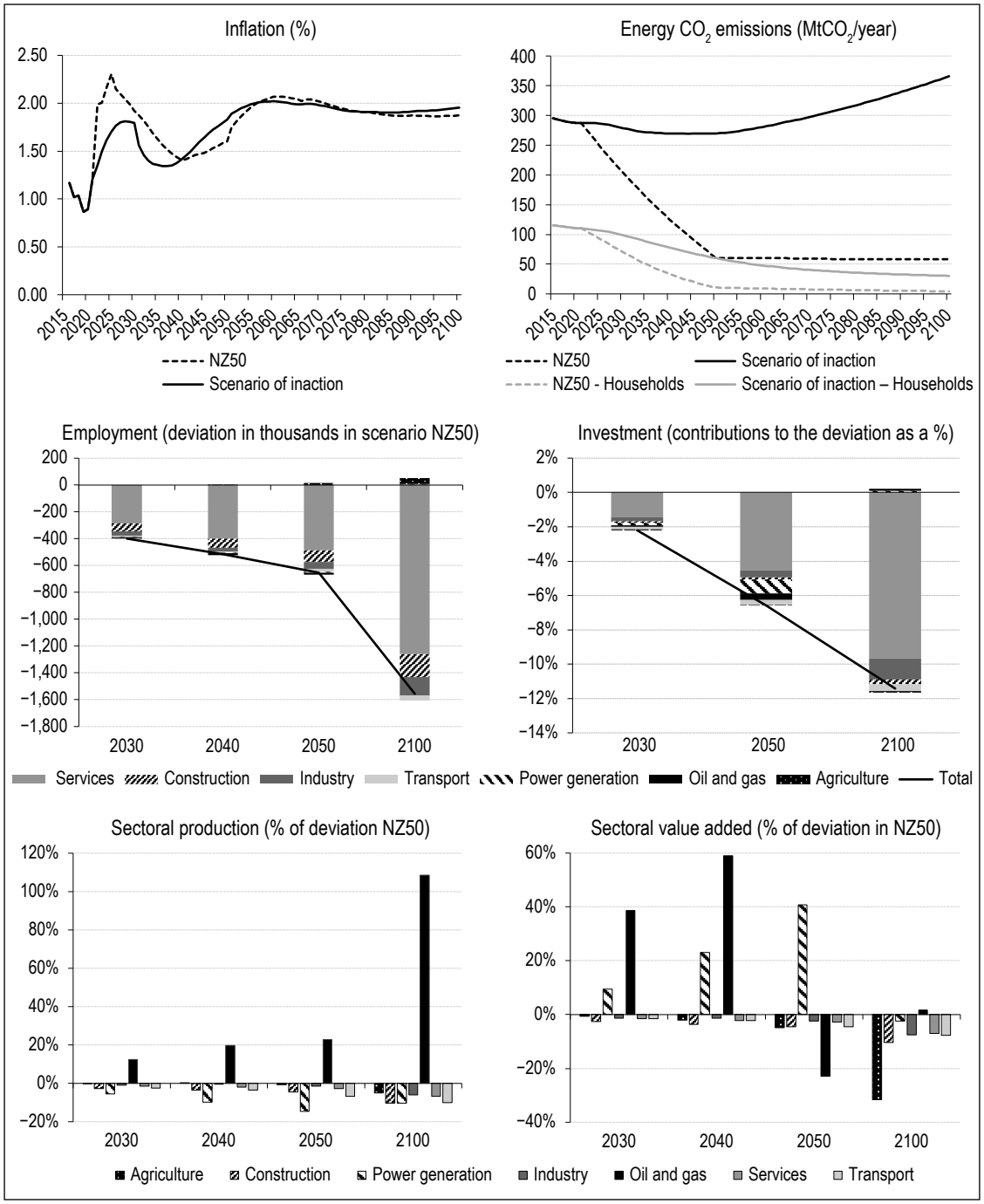
In the short-term, inflation is lower than in the transition scenario, but becomes higher once the main climate actions (of the transition scenario) are implemented. Job losses and falling investment are mainly concentrated in the services sector, although the latter is not directly exposed to most climate risks. On the one hand, the increase in the price of energy and food leads to the crowding out of purchases of services; on the other hand, any reduction in consumption or investment has a negative knock-on effect on the whole economy, including the tertiary sector, which accounts for nearly 80% of it.

* *
*

By creating sectoral damage functions, we assess and compare the monetary consequences of damage using the same economic indicator (GDP) and take into account the interaction effects and the dynamic effects of that damage. This work is not immune to certain limitations, which are largely related to the uncertainties regarding the extent of the damage: difficulty in modelling the medium- and long-term effects of natural disasters, in modelling the spread of physical risks in the rest of the world and in modelling the damage to assets and its consequences on stakeholders. The projections are still based on an assumption of exogenous growth and this is unrealistic in climate scenarios that see a disruption to the means of production.

Neo-Keynesian-inspired models also remain limited in terms of assessing the physical limits and concrete effects of a shortage, which would have the effect of rationing for stakeholders, for example, but which go beyond the scope of macroeconomic models (where the equilibrium is ultimately ensured by variations in quantity).

Figure XVIII – **Detailed sectoral impact of the scenario of inaction**



Sources: Modified ThreeME model incorporating supply constraints and damage functions.

Climate change is not only a threat to the performance of the factors and production costs. It can be accompanied by a sharp reduction in production in certain sectors or locations. That is why we have proposed changes to the ThreeME model. Simulations performed before and after modification of the agricultural and energy blocks of the model show significant differences in results. The impact of the damage on macroeconomic aggregates is significantly higher when a quantitative constraint with high price flexibility is introduced into the model. This is the first time, to our knowledge, that a macroeconomic model has tried to incorporate constraints on domestic production (with demand then having to be met by more expensive imports), to determine pricing methods by sector (by production costs or market balances) and to determine the nature of goods consumed according to household preferences (basic necessities or not).

Exporting sectors are the main victims of the effects of climate change in this instance, and

damage in the agricultural and power generation sectors could also expose the entire economy to a systemic recessionary effect. Shortages would fuel higher market prices for food and electricity, increasing national dependence on imports (assuming there is no widespread global shortage). As such, these two sectors would be the main sources of a sustained increase in inflation in France; however, the activity of all sectors would also be negatively impacted by a fall in demand since it depends on disposable income "after unavoidable consumption". Other sectors could limit their losses in part by increasing their sale prices. This would be more difficult for sectors that are subject to strong competition and are price takers, because they cannot pass on inflation in their costs via their sale prices. This could cause widespread failures.

The introduction of damage functions into the models could make it possible to broaden the scope of the transition scenarios and better reflect the economic consequences of a lack of ambition in relation to transition actions at global level. Although the risks remain subject to very broad uncertainties and do not take into account extreme events and their consequences (tipping points and feedback loops), developing such tools is essential in the context of scenario analysis and new financial climate stress tests (Jacquetin, 2021). It would be a good thing for them to be re-assessed and clarified as the state of the art and modelling tools continue to develop.

The domestic impacts that we have estimated are currently based mainly on the damage that has an impact through foreign trade and they are surely underestimated, especially given that they do not take into account non-monetary costs (biodiversity) and the costs of adapting to climate change (management of heat waves or forest fires and management of migratory flows linked to climate change). Some potentially massive impacts linked to chronic risks in the rest of the world will also need to be clarified. Multi-region models would then be more relevant to "connect" trade flows with the consequences of damage estimated on a region by region basis, which would help to broaden the "national" scope of forecasting work to a wider field.

Furthermore, all shocks are introduced here in the form of gradual and linear changes during the transition period, following the example of the first "climate stress test" exercise carried out by the Banque de France (Allen *et al.*, 2020). While chronic risks should come to fruition in the long-term, intense episodes are already increasing and threatening the economy in the short-term (the summer drought in 2019 and the period of freezing temperatures in April 2021 in the Rhône-Alpes region). Anticipating the consequences of such disasters can go beyond the traditional macroeconomic framework, which continues to kick the can down the road in relation to climate risks until some far-off point in the future. □

BIBLIOGRAPHY

Aaheim, A., Amundsen, H., Dokken, T. & Wei, T. (2012). Impacts and adaptation to climate change in European economies. *Global Environmental Change*, 22(4), 959–968.
https://www.sciencedirect.com/science/article/abs/pii/S0959378012000672

ADEME (2016). Mix électrique 100 % renouvelable ? Analyses et optimisations. Synthèse technique et synthèse de l'évaluation macro-économique.
https://librairie.ademe.fr/urbanisme-et-batiment/2881-mix-electrique-100-renouvelable-analyses-et-optimisations.html

ADEME (2020). Évaluation d'un scénario SNBC 2 sans hausse de taxe carbone et sans prix-fictif ad hoc. *Note complémentaire au rapport du Haut Conseil pour le Climat*.
https://www.hautconseilclimat.fr/wp-content/uploads/2020/07/valuation-dun-scenario-snbc2-sans-hausse-de-taxe-carbone-et-sans-prix-fictifs-ad-hoc-ademe.pdf

ADEME (2022a). État des lieux et étude prospective sur les impacts du changement climatique pour le bâtiment aux horizons 2050 et 2100. Se préparer, s'organiser et agir collectivement. *ADEME Expertises*.
https://librairie.ademe.fr/changement-climatique-et-energie/5969-etat-des-lieux-et-etude-prospective-sur-les-impacts-du-changement-climatique-pour-le-batiment-aux-horizons-2050-et-2100.html

ADEME (2022b). Transitions 2050 - Feuilleton : Les effets macroéconomiques. *Horizons*. https://librairie.ademe.fr/cadic/6940/feuilleton_macroeconomie_transitions2050_ademe.pdf

Allen, T., Dees, S., Boissinot, J., Caicedo Graciano, C., Chouard, V., Clerc, L., De Gaye, A., Devulder, A., Diot, S., Lisack, N., Pegoraro, F., Rabaté, M., Svartzman, R. & Vernet, L. (2020). Climate-Related Scenarios for Financial Stability Assessment: An Application to France. Banque de France*, Working Paper Series* N° 774. https://doi.org/10.2139/ssrn.3653131

Bardaji, J., Campagne, B., Khder, M.-B., Lafféter, Q., Simon, O., Dufernez, A.-S., Elezaar, C., Leblanc, P., Masson, E. & Partouche, H. (2017). Le modèle macroéconométrique Mésange : réestimations et nouveautés. Insee, *Document de travail* N° G2017/04. https://www.insee.fr/fr/statistiques/2848300

Berrittella, M., Bigano, A., Roson, R. & Tol, R. (2004). A General Equilibrium Analysis of Climate Change Impacts on Tourism. *FEEM Working Papers* N° 127.04. https://doi.org/10.2139/ssrn.609742

Bigano, A., Bosello, F., Roson, R. & Tol, R. (2006). Economy-Wide Estimates of the Implications of Climate Change: A Joint Analysis for Sea Level Rise and Tourism. *Social Science Research Network*. https://doi.org/10.2139/ssrn.944480

Boitier, B., Le Mouël, P., Zagamé, P., Callonnec, G., Garnero, M., Jacquetin, F., Allen, T., Dees, S., De Gaye, A., Lisack, N., Couix, Q., Dang, W. & Ghersi, F. (2023). *Risques de transition : une analyse multi-modèles pour la France*. ADEME Expertises. https://librairie.ademe.fr/recherche-et-innovation/6196-risques-de-transition-analyse-multi-modeles-pour-la-france.html

Bosello, F., Eboli, F. & Pierfederici, R. (2012). Assessing the Economic Impacts of Climate Change. *Social Science Research Network*. https://doi.org/10.2139/ssrn.2004966

Bosello, F., Lazzarin, M., Roson, R. & Tol, R. (2004a). Economy-Wide Estimates of the Implications of Climate Change: Sea Level Rise. *FEEM Working Papers* N° 96.04. https://doi.org/10.2139/ssrn.556351

Bosello, F., Roson, R. & Tol, R. (2004b). Economy-wide Estimates of the Implications of Climate Change: Human Health. *Ecological Economics*, 58(3), 579–591. https://doi.org/10.1016/j.ecolecon.2005.07.032

Callonnec, G. & Cancé, R. (2022). Évaluation macroéconomique de la Stratégie nationale bas-carbone (SNBC2) avec le modèle ThreeME. *Document de Travail*. https://www.ecologie.gouv.fr/sites/default/files/documents/%C3%89valuation%20macro%C3%A9conomique%20de%20la%20Strat%C3%A9gie%20nationale%20bas-carbone_0.pdf

Callonnec, G., Landa Rivera, G., Malliet, P., Saussay, A. & Reynès, F. (2016). Les propriétés dynamiques et de long terme du modèle ThreeME - Un cahier de variantes. *Revue de l'OFCE*, 149, 47–99. https://ideas.repec.org/a/cai/reofsp/reof_149_0047.html

Carney, M. (2015). *Breaking the tragedy of the horizon – climate change and financial stability*. Speech by Mr Mark Carney, Governor of the Bank of England. London. https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability

CRED (2021). Missing data on economic losses variables from EM-DAT. *Cred Crunch*, 63. https://www.preventionweb.net/publication/cred-crunch-issue-no-63-july-2021-missing-data-economic-losses-variables-em-dat

Ciscar Martinez, J., Feyen, L., Soria Ramirez, A., Lavalle, C., Raes, F., Perry, M., Nemry, F., Demirel, H., Rózsai, M., Dosio, A., Donatelli, M., Srivastava, A., Fumagalli, D., Niemeyer, S., Shrestha, S., …, & Ibarreta Ruiz, D. (2014). Climate Impacts in Europe - The JRC PESETA II Project. *JRC Scientific and Policy Reports*. https://doi.org/10.2791/7409

Ciscar, J.-C., Iglesias, A., Feyen, L., Szabó, L., Van Regemorter, D., Amelung, B., Nicholls, R., Watkiss, P., Christensen, O.B., Dankers, R., Garrote, L., Goodess, C.M., Hunt, A., Moreno, A., Richards, J. & Soria, A. (2011). Physical and economic consequences of climate change in Europe. *PNAS*, 108(7), 2678–2683. https://doi.org/10.1073/pnas.1011612108

Conseil d'orientation des retraites (2021). Quelles sont les raisons du ralentissement de la croissance de la productivité ? Secrétariat général du Conseil d'orientation des retraites, *Document de travail* N° 4. Séance plénière du 25 novembre 2021 à 10h00 « Choix des hypothèses économiques de long terme ». https://www.cor-retraites.fr/sites/default/files/2021-11/Doc4_Raisons%20du%20ralentissement%20de%20la%20prod.pdf

De Cian, E. & Sue Wing, I. (2019). Global Energy Consumption in Warming Climate. *Environmental and Resource Economics*, 72, 365–410. https://doi.org/10.1007/s10640-017-0198-4

Deke, O., Hooss, K., Kasten, C., Klepper, G. & Springer, K. (2001). Economic Impact of Climate Change: Simulations with a Regionalized Climate-Economy Model. *Kiel Working Papers*, 1065. https://ideas.repec.org/p/zbw/ifwkwp/1065.html

Delahais, A. & Robinet, A. (2023). Coût de l'inaction climatique face au changement climatique en France : que sait-on ? France Stratégie, *Document de travail* N° 2023-01.
https://www.strategie.gouv.fr/publications/cout-de-linaction-face-changement-climatique-france-sait

Dellink, R., Hwang, H., Lanzi, E. & Chateau, J. (2017). International trade consequences of climate change. *OECD Trade and Environment Working Papers* N° 2017/01. https://doi.org/10.1787/9f446180-en

Dietz, S., van der Ploeg, F., Rezai, A. & Venmans, F. (2020). Are Economists Getting Climate Dynamics Right and Does It Matter? *CESifo Working Papers* N° 8122. https://doi.org/10.2139/ssrn.3545718

Eboli, F., Parrado, R. & Roson, R. (2009). Climate Change Feedbacks on Economic Growth: Explorations with a Dynamic General Equilibrium Model. *IEFE Working Paper*s N° 29. https://doi.org/10.2139/ssrn.1544260

ECB (2022). 2022 Climate Stress Test.
https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climate_stress_test_report.20220708~2e3cc0999f.en.pdf

France Assureurs (2021). Impact du changement climatique sur l'assurance à l'horizon 2050.
https://www.franceassureurs.fr/wp-content/uploads/2022/09/vf_france-assureurs_impact-du-changement-climatique-2050.pdf

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

Gosling, S. N., Zaherpour, J. & Ibarreta, D. (2018). PESETA III: Climate change impacts on labour productivity. *Publications Office of the European Union*. https://doi.org/10.2760/07911

Gourdier, S. & Plat, E. (2018). Impact du changement climatique sur la sinistralité due au retrait-gonflement des argiles. *Journées Nationales de Géotechnique et Géologie de l'Ingénieur (JNGG)*.
https://brgm.hal.science/hal-01768395

Howard, P. & Sterner, T. (2017). Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates. *Environmental and Resource Economics*, 68, 197–225. https://doi.org/10.1007/s10640-017-0166-z

IEA (2021). *World Energy Outlook*. https://www.iea.org/reports/world-energy-outlook-2021

IPCC (2023). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009325844

Jacob, D., Kotova, L., Teichmann, C., Sobolowski, S., Vautard, R., Donnelly, C., Koutroulis, A.G., Grillakis, M.G., Tsanis, I.K., Damm, A., Sakalli, A. & van Vliet, M.T.H. (2018). Climate Impacts in Europe Under +1.5°C Global Warming. *Earth's Future*, 6, 264–285. https://doi.org/10.1002/2017EF000710

Jacquetin, F. (2021). *Stress-tests climatiques par scénarios : de l'analyse des risques à la modélisation*. ADEME Expertises.
https://librairie.ademe.fr/changement-climatique-et-energie/4218-stress-tests-climatiques-par-scenarios-de-l-analyse-des-risques-a-la-modelisation.html

Kalkuhl, M. & Wenz, L. (2020). The Impact of Climate Conditions on Economic Production. *Journal of Environmental Economics and Management*, 103. https://doi.org/10.1016/j.jeem.2020.102360

Kitous, A. & Després, J. (2018). Assessment of the impact of climate change on residential energy demand for heating and cooling. *JRC Science for Policy Reports*. https://doi.org/10.2760/96778

Kompas, T., Pham, V. H. & Nhu, T. (2018). The Effects of Climate Change on GDP by Country and the Global Economic Gains from Complying with the Paris Climate Accord. *Earth's Future*, 6, 1153–1173.
https://doi.org/10.1029/2018EF000922

Lafakis, C., Ratz, L., Fazio, E. & Cosma, M. (2019). The Economic Implications of Climate Change. *Moody's Analytics*.
https://www.moodysanalytics.com/-/media/article/2019/economic-implications-of-climate-change.pdf

Lancesseur, N., Labrousse, C., Valdenaire, M. & Nakaa, M. (2020). Impact économique du changement climatique : revue des méthodologies, d'estimation, résultats et limites. DG Trésor, *Documents de travail* N° 2020/4.
https://www.tresor.economie.gouv.fr/Articles/2020/07/10/document-de-travail-n-2020-4-impact-economique-du-changement-climatique-revue-des-methodologies-d-estimation-resultats-et-limites

Luderer, G., Leimbach, M., Bauer, N., Kriegler, E., Baumstark, L., Bertram, C., Giannousakis, A., Hilaire, J., Klein, D., Levesque, A., Mouratiadou, I., Pehl, M., Pietzcker, R., Piontek, F., Roming, N., Schultes, A., Schwanitz, V. J. & Strefler, J. (2015). Description of the REMIND Model (Version 1.6).
https://doi.org/10.2139/ssrn.2697070

Missirian, A. & Schlenker, W. (2017). Asylum applications respond to temperature fluctuations. *Science*, 358(6370), 1610–1614. https://doi.org/10.1126/science.aao0432

NGFS (2020). *NGFS Climate Scenarios for central banks and supervisors.* https://www.ngfs.net/en/ngfs-climate-scenarios-central-banks-and-supervisors

NGFS (2021). *Climate Scenarios Database - Technical Documentation V2.2*. https://pure.iiasa.ac.at/id/eprint/17511

Nordhaus, W. (1992). An Optimal Transition Path for Controlling Greenhouse Gases. *Science.* 258(5086), 1315–1319. https://doi.org/10.1126/science.258.5086.1315

Nordhaus, W. (2016). Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies. *Cowles Foundation Discussion Papers* N° 2057. https://doi.org/10.2139/ssrn.2881947

Nordhaus, W. & Moffat, A. (2017). A Survey of Global Impacts of Climate Change: Replication, Survey Methods, and a Statistical Analysis. *Cowles Foundation Discussion Papers* N° 2096. https://doi.org/10.2139/ssrn.3009427

OCDE (2015). *Les conséquences économiques du changement climatique*. Paris: OECD Publishing. https://doi.org/10.1787/9789264261082-fr

ONERC (2009). *Changement climatique – Coûts des impacts et pistes d'adaptation.* Paris: La Documentation française. https://www.vie-publique.fr/files/rapport/pdf/094000463.pdf

Paci, D. (2014). Human Health Impacts of Climate Change in Europe. *JRC Technical Reports*. https://doi.org/10.2791/64481

Pindyck, R. S. (2017). The Use and Misuse of Models of Climate Policy. *Review of Environmental Economics and Policy*, 11(1), 100–114. https://doi.org/10.3386/w21097

Reilly, J., Paltsev, S., Strzepek, K., Selin, N., Cai, Y., Nam, K.-M., Monier, E., Dutkiewicz, S., Scott, J., Webster, M. & Sokolov, A. (2012). Valuing climate impacts in integrated assessment models: the MIT IGSM. *Climatic Change*, 117, 561–573. https://doi.org/10.1007/s10584-012-0635-x

Reynès, F., Callonnec, G., Saussay, A., Landa, G., Malliet, P., Guéret, A., Hu, J., Hamdi-Chérif, M., Gouëdard, H. (2021). ThreeME Version 3 Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy Policy - A full description. https://www.threeme.org/_files/ugd/e33ac5_0fb7e9f40b3e413f87bbc132822dc816.pdf

Roson, R. & van der Mensbrugghe, D. (2010). Climate Change and Economic Growth: Impacts and Interactions. University Ca' Foscari of Venice, *Dept. of Economics Research Paper Series* N° 07_10. https://doi.org/10.2139/ssrn.1594708

Roson, R. & Sartori, M. (2016). Estimation of climate change damage functions for 140 regions in the GTAP database. *Journal of Global Economic Analysis*, 1(2), 78–115. https://doi.org/10.21642/JGEA.010202AF

RTE (2022). Futurs énergétiques 2050. Rapport complet. https://rte-futursenergetiques2050.com/documents

Schleypen, J., Dasgupta, S., Borsky, S., Jury, M., Ščasný, M. & Bezhanishvili, L. (2019). D2.4 Impacts on Industry, Energy, Services, and Trade. Deliverable of the H2020 COACCH project. https://www.coacch.eu/wp-content/uploads/2020/05/D2.4_after-revision-to-upload.pdf

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70(1), 65–94. https://doi.org/10.2307/1884513

Spandre, P., François, H., Verfaillie, D., Pons, M., Vernay, M., Lafaysse, M., George, E. & Morin, S. (2019). Winter tourism under climate change in the Pyrenees and the French Alps: relevance of snowmaking as a technical adaptation. *The Cryosphere*, 13(4), 1325–1347. https://doi.org/10.5194/tc-13-1325-2019

TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. https://www.fsb-tcfd.org/recommendations

Tobin, I., Greuell, W., Jerez, S., Ludwig, F., Vautard, R., van Vliet, M. & Breon, F.-M. (2018). Vulnerabilities and resilience of European power generation to 1.5 °C, 2 °C and 3 °C warming. *Environmental Research Letters*, 13(4). https://doi.org/10.1088/1748-9326/aab211

Vousdoukas, M., Mentaschi, L., Voukouvalas, E. & Feyen, L. (2019). PESETA III – Task 8: Coastal Impacts. *JRC Technical Reports*. https://doi.org/10.2788/204754

WWF France (2021). Dérèglement climatique. Le monde du sport à +2°C et +4°C. Rapport. https://www.wwf.fr/vous-informer/actualites/dereglement-climatique-sport

Zhao, C., Bing, L., Piaoa, S., Wang, X., Lobell, D.B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J.-L., Elliot, J., Ewert, F., Janssens, I.A., Li, T., Lin, E., Liu, Q., Martre, P., Müller, C., Peng, S., Peñuelas, J., Ruane, A.C., Wallach, D., Wang, T., Wu, D., Liu, Z., Zhu, Y., Zhu, Z.& Asseng, T. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *PNAS*, 114(35), 9326–9331. https://doi.org/10.1073/pnas.1701762114

APPENDIX

Table A1 – **Review of the macroeconomic impacts of physical risks in europe taken from the "bottom-up" approach**

Study	Model	Scenario	Damage studied	Macroeconomic effects
Deke *et al.* (2001)	DART A global dynamic multi-region and multi-sector CGE model	Scenario B (IPCC II) "Back-to-Coal" Scenario	Agricultural yields Sea level	+0.5% of agricultural production −0.1% of other production 2 percentage points of GDP to be devoted to adaptation
Bosello *et al.* (2004b)	GTAP-EF A global static multi-region and multi-sector CGE model	Scenario B1 (IPCC II)	Vector-borne diseases	−0.7 of a percentage point of GDP
Bosello *et al.* (2004a)	GTAP-EF	Scenario B1 (IPCC II)	Sea level	−0.001 of a percentage point of GDP
Berrittella *et al.* (2004)	GTAP-EF	Scenario B1 (IPCC II)	Tourism	−0.1 of a percentage point of GDP
Bigano *et al.* (2006)	GTAP-EF	Scenario B1 (IPCC II)	Sea level Tourism	−0.1 of a percentage point of GDP
Eboli *et al.* (2009)	ICES A global dynamic multi-region and multi-sector CGE model	Scenarios A1B, A2, B1 (IPCC 2007)	Health and productivity Agricultural yields Tourism Energy demand Sea level	+0.2 of a percentage point of GDP
Roson & van der Mensbrugghe (2010)	ENVISAGE A global dynamic multi-region and multi-sector CGE model with a climate module	Endogenous global warming scenario (+4.8°C in 2100)	Sea level Agricultural yields Water availability Health Tourism Energy demand	+0.5 of a percentage point of GDP (2050) +1.2 of a percentage point of GDP (2100)
Ciscar *et al.* (2011)	GEM-E3 Europe	4 scenarios up to 2080 2.5°C 3.9°C 4.1°C 5.4°C	Agricultural yields Sea level Coastal flooding River flooding Tourism Health	< −1 percentage point of GDP in 2080 (from €20 billion (2.5°C) to €65 billion (5.4°C) in GDP losses)
Bosello *et al.* (2012)	ICES	Scenario A1B (IPCC)	Sea level Tourism Agricultural yields Energy demand River floods Labour productivity Forest productivity	−0.15 of a percentage point of GDP
Aaheim *et al.* (2012)	CGE model	Scenarios +2°C and +4°C	Extreme events Agricultural and forestry yields Power generation Energy demand Sea level Health Tourism	Up to −0.7 of a percentage point of GDP (2080)
Ciscar *et al.* (2014)	GEM-E3 A European dynamic multi-region and multi-sector CGE model	Scenario A1B (IPCC)	Agricultural yields Energy demand Forest fires Sea level Tourism Health	−1.1 percentage points of GDP
OCDE (2015)	ENV-Linkages A global dynamic multi-region and multi-sector CGE model	Scenario A1B (IPCC) and RCP 8.5	Extreme events Agricultural and forestry yields Sea level Health Energy demand Tourism	−0.5 of a percentage point of GDP (2060)

➔

Table A1 – *(contd.)*

Study	Model	Scenario	Damage studied	Macroeconomic effects
Roson & Sartori (2016)	Damage functions based on GTAP	Temperature rise of +3°C	Sea level Agricultural yields Labour productivity Health Tourism	France 0 percentage points of GDP +0.0002 of a percentage point of GDP 0 percentage points of GDP +0.0501 of a percentage point of GDP −0.3515 of a percentage point of GDP **−0.30 of a percentage point of GDP in total**
Kompas *et al.* (2018)	GTAP-INT Intertemporal global multi-region and multi-sector general equilibrium model	RCP scenarios 2.6/4.5/6.0/8.5	Agricultural yields Sea level Labour productivity Tourism Energy demand Water stress	From −0.139 of a percentage point of GDP (+1°C) to −0.662 of a percentage point of GDP (+4°C)
Lafakis (2019)	Moody's Analytics Global Macroeconomic Model Multi-regional structural model	RCP scenarios 2.6/4.5/6.0/8.5	Sea level Health Labour productivity Agricultural yields Tourism Energy demand	France +0.1 of a percentage point of GDP

Notes: Overall, impacts in the scenarios are assessed against a theoretical counterfactual scenario "without climate change". The macroeconomic impacts are presented for 2050 for Europe or similar groups (the EU, western Europe or southern Europe) including France. The assessments are sometimes more granular and extend until 2100 or are specifically for France.

COMMENT

The Lack of Interest in Economics for the Challenge of the Century

Xavier Timbeau*

Abstract – The publication of a thematic section on the environment gives us an opportunity to assess the position of environmental issues within economics. On one level, vacancies for economists published by the American Economic Association (the Job Openings for Economists (JOE) Network) suggest that the net increase in vacancies for positions related to the environment comes from establishments that are not central to the academic economy and that such vacancies specifically labelled as relating to the "environment" tend to decrease in number when looking solely at departments of economics. The proportion of articles published in *Economie et Statistique / Economics and Statistics* dedicated to the environment is fairly similar to the low rates seen in terms of vacancies. It is hoped that these new publications will reverse these trends. The three articles published provide important insights into the main areas that applied research in economics must address to be of use in guiding public policies; however, there remains a considerable amount of research work to be carried out.

JEL: A11, A14, Q50
Keywords: environment, climate change mitigation, adaptation to climate change, economics, empirical research

* *OFCE and Sciences Po Paris.* Correspondence: *xavier.timbeau@sciencespo.fr*

Translated from: "Le peu d'intérêt de la science économique pour le défi du siècle".
The opinions and analyses presented in this article are those of the author(s) and do not necessarily reflect their institutions' or INSEE's views.

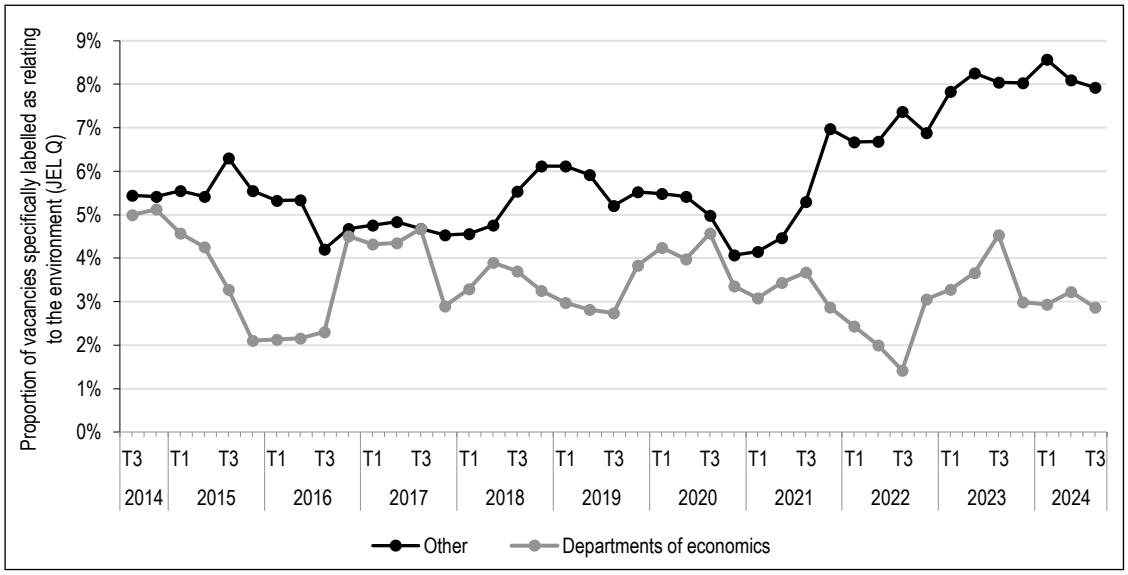
Citation: Timbeau, X. (2024). The Lack of Interest in Economics for the Challenge of the Century. *Economie et Statistique / Economics and Statistics*, 543, 65–74. doi: 10.24187/ecostat.2024.543.2119

Is the Environment Overlooked by Economists?

Environmental economics has long been considered a peripheral discipline of economics. This is one of the many symptoms of the trend in economics (Heckman & Moktan, 2020) which, through the pressure to "publish or perish", guides research, especially research by young researchers, towards what is most profitable in terms of their careers and not in terms of scientific interest. In addition to this pressure on individuals through misguided incentives, there are institutional choices and, through a certain conservative outlook, departments of economics around the world have been slow to address environmental issues. One can only agree with the judgment of Polasky *et al.* (2019), in whose opinion environmental economics is not a core economic discipline. Until recently, there have been few publications in the main economic journals with the keyword "environment" (JEL Q code) and it is those journals that determine careers. Major departments of economics often overlook this issue and advertise few vacancies specifically labelled as relating to environmental issues. It is instead schools of public affairs, departments of agriculture and institutes dedicated to the environment that actually take on the economists, pushing environmental research to the periphery of economics.

The figure shows the proportion of vacancies in the field of environmental economics on the JOE Network, which is now the central repository for most of the vacancies in the academic world for economists, over the last ten years. This graph makes a distinction between, on the one hand, departments of economics (identified in a manner that can lead to some being overlooked, meaning false negatives, however this has a minor impact on the proportions) and, on the other hand, other institutions, whether departments or schools of public affairs, departments of agriculture, environmental institutes (such as the Grantham Research Institute at LSE) or international institutions (e.g. the World Bank, the IMF or the OECD). On the basis of this definition, departments of economics account for just over a quarter of vacancies. No distinction is made based on the nature of the position (assistant professor, post-doctoral, thesis or other), nor its duration. The date chosen for the graph is the date on which the position became vacant, rather than the date on which the vacancy was published. We simply quantify the content of the positions through the JEL codes associated with them without trying to better describe the nature of these vacancies. In addition, some vacancies could be for jobs in the environment sector, even though the JEL Q code is not included (such as an econometrician role in an institute dedicated to the environment, for example). A great deal could undoubtedly be learnt from more in-depth work but, in a preliminary manner, this analysis

Figure – **Proportion of vacancies in the environment sector 2014–2024**



Notes: The date used for vacancies is the date on which the position became vacant. The percentage is calculated as the number of vacancies tagged with a JEL Q code out of the total number of vacancies as a rolling average over four quarters. Departments of economics are identified by the fields jp_division and jp_department, which equate to "*Department of Economics*" or "*Economics*". Of 18,500 vacancies published between the third quarter of 2014 and mid-August 2024, 4,700 are in departments of economics, on the basis of this definition, equating to 25.4%.
Sources: JOE (Job Openings for Economists) Network, American Economic Association, www.aeaweb.org.

focused solely on the data published by the American Economic Association sheds light on some trends.

Between 2014 and 2024, vacancies in the environment sector represented just over 5.5% of all vacancies, but this proportion was 3.5% in departments of economics. After 2020, vacancies in the environment sector increase sharply, but not in departments of economics where, if there is any trend, it is one of a very slight decrease, with the proportion reaching just over 2% for 2024.

This is not to say that the environment has not been covered by economists. From the most prestigious forerunners such as Arrow, Costanza, Nordhaus, Ostrom, Weiztman, Stern, Dasgupta, Heal, Stiglitz, Tobin, Daily, Daly, Porter, Kuznet, Georgescu-Rosen, Hardin, Pigou and Hotelling to name but a few (Costanza *et al.*, 2016), to the Sveriges Riksbank Prize (also known as the Nobel Prize) in Economic Sciences awarded to Elinor Ostrom in 2009 or to William Nordhaus in 2018, the economic literature is not silent on the subject. If we were to go into the details of the publications, it would be possible to conclude that this lack of focus afforded to the environment results in a bias that prevents us from fully investigating the disruptions that would be entailed in respecting planetary boundaries (Richardson *et al.,* 2023; Rockström *et al.*, 2009b; Steffen *et al.*, 2015). This is the theory put forth by Antonin Pottier (Pottier, 2016), which associates the lack of focus on environmental issues with implicit censorship that leads to underestimating the issues, or even exacerbating them. Thus, the challenge of the century is not filling the shelves of university libraries and the impetus provided by the IPCC for almost 40 years is struggling to stimulate economic research. However, allocating the planet's finite resources to, in the words of the Brundtland Report (Visser & Brundtland, 1987), meet the needs of the present without compromising the ability of future generations to meet their own needs is a crucial challenge. It is a case of resolving both the tragedy of the commons and the tragedy of the horizons and bewilderment is the only appropriate response to the lack of engagement on the part of the scientific community with these issues.

As far as *Economie et Statistique / Economics and Statistics* is concerned, the record is mixed (Table). The publication of a special issue dedicated to the environment in 1992, just two years after the first IPCC report, was remarkable as the subject seemed far from public policy priorities at the time. The environment was a subject of public policy, but such policy was often limited to the management of finite resources, air pollution, the value of landscapes or the nuisances of modernity, which is a long way off the systemic question formalised by Rockström *et al.* (2009a). Yet that special issue already went further than previous environmental concerns. It was followed in 2013 by a thematic section on the micro-assessment of the environment, accompanying the, at that time, recent empirical turning point in environmental studies (Castro e Silva & Teixeira, 2011).

However, the proportion of articles dedicated to the environment in *Economie et Statistique / Economics and Statistics* since 1992 is "only" 3.3% (falling to 2.6% since 2014), according to our count. This is the same order of magnitude as the vacancies in departments of economics alone over the last ten years (3.5% since 2014) – though the comparison is not directly relevant – but less than the profession as a whole (5.5% since 2014), with this figure remaining stable in recent years. Notable facts: 1. In the 50th anniversary issue of *Economie et Statistique / Economics and Statistics*, in 2019 (Djiriguian & Sémécurbe, 2019), the word "environment" does not appear in the word clouds taken from the abstracts; 2. In the highly informative special issue of *Economie et Statistique* devoted to modelling in 2012 (No 451-453), the environment is not mentioned (Laffargue *et al.*, 2012).

This is why the publication of three additional articles in *Economie et Statistique / Economics and Statistics* is an important step, which, while it will not reverse the statistics mentioned,[1] provides important insights on a fundamental subject. Because the subject has barely been explored, public policies that are (or will be) implemented on a large scale are created with insufficient knowledge and guidance, which runs the risk of policies that are poorly calibrated, poorly conducted, ineffective and ultimately abandoned because they are too expensive, too brutal or too unfair – there are many examples of this, ranging from carbon taxes to energy performance assessments and social leasing.

1. It should also be noted that almost 50% of the articles on this subject since 2014 and some of the articles from the call for papers on environmental issues of March 2023 (https://www.insee.fr/fr/statistiques/fichier/3897066/ES_appel_environnement_2023_FR-EN.pdf) have not been published yet.

Table – **39 Articles on the environment published in *Economie et Statistique / Economics and Statistics* since 1992**

Title	Authors	Years	N°	Pages
Beyond GDP: A Welfare-Based Estimate of Growth for 14 European Countries and the USA Over Past Decades	Germain, Jean-Marc	2023	539	3–25
Impact of COVID-19 Activity Restrictions on Air Pollution: Methodological Considerations in the Economic Valuation of the Long-Term Effects on Mortality	Chanel, Olivier	2022	534-35	103–118
Building Indicators for Inclusive Growth and its Sustainability: What Can the National Accounts Offer and How Can They Be Supplemented?	Blanchet, Didier ; Fleurbaey, Marc	2020	517-518-519	9–24
The Social Cost of Global Warming and Sustainability Indicators: Lessons from an Application to France	Germain, Jean-Marc ; Lellouch, Thomas			81–102
Price Elasticity of Electricity Demand in France	Auray, Stéphane ; Caponi, Vincenzo ; Ravel, Benoît	2019	513	91–103
What Value Do We Attach to Climate Action?	Quinet, Alain		510-511-512	165–179
Accessibility, Local Pollution and Housing Prices. Evidence from Nantes Métropole, France	Brécard, Dorothée ; Le Boennec, Rémy ; Salladaré, Frédéric	2018	500-501-502	97–115
Introduction. The Economic Evaluation of Environmental Services or Damage, Twenty Years Later	*Bureau, Dominique ; Point, Patrick*	2013	460-461	*71–77*
Industrial Hazards and the Price of Housing	Grislain-Letrémy, Céline ; Katossky, Arthur			79–106
How Do Individuals Put A Value On Deaths Associated With Atmospheric Pollution? A Comparison of Three Hypothetical Scenarios	Ami, Dominique ; Aprahamian, Frédéric ; Chanel, Olivier ; Luchini, Stéphane			107–128
Identification and Analysis of Lexicographic Preferences in Economic Assessment	Rulleau, Bénédicte ; Dachary-Bernard, Jeanne			129–144
Assessing Urban Amenities By The Hedonic Price Method: An Application Using The Example of The Town of Angers	Travers, Muriel ; Appere, Gildas ; Larue, Solène			145–163
General Introduction	*Hubert, Jean-Paul*	2012	457-458	*3–11*
Recent Growth in CO_2 Emissions Caused by the Mobility of the French People: Analysis of the Dynamics at Work via the National Transport Surveys of 1994 and 2008	Nicolas, Jean-Pierre ; Verry, Damien ; Longuar, Zahia			161–183
Assessing the Effects of Environmental Zoning on Urban Growth and Farming	Geniaux, Ghislain ; Napoléone, Claude	2011	444-445	181–199
Greenhouse-Gas Emissions Due to Agriculture and Land Use in France: A Spatial Analysis	Chakir, Raja ; De Cara, Stéphane ; Vermont, Bruno			201–221
A Multidimensional Approach to the Economic Value of Nature-Based Recreation	Rulleau, Bénédicte ; Dehez, Jeoffrey ; Point, Patrick	2009	421	29–46
Towards a Still-Fragile Revival of Stated-Preference Methods – Commentary About "A Multidimensional Approach to the Economic Value of Nature-Based Recreation"	Ami, Dominique ; Chanel, Olivier			47–51
Is the ISO 14001 Standard Effective? An Econometric Study of French Industry	Riedinger, Nicolas ; Thévenot, Céline	2008	411	3–19
Comment: The Environmental Effectiveness of Iso 14001 Standard: A Concept With Multiple Dimensions	*Grolleau, Gilles ; Mzoughi, Naoufel*			*21–23*
An Economic Evaluation of the Landscape	Dachary-Bernard, Jeanne	2004	373	57–74
Comment on 'An Economic Evaluation of the Landscape', An Innovative Method to Develop, Results Still Fragile	*Cavailhès, Jean*			*75–80*
The Singularity of the Contingent Valuation Method	Luchini, Stéphane	2002	357	141–152
The Loss of Recreational Forest Use Following the 1999 Storms: The Case of Fontainebleau Forest	Scherrer, Sylvie			153–172
Evaluation of the Damage Caused by Oil Slicks: An Illustration Based on the Case of Erika and the Residents' Loss of Amenities	Bonnieux, François ; Rainelli, Pierre			173–187
Advantages and Limits of the Benefit Transfer Method	Rozan, Anne ; Stenger, Anne	2000	336	69–78
An Economie Assessment of Atmospheric Pollution	Lescure, Roland; Nogier, Antoine; Tourjansky-Cabart, Laure	1997	307	3-20

➔

Table – *(contd.)*

Title	Authors	Years	N°	Pages
Household Packaging Waste: An Economic Analysis of the German and French Policies	Defeuilley, Christophe ; Quirion, Philippe	1995	290	69–79
The Waste Policy in the United Kingdom	Litvan, David			81–90
General Presentation	*Henry, Claude ; Bureau, Dominique*	1992	258-259	*3–7*
The Services Provided by our Natural Heritage An Evaluation Based on Economic Principles	Point, Patrick			11–18
The French and the Environment: From Intentions to Action	Dufour, Ariane			19–25
Environmental Policy Instruments	Delache, Xavier ; Gastaldo, Sylviane			27–34
"Marketable Emission Permits" in the United Stateds	Gastaldo, Sylviane			35–41
The Greenhouse Effect: Why Use a Pricing Approach?	Gastaldo, Sylviane			45–54
The Greenhouse Effect and North-South Relations: Opportunities for and Threats to a Global Agreement	Burniaux, Jean-Marc ; Oliveira Martins, Joaquim			55–68
The Environment and Growth: A False Dilemma for Developing Countries	Kenigswald, Laurent			69–75
Protecting the Environment in Developed Countries	Avérous, Christian			77–85
The Clean Car	Brunel, Philippe ; Perillo, Thierry			89–94
The Water Situation in France	Paoli, Dominique ; Rieu, Thierry			95–104
Including the Environment in Agricultural Policies	Amand-Madelin, Virginie			105–112
Protecting Species: What Do the Economists Have to Say?	Angel, Martin ; Glachant, Matthieu ; Lévèque, François			113–119
Transport and the Environment: How to Improve and Control External Effects?	Bonnafous, Alain			121–128
Solid Waste: Scrap or Resources?	Bertolini, Gérard			129–134

Notes: The selection by the author and Dominique Goux is necessarily somewhat subjective. In addition to the 39 articles, the table includes, in italics, the introductions to and comments on articles on the environment.
Sources: www.insee.fr, www.persee.fr.

The Challenges of the Challenge of the Century

Bretschger & Pittel (2020) list 20 challenges for economics.[2] Three main areas of focus can be identified for the design and conduct of policies for the environmental transformation of societies:

1. Making forecasts and anticipating and quantifying the consequences of climate change and of transition and adaptation policies. This involves identifying exposures to climate change and to environmental policies. Complex and expensive choices will have to be made regarding the granularity of the analyses: the multiplication of dimensions, from geography to social categories, from types of climatic events to the sectoral dimension, requires an effort to compile data that has never been carried out;
2. Developing public policies for "net zero carbon emissions", meaning policies for radical transformation of the productive system, from energy production to energy use, consumption patterns, conversion of installed capital or innovation and directed innovation. And this will be achieved by adding new activities such as recycling, repairing ecosystems or managing carbon sinks;
3. Understanding the change underway by compiling data and, therefore, by rebuilding official statistics and adapting the concepts of public accounting to not only understand well-being – to allow societies to be reflexive – but also to reflect the redistributive, conflicting and uncertain aspects of the evolution of well-being during the transition. Tools to allow understanding may seem secondary to the "doing" in point 2, but they are one of the necessary conditions

2. 1) Deep decarbonisation and climate neutrality; 2) Dynamics of the economic-ecological system; 3) Risk, uncertainty and resilience; 4) Disruptive development and path dependencies; 5) Behavioural environmental economics; 6) Institutional analysis of environmental policy; 7) Equitable use of the environment; 8) Loss of biodiversity and natural capital; 9) Valuing and paying for ecosystem services; 10) Conflicts over natural resources; 11) Population development and use of the environment; 12) Land use and soil degradation; 13) Environmental migration; 14) Urbanisation as a key for environmental development; 15) Health and epidemiological environment; 16) Carbon exposure and green finance; 17) Energy system transformation; 18) Sustainability perspective on digitalisation; 19) Quantitative analysis of environmental use; 20) Structural assessment modelling and modelling transparency.

and a necessary condition for ensuring the acceptance of public policies.

These three areas of focus revolve around climate change and the goal of decarbonising societies. The work on biodiversity conservation is an essential element that is sometimes aligned with the objective of achieving net zero but sometimes conflicts with it. Knowledge on this subject is still patchy and inadequate for its complexity and moving forward requires a considerable effort to break down the data. While we know how to make linked climate and macroeconomics models with varying degrees of credibility, integrating ecosystems and the economy requires a level of granularity that is unattainable given the current state of not only information systems but also modelling capabilities. In just under four decades, the IPCC has advanced climate modelling. It is now close to being able to anticipate the main aspects[3] of local impacts of climate change. The work of anticipating the evolution of ecosystems and their interaction with human societies is barely touched upon today.

These three focus areas are the topics addressed by Selma Mahfouz and Jean Pisani-Ferry's report entitled *The Economic Implications of Climate Action* (Pisani-Ferry & Mahfouz, 2023), which also takes biodiversity into consideration. By including many authors, particularly within the French government, the drafting of that report prompted summation work regarding the methodological, theoretical and empirical framework for the environmental transition and its consequences. The three articles published by *Economie et Statistique / Economics and Statistics* stem directly from these contributions and provide elements of answers for the three focus areas mentioned.

The article by **Didier Blanchet** and **Craig Pesme** (Blanchet & Pesme, 2024) develops an original, modelled framework that makes it possible to discuss the practical measurement of well-being and its evolution and is directly in line with the third focus area. The article excludes questions relating to redistribution by limiting itself to a representative individual. The difficulty raised in this simplified framework justifies the approximation, but one can only hope that such limitations will be removed in the near future. The first point made by Blanchet and Pesme is that the measurement for well-being proposed by the national and social accounts, namely disposable income deflated using a chained price index, may be relevant when prices are the lever used to achieve the transition trajectory. In this case, with a few details relating to pathway dependence caused by the chained indices, it is possible to use disposable income as a proxy for the evolution of well-being and thus to continue to talk about the evolution of purchasing power. This does not take away from the many criticisms made in relation to this indicator, some of which are acute in the transition. For example, taking into account collective expenditure, individualisable non-monetary elements (health) or non-individualisable non-monetary elements (the state of nature) requires specific measures to build an expanded income, some of which are difficult to systematise for regular output. Another difficulty, one that is particularly acute when analysing profound changes, is that price indices are blind to the introduction of new goods. This problem is not new and is at the heart of the difficulty experienced in analysing innovation in national accounts (pointed out by many authors). Without new assumptions it is difficult to quantify the benefit of a new product. The environmental transition cannot avoid this difficulty, unless we take the view that the green goods that replace brown goods are highly similar or interchangeable and the price (of the green goods relative to the brown goods) represents the loss of utility for the consumer fairly well.[3]

However, the contribution made by Blanchet and Pesme's article is not a reiteration of these known aspects. If the transformation of society takes place through prohibitions or standards, rather than prices, the concept of a deflator loses its ability to measure well-being. There is a price equivalent to constraint, but quantifying that price requires a level of work that puts this equivalence beyond the reach of national accountants. An alternative is equivalent income, a concept developed over the last few decades by Marc Fleurbaey or Didier Blanchet (Blanchet & Fleurbaey, 2020, 2022; Fleurbaey, 2016; Fleurbaey & Blanchet, 2013). Using equivalent income makes it possible to simply address questions regarding constraint and to find equivalence between price and standard. However, a difficulty is becoming apparent: the radical transformation of society to respond to the climate emergency can be understood as a change in preferences. This change can be before the transition and be the driver of it, it can be after it, taking place after the fact and once the change of social values affected by the transformation

3. These main aspects include average temperatures over the year, the probability of extreme temperatures, the probability of extended periods of extreme temperatures, average precipitation and elements relating to precipitation distribution and extreme weather events (storms).

has been completed or it can evolve alongside the transformations. This change in preferences can come out of the blue or it can be driven by nudges, public policies or education. The change in preferences opens up dizzying prospects for the analysis of well-being, almost nullifying measurement attempts and casting doubt on any measurements that will be proposed. Equivalent income does not provide a miracle solution to changes in preferences, but it does make it possible to geometrically determine the consequences. Blanchet and Pesme's work does not provide a simple roadmap for economic and social accounting, but it does make it possible for the accounts to avoid stating inaccuracies during the transition.

The article by **Miquel Oliu-Barton, Aude Pommeret, Alice Robinet, Katheline Schubert** and **Mathilde Viennot** specifically explores the question of changes in preferences and the public policy levers that can bring them about. While Blanchet and Pesme attempt to incorporate the change in preferences into the framework for the quantification of variations in well-being, the aim of Oliu-Barton *et al.* (2024) is completely in line with the second focus area. The abstract notion of changes in preferences is reduced to the more operational notion of sufficiency, which is identified as one of the major tools of the transition (Saheb, 2021). Using the four types of sufficiency defined by the French association négaWatt (structural, dimensional, usage and cooperative sufficiency), the authors focus on identifying the existing literature to find the basis for a change in preferences and identify how to bring it about through public policies.

The subject is off the beaten track of mainstream economics, in which preferences are an unobserved concept that relates to the sovereign free will of individuals. Behaviours are observed and it is possible to associate them with preferences from which those behaviours logically follow. The real assumption made by economists is, in fact, in the consistency of these preferences, at least locally, which allows for empirical identification and behaviour predictions. This view has, of course, been widely criticised, both inside and outside the field of economics. Reducing rationality to a constrained maximisation of preferences and imposing an unambiguous axiom on preferences is a convoluted and weak way of addressing the rationality of social individuals. Imagining the change in preferences is a roundabout way of bringing these stronger concepts of rationality into the field of economics.

Alternatively, following the work of Richard Thaler and Cass Sunstein (Thaler & Sunstein, 2009), it can be postulated that the decisions taken are not a direct reflection of preferences but that cognitive biases divert the actual decision away from the optimal decision. This does not reverse epistemological tautology but it allows a more direct formal representation of the ability of nudges to change people's choices and bring them closer to rationality (what is sometimes called paternalistic liberalism). Simple models of these cognitive biases have been proposed, with the advantage of being able to retain the usual models and introduce the public policies altering cognitive biases (generally in the sense of reducing the extent of the bias).

In either case, we are far from being able to "quantify" these changes in preferences and thus fully justify the use of this approach of relying on preferences – increased by their dynamics – in a modelled framework. The work of Oliu-Barron *et al.* is in line with this perspective and, starting from a reference model, shows what sufficiency policies bring to the public policy toolbox. One of the arguments advanced in the article is that it is not necessary to levy a tax, and possibly redistribute it afterwards, in order to change behaviour. It is therefore a way of circumventing resistance to tax policies, for which it is very difficult to provide transparency and ensure that they are accepted and sustainable over time. In addition to the fact that sufficiency does not mean decline – avoided consumption is transferred to other areas and sufficiency allows for more efficient consumption in terms of greenhouse gas emissions – one of the important findings of the article is the equivalence between a redistributed tax and a change in preferences. This finding raises an immediate issue: taxation and redistribution of the tax collected pose three distributive problems (exposure to the tax, construction of the tax base and the redistribution base). Introducing the heterogeneity of agents into the model and producing empirical identifications of these "dynamics of preferences" is undoubtedly an achievable goal. This would make it possible to answer the question "is it possible, through the use of sufficiency policies, to ask questions around sharing the burden in a different manner?".

The article by **Florian Jacquetin** and **Gaël Callonnec** (Jacquetin & Callonnec, 2024) follows this line of thinking. They seek to assess climate damage using a macro-sectoral method and by compiling different estimates taken from the literature in each sector – using a combination of highly diverse methods.

Nevertheless, the authors strive to produce a coherent and comprehensive diagnosis. They diverge from damage assessments such as that produced by the JRC (Joint Research Centre of the European Commission, Feyen *et al.*, 2020). They do not seek to estimate well-being, from a cost-benefit analysis perspective, but they construct a macroeconomic scenario, providing information on, among other things, the trajectory of GDP, using its usual definition, as well as on the trajectories of public finances or the labour market. The exercise is one of a different nature, performed from an applied perspective and seeking to inform public policy. This work thus joins that of the Network for Greening the Financial System (NGFS), for which forward planning is essential for assessing the stability of the financial system in the future.

Forward planning is unsatisfactory for several reasons that the work of Jacquetin and Callonnec is unable to avoid:

a. Extrapolation based on the past, especially outside the intervals observed in the past, is blind to phenomena that are unfortunately highly probable. The acceleration of trends through positive feedback loops leads to underestimating changes, whereas negative feedback loops lead to exaggeration. The combination of the two errors can lead the economic system to states that are difficult to accept and far removed from what extrapolation produces. The simple construction of a trend scenario thus assumes that the distribution of errors is sufficiently "normal" (does not conform to the Cauchy distribution, for example) and that the expectation of state variables can be calculated, or that the system is sufficiently deterministic for a trend to have a meaning. The decision by Jacquetin and Callonnec not to take into account transition or adaptation policies illustrates the direction and limits that can be attributed to an extrapolated trajectory: extrapolation is not a trivial exercise because the system under consideration has many state variables that needed to be chosen, but the extrapolated trajectory is not a probable future. It serves only as a reference for establishing answers that will change the future of the system;

b. Modelling error, that is to say forgetting, during the construction of the scenario, dimensions that are nevertheless key factors in determining the dynamics of the system, leads to overlooking certain phenomena and state variables that are not observed. The anticipated trajectory is thus constrained to one plane, while it develops in a three-dimensional space. The decision by Jacquetin and Callonnec to carry out a sectoral analysis is an input, compared to a more aggregated analysis such as the one carried out in Nordhaus' DICE model (Nordhaus, 2019). This input allows the incorporation of sector-specific assessments using specific data and analyses of trends and mechanisms specific to each sector. Tourism does not respond to the same determining factors as agriculture and involves radically different approaches, from taking into account the impact of the climate to macroeconomic consequences. By escaping the need for a unified framework, the analysis can be refined and made more credible. However, choosing the sectoral dimension results in overlooking the geographical dimension; yet by making areas less attractive or even unliveable, climate change can induce internal migration and spatially differentiated changes in prices. In turn, this change in spatial structure can be a decisive factor for the macroeconomic trajectory and may require specific public policies. One can dream of combining the two dimensions and of being able to link their dynamics with the global dynamics, thus revealing transmission and feedback channels that are not very intuitive but are significant – it is the purpose of modelling to produce such analyses. However, this dream is costly in terms of computing capacity and information acquisition, to the point that it is inaccessible at present. If the work of Jacquetin and Callonnec tells us anything, it is that we need theoretical guides to enable us to allocate our limited applied modelling resources to the phenomena and dimensions that are critical in anticipating the consequences of climate change.

Informing Public Choices

Economie et Statistique / Economics and Statistics is *aimed at contributing to the economic and social debate by providing analyses (...) accessible to readers not necessarily specialists on the topics or methods implemented in articles*. Undeniably, the publication of these three articles is a useful and welcome contribution to inform public choices during the transition. The topics addressed by the Pisani-Ferry Mahfouz report are reflected in a more rigorous and yet accessible manner here. However, the field is far from exhausted and one can only hope that each issue to come will succeed in contributing at least as much as this one to the challenge of the century. □

BIBLIOGRAPHY

Articles of the thematic section

Blanchet, D. & Pesme, C. (2024). Costs and Co-Benefits of Climate Transition Policies: How Accurately Will They Be Measured by Standard of Living and Well-Being Indicators? *Economie et Statistique / Economics and Statistics*, 543, 3–20 (this issue).

Jacquetin, F. & Callonnec, G. (2024). Macroeconomic Impact of Climate Damage in France. *Economie et Statistique / Economics and Statistics*, 543, 39–64 (this issue).

Oliu-Barton, M., Pommeret, A., Robinet, A., Schubert, K. & Viennot, M. (2024). Chosen Energy Sufficiency: Preference Shocks and Behavioural Biases. *Economie et Statistique / Economics and Statistics*, 543, 21–37 (this issue).

Other references

Blanchet, D. & Fleurbaey, M. (2020). Building Indicators for Inclusive Growth and its Sustainability: What Can the National Accounts Offer and How Can They Be Supplemented? *Economie et Statistique / Economics and Statistics*, 517-518-519, 9–24. https://doi.org/10.24187/ecostat.2020.517t.2020

Blanchet, D. & Fleurbaey, M. (2022). Values, Volumes, and Price-Volume Decompositions: On Some Issues Raised (Again) by the Health Crisis. *Economie et Statistique / Economics and Statistics*, 532-33, 71–88. https://doi.org/10.24187/ecostat.2022.532.2072

Bretschger, L. & Pittel, K. (2020). Twenty Key Challenges in Environmental and Resource Economics. *Environmental & Resource Economics*, 77(4), 725–750. https://doi.org/10.1007/s10640-020-00516-y

Castro e Silva, M. & Teixeira, A. C. (2011). A bibliometric account of the evolution of EE in the last two decades: Is ecological economics (becoming) a post-normal science? *Ecological Economics*, 70(5), 849–862. https://doi.org/10.1016/j.ecolecon.2010.11.016

Costanza, R., Howarth, R. B., Kubiszewski, I., Liu, S., Ma, C., Plumecocq, G. & Stern, D. I. (2016). Influential publications in ecological economics revisited. *Ecological Economics*, 123, 68–76. https://doi.org/10.1016/j.ecolecon.2016.01.007

Djiriguian, J. & Sémécurbe, F. (2019). Fifty Years of Abstracts in the Journal Economie et Statistique. *Economie et Statistique / Economics and Statistics*, 510-511-512, 7–11. https://doi.org/10.24187/ecostat.2019.510t.1999

Fleurbaey, M. (2016). *Equivalent Income*. Matthew D. Adler & Marc Fleurbaey (dir.), Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199325818.013.15

Fleurbaey, M. & Blanchet, D. (2013). *Beyond GDP: Measuring Welfare and Assessing Sustainability*. https://doi.org/10.1093/acprof:oso/9780199767199.001.0001

Heckman, J. J. & Moktan, S. (2020). Publishing and Promotion in Economics: The Tyranny of the Top Five. *Journal of Economic Literature*, 58(2), 419–470. https://doi.org/10.1257/jel.20191574

Feyen, L., Ciscar, J., Gosling, S., Ibarreta, D. & Soria, A. (2020). *Climate Change Impacts and Adaptation in Europe.* JRC Publications Repository, 13 may 2020. https://doi.org/10.2760/171121

Laffargue, J.-P., Malgrange, P. & Morin, P. (2012). Préface : La modélisation macroéconomique : continuités, tensions. *Economie et Statistique,* 451-453, 11–20. https://doi.org/10.3406/estat.2012.9735

Nordhaus, W. (2019). Climate Change: The Ultimate Challenge for Economics. *American Economic Review*, 109(6), 1991–2014. https://doi.org/10.1257/aer.109.6.1991

Pisani-Ferry, J. & Mahfouz, S. (2023). Les Incidences économiques de l'action pour le climat. France Stratégie, Rapport.
https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/2023-incidences-economiques-rapport-pisani-5juin.pdf

Polasky, S., Kling, C. L., Levin, S. A., Carpenter, S. R., Daily, G. C., Ehrlich, P. R., Heal, G. M. & Lubchenco, J. (2019). Role of economics in analyzing the environment and sustainable development. *Proceedings of the National Academy of Sciences*, 116(12), 5233–5238. https://doi.org/10.1073/pnas.1901616116

Pottier, A. (2016). *Comment les économistes réchauffent la planète*. Seuil. https://doi.org/10.3917/ls.potti.2016.01

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Bloh, W. von, Feulner, G., …, Weber, L. & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, 9(37), eadh2458. https://doi.org/10.1126/sciadv.adh2458

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S.I., Lambin, E., Lenton, T., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., …, Crutzen, P. & Foley, J. (2009a), Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, 14(2). https://doi.org/10.5751/ES-03180-140232

Rockström, J., Steffen, W., Noone, K. & Persson, Å. (**2009b**). A safe operating space for humanity. *Nature*, 461, 472–475. http://www.nature.com/nature/journal/v461/n7263/full/461472a.html

Saheb, Y. (2021). COP26: Sufficiency Should be First. https://www.buildingsandcities.org/insights/commentaries/cop26-sufficiency.html

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., Vries, W. de, Wit, C.A. de, Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B. & Sörlin, S. (**2015**). Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223). https://doi.org/10.1126/science.1259855

Thaler, R. H. & Sunstein, C. R. (**2009**). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. Penguin Publishing Group.

Visser, W. & Brundtland, G. H. (1987). *Our Common Future ('The Brundtland Report'): World Commission on Environment and Development*. In: Greenleaf Publishing Limited, 52–55. https://doi.org/10.9774/gleaf.978-1-907643-44-6_12

Attachment to Pets Revisited

Cécile Brousse* and Marceline Bodier**

Abstract – It has long been perceived wisdom that single people are those least likely to own a pet. The 2010 *Emploi du temps* (Time Use) survey confirms this pattern, while also making it possible to examine the activities and time shared with pets. It also allows an analysis of the terms people use to describe the activities carried out with their pets. We show that single people who own a pet spend more time with it, especially playing together with it. We also show that women and the elderly use language from a register that could be described as "anthropomorphic" to describe the way their pets fit into their daily lives more than other groups. It explains why single people use "anthropomorphic" language more than others, since they are more likely to be women and elderly people.

JEL: J22, N30
Keywords: time use, leisure activities, pets, household status, textual analysis

**INSEE, École normale supérieure-PSL ; **INSEE.* Correspondence: *cecile.brousse@insee.fr*

The authors would like to thank Dominique Goux and Pauline Givord for their time and valuable advice on the authors' work, the participants at the 8th congress of the Association Française de Sociologie, the French Sociology Association, (Aix-en-Provence, 2019), and the two anonymous reviewers for their thought-provoking and encouraging comments.

Received in July 2023, accepted in February 2024. Translated from : "L'attachement aux animaux de compagnie revisité".
The opinions and analyses presented in this article are those of the author(s) and do not necessarily reflect their institutions' or INSEE's views.

Citation: Brousse, C. & Bodier, M. (2024). Attachment to Pets Revisited. *Economie et Statistique / Economics and Statistics*, 543, 75–92.
doi: 10.24187/ecostat.2024.543.2120

In 2010, according to the most recent *Emploi du temps* (Time Use) survey, 49% of French households owned a pet or livestock animal. If we limit the scope to households in employment and residing in towns and cities, for which the oldest data are available, this proportion is thought to have increased by 5 percentage points since 1966, despite the increasing urbanisation of lifestyles and the increasing economic difficulties that could lead some to shy away from the cost of owning an animal.

So, the question is, do the French have an attachment to the presence of an animal in their lives? In order to reflect this attachment, "sociologists have focused on the symbolic relationship with animals and the largely subconscious expectations that owners have towards them" (Herpin & Verger, 2016). In Yonnet's opinion (1983), it is a means of maintaining authority when one no longer has authority over children, while for Héran (1988), "the animal provides a way for owners to, in a playful manner, 'repeat' relationships of dominance or, conversely, to 'distance' themselves from them symbolically".

In their successive articles, Herpin and Verger use the approach to the sociology of consumption developed by Gary Becker (1973; 1974): the acquisition of a pet thus appears to be "the result of a decision that is not fundamentally different from decisions made by the household with regard to consumer products" (Herpin & Verger, 1991; 1992; 2016). These studies allow us to determine the reasons why households acquire animals with a reasonable degree of accuracy. However, they are limited by the fact that the "quantitative" surveys of the official statistics system on which they are based do not provide "information on the emotional aspect of the relationship between the animal and its owners".

Furthermore, these authors wonder if "a pet is [...] a way to relieve loneliness" (Herpin & Verger, 2016). The only indicator they can use to examine this issue is the rate of animal possession, which they compare according to family structure. Analysis of this individual indicator quickly leads to the conclusion that a pet is not a way to relieve loneliness, given that single people are less likely to have one. They also compare the rate of animal possession at different points in the life cycle, and find that the presence of animals is greater in the middle of the life cycle, when there are children: once again, animals appear to be the opposite of a way of relieving loneliness.

The authors conclude, however, that their article "does not address the emotional place that owning a pet has in the lives of owners of dogs, cats or horses". In fact, reducing a bond with an animal to the simple act of living in a household that owns one likely does not fully examine the subject, especially given the fact that, if single people are less likely to have animals, it may be because there are material obstacles (especially as regards the ability to have it walked or taken care of when they are not home), meaning that it is not necessarily by choice, but due to constraints.

To examine the bond with an animal, social psychology starts from an approach that is the exact opposite of that used to analyse the results of large statistical surveys. It starts with a scale to measure attachment to the animal (which is often ad hoc, meaning that there are many). A small sample of volunteers (e.g. a veterinarian's customers or students) who have an animal is then asked where they would place their attachment on that scale. The results, which are robust across studies, conclude that single people have a greater attachment to their animals, as well as with women and people living in urban areas (Archer, 1997; Epley *et al.*, 2008).

However, those studies suffer from several limitations (literature reviews, such as Gilbey & Tani (2015) or Scoresby *et al.* (2021), underline the need for broader studies).

First, they are able to establish correlations, but cannot address the issue of causality, since they are not usually based on following the sample over time. Second, there is concern that the social psychology results may be obtained from unrepresentative samples, because people with a strong attachment to their animals are probably more likely to participate in such studies. Moreover, the use of an attachment scale leads to respondents inferring that having an attachment to their dog or cat is a legitimate form of relationship. Finally, in the same way that there is always a publication bias in favour of conclusive results, there could be a bias in the publication of social psychology articles when the initial hypothesis, that of an attachment, is verified.

Sociology and statistics are social sciences, while social psychology is a behavioural science. Typically, the degree of overlap between their theoretical frameworks is marginal. However, according to Claidière & Guillo (2016), social sciences reduce behavioural sciences to "caricatural culturalism", while behavioural sciences criticise the "scientific reductionism" of

social sciences. Interactionist sociology would therefore be a way to bring the two disciplines together.

In *Des chiens et des humains* (Dogs and Humans), Guillo (2009) asks whether the dog is an "emotional substitute" for a lack of human connection, associated with needs that have emerged along with industrial society. With the arrival of industrial society, lifestyles have become more frequently urban, with all the consequences that this entails in terms of anonymity and the breakdown of social interaction, together with the narrowing of family ties to focus on couples and their children and the increase in people remaining single or in single-parent families. If dogs (or other pets, Guillo adds) were an "emotional substitute", they should be found more often with people who lack social connections. Finding that pets are more often found in households with children, as well as more often found with couples, and therefore more often found with people whose "expectations are met in terms of human social interaction", and less often with single people, Guillo concludes that pets cannot be an emotional substitute. However, he draws this conclusion by examining no other indicator than ownership rates alone. We therefore encounter the problem, as already highlighted, of the lack of relevant indicators to examine this question of whether a pet is an "emotional substitute".

Another corpus of American studies, which claims to adhere to interactionist sociology, supports the need to recognise a form of agency in animals (i.e. a status as subjects or actors, rather than objects at the disposal of humans). Those studies focus on real interactions observed in places such as veterinary clinics or trade fairs, or even those reported in interviews or in personal blogs on websites. Clinton Sanders, a pioneer of this trend, studied his interactions with his own dog over four years (Sanders, 1993). Arluke (1988; 1990) and Sanders (1993) studied how owners address veterinarians, making their pet talk and claiming to be the "mum" or "dad" of the dog.

That research therefore has more of a qualitative focus. It delves further into examining the nature of bonds with animals, but by studying people who demonstrate their investment in an animal through their mere presence at the place of observation: they cannot be assigned a more general scope than that of social psychology.

The available literature on attachment to animals therefore consists, on the one hand, of studies conducted among the general population, which essentially find that single people have fewer pets than others, and, on the other hand, of qualitative studies, which highlight attachment phenomena without quantifying them and without being able to confirm that they are universal. These two sections of the literature lead to opposing conclusions in relation to the hypothesis that the animal is an "emotional substitute".

To reframe this within the narrower limits in which we are operating, the theory whereby attachment to an animal is greater when people live alone is not held uniformly. This is why it is important to have new tools making it possible to answer the following question: does attachment to an animal vary depending on whether or not the person lives alone?

What we propose here is an original approach based on a very well-known and rich statistical source, but one which has never been used to answer this question: the *Emploi du temps* survey (Box 1). It was first conducted in 1966 and the most recent edition, which we mainly use, is from 2010. In their successive publications on pet ownership, Herpin & Verger (1991; 1992; 2016) used other sources (the 1966–1967 *Loisirs* [Leisure] survey, the 1983 Contacts survey, the 1988 *Trois aspects du mode de vie* [Three Aspects of Lifestyle] survey and the 2010 *Budget de Famille* [Family Budget] survey). However, since 1966, the *Emploi du temps* surveys have been asking households about the animals they own (except in 1998) and, since 1998, the transcript of the descriptions of their days that respondents provide has also provided information on the relationship with animals.

Later on in this article, the *Emploi du temps* survey will allow us not only to replicate the results obtained by Herpin & Verger, but also to study the activities carried out and the time spent with animals, which, to the best of our knowledge, has never been done before. We will use an analysis of the terms used by respondents to describe how they use their time, including the words used when they talk about animals, to provide new answers to the question: does attachment to an animal vary depending on whether the person lives alone?

1. Single People Less Often Have a Pet

The 2010 *Emploi du temps* survey confirms the results obtained by Herpin & Verger based on the 2010 *Budget de Famille* survey (Herpin & Verger, 2016). In 2010, 48% of households

Box 1 – **The 2010 *Emploi du Temps* Survey**

The purpose of *Emploi du temps* surveys (Time Use Surveys) is to quantify the duration of daily activities as accurately as possible. They estimate the time spent on each activity undertaken throughout a particular day. The information is collected on the same day. Requiring very little memory, this collection method is more precise than retrospective questioning (Brousse, 2015).

The 2010 *Emploi du temps* survey interviewed 10,675 households, representative of France excluding Mayotte. 15,836 individuals aged 18 or older responded, each describing one or two of their days in a diary, generating a total of 27,903 diaries. The day's activities are described in 10-minute periods: for each 10-minute period, the respondent can describe their main activity and, if necessary, another activity performed at the same time: there are thus one or two activity descriptions for each 10-minute period of the day described. Among those aged 18 or over, there are 726,601 (main or secondary) activity descriptions, of which 8,362 directly relate to animals of any kind (pets, farm animals, game, etc.).

owned at least one pet.[1] That pet may be a dog (a quarter of households, half of which have no pets other than one or more dogs), a cat (about a quarter of households as well, half of which have no pets other than one or more cats), a guinea pig, a goldfish, a bird, or even a horse or an anusual pet, such as a stone marten or a snake. An animal is classed as a pet if the surveyed person describes it in that manner: animals are therefore not pets inherently, but it depends on the circumstances and, in principle, any animal can be a pet. In France, it is rarer for animals that are also farmed, such as rabbits, or those that are also wild, such as snakes, to be classed as pets. The fact that the survey questionnaire separates questions on farm animals and pets is implicitly based on Digard's (1998) distinction between production animals and pets, with the former being deemed "useful" and the latter being deemed "useless".

Whether or not a person owns a pet, regardless of whether that pet is a dog or a cat, primarily depends on where they are in their life cycle. The presence of an animal is more common in mid-life, as well as among those with intermediate standards of living. Couples have pets more often than single people, and all people have pets more often if they have children. These results are confirmed by an econometric analysis all other things being equal.[2]

The mere fact of owning an animal is a useful indicator, but it is not suitable for studying emotional bonds with an animal.

2. Study of Time Spent on Activities with Pets

2.1. The *Emploi du Temps* Surveys Allow the Study of Time Spent with Pets

A bond with an animal is first materialised by the household's decision of whether or not to acquire one. The quality or strength of that bond will also be reflected in the amount of time spent with the animal. The time spent taking care of an animal is unavoidable (it is necessary to feed it, care for it and walk it, or give it the possibility to get out, in the case of a dog); but the amount of time can vary. There is no reason for time spent playing with an animal to be high if it is only a guard animal; time spent walking[3] a dog is a leisure activity in competition with other leisure activities available to the household.

Overall, it is expected that the total amount of time spent with a pet will be linked to the strength of the bond with it. However, while information on time spent with animals is available in the *Emploi du temps* surveys, to the best of our knowledge it has never been used. Information on time spent carrying out activities with animals also has the advantage of being available at individual level rather than at household level. It is therefore this individual information on the amount of time spent with animals that we now use as an indicator of the strength of the bond between individuals and animals.

In the *Emploi du temps* survey, each respondent provides a detailed description of the domestic and professional tasks they perform, their journeys and how they spend their free time. Each

*1. The term used to describe pets in France has changed over time (Brousse & Bodier, 2024). The original French version of this article uses the term from the survey ("*animal de compagnie*", which translates literally as "companion animal"), which makes a distinction between pets and livestock animals, even though the study does not necessarily confirm the fact that the relationship is one of a "companion", based on the meaning of being "in the company of someone".*

2. A logistic regression model of household ownership of at least one pet was estimated based on 14 variables: age, socio-professional group, country of birth of the reference person, type of household, number and age of children, income quintile, urban unit division, region, type of dwelling, number of rooms in the dwelling, occupancy status of the dwelling, ownership of a car, ownership of a second residence and use of a domestic helper.

3. We are referring to walks in the sense of a private leisure activity, and not professional dog walking, for example.

activity described is then classified as part of a classification which, in the 2010 survey, includes 140 items. Two items concern pet care, and are classified as "domestic work": "looking after pets" and "walking the dog, taking out a pet".

Those items in the classification have the merit of existing and they are sufficient for describing how time is distributed between major categories; however, they are poorly suited to studying the amount of time spent with an animal and even less well suited to studying the bond that animal owners have with their animal.

First, by providing only two items, the classification de facto limits the scope of activities taken into account: some of the playing, everyday activities (sleep, commuting, etc.) that are carried out "with their animal", or even simply doing nothing or watching television in the company of an animal (and describing it in this way in the survey) are activities classified (ex post) in the classification as though the animal did not exist, even when it is mentioned. There are no clear instructions, but it seems that there are even differences in how the activity is classified depending on whether the animal is a dog or a cat: playing with a dog can be classed as "caring for a pet", but with a cat, it is classed as part of "doing nothing, strolling, thinking, smoking, relaxing, resting, etc.".

For our study, we used a variant of this classification, one that explicitly identifies recreational activities carried out in the company of an animal (Brousse & Bodier, 2024). This variant redefines what is included in "animal activities": the scope of "animal" activities is broader than that provided for in the initial classification and it includes activities that had been classified elsewhere. It also shifts the boundaries between items by creating more granular categories (Table 1).

In this redefined classification, by convention,[4] taking out an animal (mainly a dog) is considered to be a mandatory "care" activity for the first twenty minutes and a (leisure) walk for any further time.

There is another consequence of the fact that the standard classification of the survey was not designed to identify all animal-related activities: the automatic classification tool (Sicore) gives preference to information derived from terms other than those that refer to animals. For example, "I prepare my dog's meal" is considered a cooking activity. This is not an error; but if the objective becomes the identification of all activities related to animals, then the preparation of their meal is "care" that is given to them. By going back to the analysis of the descriptions as written by the respondents,[5] and taking into account the mention of an animal in the description, our re-classification instead systematically gives preference to references to animals.

In this re-classification, we finally took into account secondary information provided by respondents, which is usually not taken into account to classify activities (Lemel, 1982). When describing how they use their time in 10-minute slots, as provided for in the survey,

4. This convention is justified by the nature of the distinction sought, but also by the fact that the distribution of the amounts of time spent on the activity "walking the dog, taking out a pet" (item 385 of the standard classification) shows a mode of 20 minutes (a quarter of the walks last for 20 minutes).

5. Access to the descriptions is a specific feature of the French Emploi du temps *survey, which we are taking advantage of both here and again later in this study.*

Table 1 – **Redefined classification of activities performed with pets**

Type of activity		Link to the survey classification	Examples
Looking after	Caring for a pet	Similar to category 384, which it expands on and complements	Feeding the dog, caring for the cat, cleaning the cat box, visiting the veterinarian, training, telling off, etc.
	Brief outings (maximum of 20 minutes)	Similar to category 385, which it divides in two and complements	Taking the dog out, etc.
Leisure activities	Walking a pet (over 20 minutes)		Walking with the dog, going for a walk with the dog and children
	Recreational activities exclusively with a pet	Categories created by identifying all the descriptions initially classified in categories that are not related to animals, but in which an animal is mentioned	Playing with the dog, petting the cat, watching the puppies, talking to the parrot, taking photos of the cat, etc.
	Recreational activities performed with a pet alongside another activity		Watching TV while stroking the cat, going to get bread with the dog, having a lie in with the cat, etc.

respondents must indicate their main activity during those 10 minutes, and they may optionally add a secondary activity. In practice, for 27% of the main activities, a secondary activity is also mentioned.[6] In addition, one animal-related activity in ten is reported as a secondary activity: in this study, they are processed in the same way as main activities.[7]

2.2. Every Day, 22% of People Living with a Pet Dedicate Time to it

In 2010, 52% of people aged 18 or over lived in a household that had at least one pet. Those people are likely to spend time with household animals to take care of them and take them out, to walk with them and to play or have company.[8]

The amount of time that those people dedicate to their pets each day averages thirteen minutes per person (Table 2).[9] However, only 22% of these people actually dedicate time to their pets, and for them the average time dedicated to animals is almost an hour a day.

The time spent with a pet increases with age, at least up until the age of 75. Among working age people, those in employment dedicate less time to their pet. For families, the time dedicated to the pet by any of the adults is lower the more children there are and the more they are young in age. The amount of time dedicated to pets is higher for single people (Figure I): 65% higher than for people living in couples without children, twice as high compared with those living in single-parent families, and more than five times higher than for spouses in couples with children. These findings are confirmed on the basis of all other things being equal (Table 3).

This comparison is performed between individuals, not between households. In order to compare the time dedicated to an animal by the household to which it belongs, it must be possible to take the composition of the household into account (Figure I). Thus, a household made up of two spouses dedicates to its animal at least the exact amount of time reported by one of the spouses (in the event that such time is always shared) and, at most, twice the time reported by that spouse (in the event that such time is never shared).[10] In fact, the time dedicated by single people to their animal is not double the time dedicated by couples without children: this is potentially partly a reflection of the fact that they cannot share tasks with another person.

To go into greater depth in the analysis, we will now break down the time spent with animals

---

6. For "animal" activities alone, this decision is made in only one case in ten.

7. Nevertheless, the Emploi du temps *surveys have their limitations. One is that they do not make it possible to assess the time spent on activities that are difficult to disclose to an interviewer (sexuality, conflicts and socially undesirable or even reprehensible acts). They depict a sanitised and violence-free universe, which is not without consequence when we are interested in the relationships between humans and animals. In the 2010* Emploi du temps *survey, only one respondent confessed to hitting his cat, who was attacking his pen.*

8. Animals are referred to in the plural here for reasons of simplicity, but this applies equally in cases in which there is only one animal.

9. Using the two items relating to pets in the standard survey classification, the time spent on an animal activity by owners of at least one pet is 10 minutes per day. On average, every day, 19% of those aged 18 or older "perform" an animal activity. These "performers" spend an average of 51 minutes doing so. In addition, the new classification and re-classification increase the time dedicated to pets for single-parents and single people more than for other people. There is therefore a bias that is being corrected, which is not inconsequential for our subject since if we did not take it into account, we would be underestimating the time they spend with their animal more than for any other type of person.

10. In 1987, based on data from 1983, Héran demonstrated that the average number of animals per household did not increase as fast as household size (Héran, 1987). However, there is no more recent data allowing us to verify that this is still the case; at most, we can see that it is much less common for single people to have at least two different types of pets than for other people, but this does not rule out cases of them having two cats, two dogs or two animals of another type. Furthermore, it should be borne in mind that when a household has multiple animals, there are economies of scale in relation to the time spent caring for them (you can feed several animals or walk several dogs at the same time, etc.).

Table 2 – **Time dedicated to pets in 2010**

	Duration (in minutes)	Performance rate (as a %)	Duration per performer (in minutes)
Activities to look after pets	8	21	39
Care	5	12	38
Going out	3	11	31
Leisure activities performed with pets	5	9	49
Leisure walks	3	7	45
Other recreational activities	1	2	54
Total	13	22	58

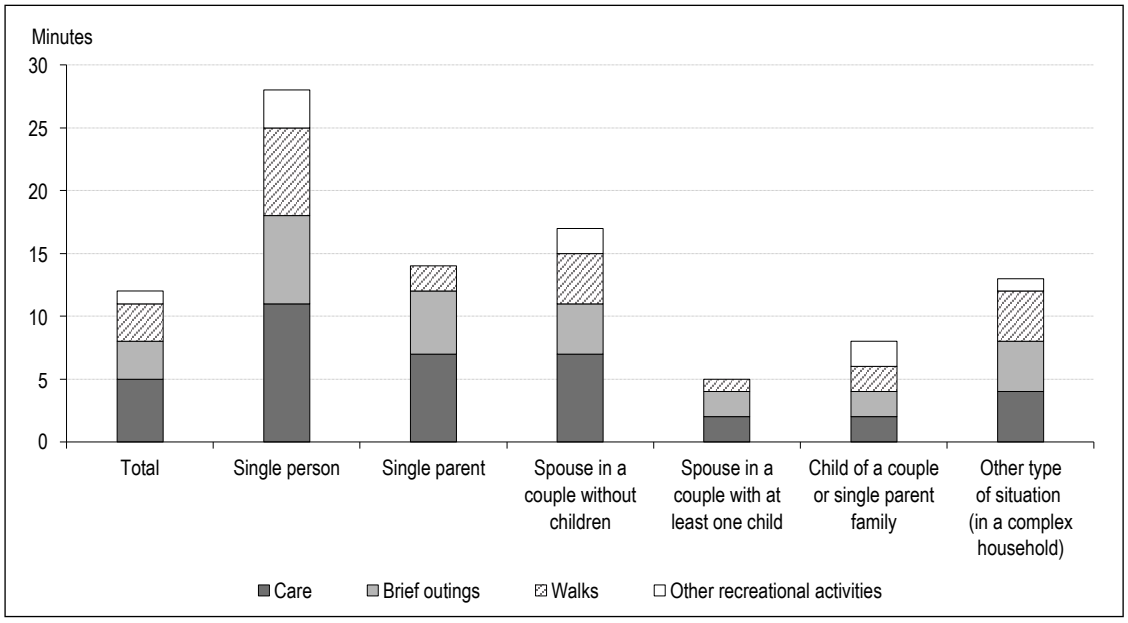
Reading note: People who own a pet dedicate an average of 13 minutes a day to it; 22% of people who own a pet dedicate time to it (58 minutes on average).
Sources and coverage: INSEE, 2010 *Emploi du temps* survey, France excluding Mayotte, people aged 18 or over living in a household with at least one pet.

Table 3 – **Individual characteristics and duration of activities related to pets**

	Dependent variable: duration of activities related to pets
Constant	−3.4* (1.9)
Age and employment status	
18 to 24	−1.4 (1.9)
25 to 49 - in employment	*Ref.*
25 to 49 - unemployed or non-working	2.0 (2.3)
50 to 64 - in employment	3.7*** (1.4)
50 to 64 - unemployed or non-working	8.2*** (1.8)
65 to 74	12.8*** (2.4)
75 or older	10.9*** (2.6)
Gender	
Women	*Ref.*
Men	0.2 (0.9)
Status in the household	
Single person	13.2*** (2.1)
Single parent	6.1** (2.6)
Spouse in a couple without children	3.8*** (1.5)
Spouse in a couple with at least one child	*Ref.*
Child of a couple or single-parent family (aged 18 or older)	2.9 (2.1)
Person belonging to a complex household	1.9 (2.1)

Notes: *Estimated coefficient significant at the 10% level; **estimated coefficient significant at the 5% level; ***estimated coefficient significant at the 1% level. Model: linear regression estimated by ordinary least squares with cluster-robust standard errors making it possible to take into account the non-independence between two diaries when they are completed by the same person. N = 13,451. Stewart (2013) has shown that multiple linear models are preferable for data from the *Emploi du temps* survey, even though the durations cannot be negative. The other variables taken into account in the model are the social group (7 options), the size of the urban area (6 options), the type of home (taking into account the presence of a garden, 9 options), the number of rooms in the dwelling (6 options), the geographical area of birth (6 options), limitations in daily life (4 options), the type of animal owned by the household (7 options), the day of the week (3 options: Saturday, Sunday or other), whether or not it is a day off work, the season (4 options), the weather (5 options), the number of diaries completed (2 options: 1 or 2) and the presence of a "Stiglitz column" (which reduces the space available to describe the activities).
Sources and coverage: INSEE, 2010 *Emploi du temps* survey, France excluding Mayotte, people aged 18 or over living in a household with at least one pet.

Figure I – **Time dedicated to pets by activity type and household type**



Reading note: Single people who own a pet dedicate an average of 28 minutes per day to it. Of those 28 minutes, 11 are for care.
Sources and coverage: INSEE, 2010 *Emploi du temps* survey, France excluding Mayotte, people aged 18 or over living in a household with at least one pet.

according to type of activity, making a distinction between activities to look after the animal (care and short walks) and leisure activities (long walks and recreational activities). Each day, 21% of owners perform activities related to looking after their animal (cf. Table 2), whether it be care (feeding, caring, cleaning their habitat, etc.) or taking them out briefly (for less than 20 minutes). In total, these activities last an average of 39 minutes. 9% of owners perform a leisure activity with their pet. Generally, this refers to walks, which take an average of three quarters of an hour during the day. However, a small fraction (2%) also reports, on average, 54 minutes of other leisure activities with their pet: a game, or simply the presence of an animal during a daily activity (relaxing, watching TV, etc.).

Single people dedicate more time to looking after their pet that is deemed "mandatory" (care and brief outings). In addition, the time spent on long walks or recreational activities is longer for single people (more than twice as long as for single parents and spouses in a couple with at least one child, and almost twice as long as for the spouses in a couple without children). Dedicating more time to these activities that are "intentionally shared" with the animal can be a sign of greater attachment. Overall, the study of the duration of activities performed with animals therefore gives rise to a conclusion that cannot be squared away: while single people less often have an animal, it is probably due to the constraints it creates; but when they do have an animal, they also spend more "intentionally shared" time with it.

3. Textual Analysis of the Vocabulary Used to Describe Activities Related to Pets

3.1. Vocabulary as a Demonstration of Bonds with the Animal

It is well-known that specific language is used to address animals (Hirsh-Pasek & Treiman, 1982). Mondémé (2018) has also shown that this language has common features with the language used to address children. By seeking "to identify, with the help of precise empirical work, the actual methods by which we call, address, or even hold strictly *conversational* modes of communication with pets", she showed that those modes "sometimes resemble the methods (relating to prosody, intonation, and sequence) used when speaking to very young children, but are sometimes entirely new" (Mondémé, 2018, p. 77).

Moreover, Morand & de Singly (2019) have shown that people who have the greatest "conversational proximity" to their animal (dog or cat), i.e. those who talk to and confide in them, are also the people who give their pet a nickname more often and the ones who "talk to others about it most often". It is therefore thought that there is a link between the different types of speech around pets (those who speak to them and those who talk about them). We do not have a body of texts from pet owners addressing their animals, but in the 2010 *Emploi du temps* survey, we have the exact terms they use to describe activities with their pets: this is the information collected in the diaries completed by the respondents to describe how they use their time, to which we returned to amend the classification of activities performed in the company of animals. By examining those descriptions, we can see that, for the same activity, the terms used are very different from one respondent to another, even though one might think that the space restrictions and binding framework that requires them to describe an entire day (often even two) in detail could lead to a strong degree of standardisation.

This is not the case, as the phrases reported differ greatly, e.g.: "Animal", "I chat with [first name] the parrot", "I cuddle the cat", "Woken up by the cat going out and fell back to sleep quickly", "Walk with my dog and my two daughters", "Visit to the canine specialist" and "Cleaning the aquarium".

There may be several causes for this diversity. First, the space provided to describe a 10-minute activity is not consistent across all diaries. The so-called "Stiglitz" diaries[11] have less space: this is the case for just under 10% of the diaries (Ponthieux, 2015) and must be taken into account in the analysis.

Second, as people we all express ourselves differently based on our social position, our level of education and our social background. Héran (1988) analyses activities performed with animals as cultural practices and shows that there are differences according to cultural capital: labourers and basic tertiary employees exhibit more authority, so it is to be expected that the vocabulary they use is reflective of that.

Finally, there is individual variability, which is in evidence for all activities reported. In the case

11. The "Stiglitz diaries" include an additional column so that respondents can rate their assessment of the pleasant or unpleasant nature of the activity (to meet the recommendations of Stiglitz et al.*, 2009). The space provided for respondents to describe their activities is reduced by the width of this column.*

of activities involving an animal, reading the diaries gives the impression that this diversity is potentially indicative of the relationship that the person has with their animal. For example, the following phrases from the 2010 survey all refer to feeding animals: "Feeding the animals", "I make lunch for the dogs", "I eat with my wife and dogs", "I prepare the cat's snack", "Preparing the meal for us and the dogs" and "I prepare noodles for my dog". The terms chosen are quite different ("feeding", "lunch", "meal" and "snack"), but they could be used for family meals and are more or less specific to the language used with other humans (in this sense, "meal" seems more "neutral" than "snack", i.e. less specifically human – at least on the surface). The grammatical choices are also different: "for the dogs", which sets the dogs apart, is a different choice from "for us and the dogs", which places the family and the animal on the same level; "making lunch for the dogs" separates the lunch of the animal from that of the family, while "I eat with my wife and my dogs" places the animal on the same level as the family.

We therefore get the impression that something is being played out in the choice of terms used, as well as in the choice of prepositions used ("with" or "for"), and in the way in which the animal receives grammatical treatment on an equal footing with their human entourage, or not. Some of these ways of expressing oneself to talk about animals are also more similar than others to the way we talk about children.

In order to go beyond this impression, we use textual analysis. Broadly speaking, this method compares the frequency with which terms are used to describe activities performed with animals to the frequency of terms used to describe other activities performed with the family and without animals (caring for children and adults, preparation and service of meals, walks, social interactions and games). When a term is widely used to describe activities performed without animals, but is rarely used to describe activities performed with animals, we infer that its use to describe an activity performed with animals denotes language that equates the animal to a member of the household; or, in any case, it denotes a bond with the animal that makes a less clear distinction between it and members of the household than when using a term that belongs exclusively to the vocabulary used to describe activities performed with animals. At the risk of an abuse of language that would at least have the virtue of clarity, it could be said that this is a way of identifying terms that denote an "anthropomorphic" vision of the pet.

Using such a definition, there are bound to be cases that will be considered "anthropomorphic". We are not seeking to define anthropomorphism "in itself", but as part of a comparison. What is unpredictable, however, is the scale of the results.

In the 2010 *Emploi du temps* survey, we have 726,601 (primary or secondary) activity descriptions provided by people aged 18 or older, 8,362 of which are directly related to animals. Compared to the corpora usually used in the social psychology or interactionist sociology literature that focuses on animal discourse, our corpus has the advantage of being very large and constructed from a representative sample of pet owners. In contrast, it does have the limitation that the analysed texts are short (no more than two handwritten lines). In particular, care should be taken with regard to interpretations to ensure that there are grammatical signs.

3.2. Signs Indicating the Extent to which the Animal is "Anthropomorphised"

From all the descriptions provided in the 1998 and 2010 surveys, we first extract an initial "animal" corpus, which includes the terms used to describe activities performed with animals by each person who described an activity involving a pet (Box 2). We then add to this "animal" corpus the terms that describe activities performed without animals, for activities that can be seen as the human counterpart of activities performed with animals: "Looking after children", "Educating children" (which includes playing with them), "Caring for adults", "Meal at home", "Cooking: preparing and cooking food, peeling vegetables", "Setting the table, serving the meal", "Walking" and "Social interaction". In the end, we obtain a corpus consisting of the expressions used to describe all these categories of activity and also of the expressions used to describe the activities performed with an animal.

The analysis was carried out using Iramuteq text analysis software. This software allows users to classify words or groups of words (nouns, adjectives or verbs) based on how typical they are to a category of the corpus: the more typical a term is to the category, the higher its "specificity" (to that category) (Box 3). Conversely, the more atypical they are to the category, the lower their "specificity" (to that category), which is highly negative. Knowing the law of distribution of specificities, we identify the most specific words or groups of words in the corpus, using a level of 1‰, 1% or 10%, as well as those that are least specific.

Box 2 – **Creation of The Corpus of Texts for Text Analysis Using Iramuteq**

The goal of our text analysis is to identify the words or groups of words that are at the same time typically used to describe activities performed without animals and those typically used to describe activities performed with animals. The wider the corpus used to identify these words, the more precise the analysis will be, as there will be fewer rare or isolated terms. We therefore use the two *Emploi du temps* surveys in which the activity descriptions are available, the surveys for 1998 and 2010. For this part of the analysis (and only this part), the fact that we cannot identify animal owners in 1998 is not important, since the coverage is the activities for which an animal is mentioned.

Our corpus consists of descriptions of activities classified in the following activity categories: care for children and adults, preparation and service of meals, walks, games and social interaction, as well as descriptions of activities related to pets, giving a total of 246,493 activity descriptions, including primary and secondary activities (i.e. texts).

This corpus was then prepared in accordance with the following protocol. First, we simplify the few descriptions that cover multiple activities. For example, with the activity description "I wake up, biscuits for the cat", we delete the "I wake up" part, which does not directly concern the animal. We then need to remove ambiguity to avoid confusion, such as between "groom" and "grooming"[(a)]. We remove function words (only verbs, nouns and adjectives are considered in the analysis), we correct spelling errors and we standardise text (nouns and adjectives switched to male and singular, verbs switched to the infinitive). We also identify "quasi-segments", i.e. expressions to be viewed as a single term ("give food", "take it out", "prepare the meal" and "make it do"). The terms that denote family members ("father", "son", "husband", "daughter", "son-in-law", etc.) are grouped together in four categories ("parent", "partner", "child" or "friend"); other people in the respondent's entourage are grouped together. Human and non-human first names are grouped together under a single lemma for first names.

These choices are not necessarily neutral (for example, those regarding the lemma), but where they were not, we proceeded on a case-by-case basis, to verify that each choice made did not distort the results.

In the same way, we create a corpus of "human" activity descriptions corresponding to the human counterpart of activities performed with animals: caring for children and adults, preparation and service of meals, walks, games and social interaction activities.

In the end, the corpus of 246,593 activity descriptions used in Iramuteq includes 392,294 occurrences (words). There is thus just over one word per activity description: for routine activities, respondents frequently use only one word ("meal", for example); and this, more than anything else, provides a good illustration of the preparation of the corpus, as detailed above.

The corpus contains 6,685 distinct words (called "forms"[(b)]). Among these, there are 3,419 hapax legomena (words appearing only once), corresponding to 51.1% of the "forms" of the corpus, and 0.9% of the words. The hapax legomena are rare words.

If we focus solely on the corpus of activities related to pets, for the years 1998 and 2010 there were 8,568 activity descriptions, including primary and secondary activities (i.e. texts), or 13,902 occurrences (words), representing 699 forms (different words). They include 378 hapax legomena, which represent 54.1% of the "forms" of the corpus and 2.7% of the words.

[(a)] A few lemmas are also created to group together certain similar terms (from the same family); a lemma is a term that groups together others that are deemed to be equivalent. However, this remains marginal.

[(b)] The distinction between a "form" and a "word" can be easily understood: in "dog dog" there are two words, but only one "form" (one "distinct word").

The words or groups of words that are farthest (within the meaning of this law of distribution) from activities performed with animals could be described as "anthropomorphic", at the risk of an abuse of language. Table 4-A lists these words, using three definitions that vary in terms of broadness, depending on the level chosen.

The same work can be done to compile a list of words or groups of words that are least characteristic of activities performed with animals compared to terms used solely for child care ("Looking after children") (Table 4-B). Following on from Hirsh-Pasek & Treiman (1982), Mondémé (2018) showed that the vocabulary used to address animals had common features with the vocabulary used to address children: we are therefore also testing this proximity. Again, at the risk of an abuse of language, which stretches the term but makes it possible to better exemplify the impression, we could describe this list (of terms that relate very closely to child care and relate very little to animal care), as "indicative of an animal being equated to a child".

The results are generally unsurprising. All terms that relate to conversations (conversation, discuss, talk and chat) are highly atypical of relationships with animals (meaning that they are rather "anthropomorphic"). For example, the term "conversation" is far removed from the vocabulary that is usually used for activities performed with animals (having a conversation with an animal is highly atypical), while it is highly typical for social interaction-related activities.

Box 3 – **Calculation of Specificities**

The Iramuteq software calculates a statistic indicating whether the occurrences of a "form" are over-represented (or under-represented) in one part of a corpus compared to the rest of the corpus.

In order to analyse the specificity of the occurrence of a "form" in one part of a corpus rather than in the rest of it, the relative frequency of the occurrence frequency of the "form" in the part concerned is compared to its occurrence frequency in the rest of the corpus.

We rate:

A: the appearance of the "form";

V: all the "forms" in the corpus (= vocabulary);

p: the part concerned;

f: the frequency with which the "form" appears in that part;

F: the total frequency with which the "form" appears in the corpus;

t: the size of the part (total number of occurrences in the part);

T: the size of the corpus (the total number of occurrences of the corpus).

In order to make a judgement regarding the result f, it must be compared with similar figures that correspond to all the samples composed of t items that can be taken from the starting population with the size T.

The calculation of the probability of a "form" A appearing f times in a part p with the size t, the "form" appearing F times overall in the whole corpus with size T, is based on the modelling provided for such calculations by Pierre Lafon (1980) and can be expressed formally using the following equation:

$$Prob_{spéci\ f}\left(card\left\{A \in V | A \in p\right\} = f\right) = \frac{C_F^f \times C_{T-F}^{t-f}}{C_T^t}$$

where $C_n^k = \frac{n!}{k!(n-k)!}$ is the number of samples of k elements among n elements.

The specificity score is the probability of the "form" appearing as many times as it is actually observed in the part concerned (i.e. f_{obs}) or even more frequently, up to the size of the part, following the hypergeometric law described by the equation above, which depends on f, t, F and T. Specifically, this measurement is obtained by adding together the probability values $Prob_{spéci\ f}$ for each possible occurrence frequency, in accordance with the following equation:

$$Prob_{spéci\ f}\left(card\left\{A \in V | A \in p\right\} \geq f_{obs}\right) = \sum_{f=f_{obs}}^{card\{A \in V | A \in p\}} Prob_{spéci\ f}\left(card\left\{A \in V | A \in p\right\} = f\right)$$

The macro provided with Iramuteq makes it possible to calculate the specificity score for different values of its parameters.

The specificity is shown by the integer part of the logarithms in base 10 (log10) of the specificity probability estimates, with the probabilities obtained by the calculations varying exponentially, as the name "hypergeometric" suggests.

By convention, the representation of under-specificity (or under-representation) is distinguished from that of over-specificity (or over-representation) by a minus sign (−) preceding the score. We will then focus on the low probabilities (therefore the high log10 values) that report:

- either fewer occurrences than expected, if the observation is less than the mode of theoretical distribution (i.e. if the number of occurrences of the event in the part concerned is less than the maximum probability estimated using our hypergeometric distribution modelling). This is what we refer to as under-specificity or negative specificity;
- or more occurrences than expected, if the observation is greater than the mode of theoretical distribution. This is what we refer to as over-specificity or positive specificity.

A value of 3.09 (or 2.33 and 1.28) means that there was a 1 in 1,000 chance (or a chance of 1 in 100 and 10 in 100) that the frequency of the "form" would be what it is in the part concerned, with the knowledge of what the frequency is in the rest of the corpus.

If we use the terms used to describe child care as a reference ("equating the animal to a child"), we will view the following words or groups of words as being highly atypical of relationships with animals: bathing, bottle feeding, putting to bed, showering, feeding, playing, lifting, bed, waking up, nap and watching (within the meaning of supervising). Included are activities such as watching TV, taking a nap or taking a walk, for example.

These results do not necessarily correspond to the preconceptions that one might have which, in retrospect, justifies the decision to use a statistical method, rather than intuition, to determine this list of terms that are highly atypical of activities performed with animals.

Table 4-A – **Least typical terms for activities performed with animals, in contrast to a set of activities performed without animals**

	Examples used to talk about animals	Occurrence	Specificity
Terms particularly typical of the vocabulary used for activities performed without animals (level 1/1,000)			
CONVERSATION	TV conversation with my dog	1	−9,999.00
DISCUSSING	Discussion with the dog	3	−9,999.00
PREPARING_MEAL	Preparation of the dogs' meal	108	−304.55
TELEVISION	I watch TV with my cats	9	−66.38
PREPARING	I prepare my dog for the day	61	−47.18
PUTTING TO BED	Putting animals to bed	6	−36.52
BOTTLE FEEDING	I get up to give the kittens a bottle	1	−20.79
BATHING	Bathe the dog, drying and brushing	2	−13.55
VEGETABLES	Preparation of fresh vegetables for the week for the rabbit	2	−10.87
TALKING	Talk a little with the dog	18	−8.88
SHOWERING	Shower the dog	3	−8.09
VISITING	Visit by the cat next door	5	−7.15
WAKING UP	The cat wakes us up I am woken up by the cat	19	−5.88
CHATTING	(This term was not used in the corpus for 2010, only in the one for 1998)	1	−4.92
MEAL	I serve the dogs' meal	140	−4.47
LEAVING	Leave to walk the dog	4	−4.06
LIFTING	I lift up the cat	7	−3.60
NAPPING	I take a nap with my dog	3	−3.11
Terms typical of the vocabulary used for activities performed without animals (level 1/100)			
LOOKING AFTER	I look after my dogs	26	−2.84
RETURNING	I tell off the dog that returned	3	−2.53
SERVING	Serving food to cat and dog	1	−2.38
Terms fairly typical of the vocabulary used for activities performed without animals (level 1/10)			
BED	Breakfast in bed with my dogs	2	−2.16
FEEDING	I feed my dogs	5	−1.80
WAKING_UP	I cuddle the cat who wakes me up	1	−1.74
PLAYING	I play with my dog I play with my cats	177	−1.58
DAY	I prepare my dog for the day	4	−1.52
PLACING	I place the dog in the car I place more drink for the dog	19	−1.49
WALKING_AROUND	I walk around the garden with the dog	7	−1.32
TAKING	I take the dog to drop off the mail	11	−1.31

Notes: The examples taken from the corpus use the exact terms used by the respondents. The calculations were performed using the Iramuteq software. The terms are classified according to the increasing "specificity", as calculated by Iramuteq.
Sources and coverage: INSEE, 1998 and 2010 *Emploi du temps* surveys, France excluding Mayotte, people living in a household for which the reference person is aged 18 or over, having reported at least one activity related to an animal, or one activity from among "Looking after the children", "Caring for adults", "Meal at home", "Cooking: preparing and cooking food, peeling vegetables", "Setting the table, serving the meal", "Walking", games and activities related to social interaction.

For example, "playing" is included in the list of "anthropomorphic" terms (at the 10% level) as well as in the list of terms "indicative of an animal being equated to a child" (from the 1/1,000 level onwards). It is therefore a term that is in widespread use to describe everyday life with children, meaning that it seems "anthropomorphic" when used in relation to an animal. This example allows for a better understanding of what our method identifies: it is not a case of identifying terms that can intuitively evoke the intention to treat the animal as a human, but terms used that happen to be the same as those used to describe or classify an activity that does not involve any animal, regardless of whether or not there is a conscious intention.

Another example is that of the terms "preparing the meal", or "meal", which are included in both the lists of "anthropomorphic" terms and the list of terms "indicative of equating an animal to a child". One might have thought that these were

Table 4-B – **Least typical terms for activities performed with animals, in contrast to child care activities**

	Examples used to talk about animals	Occurrence	Specificity
Terms particularly typical of the vocabulary used for activities performed without animals (level 1/1,000)			
PUTTING TO BED	Putting animals to bed	6	243.90
BOTTLE FEEDING	I get up to give the kittens a bottle	1	108.17
BATHING	Bathe the dog, drying and brushing	2	92.72
DISCUSSING	Discussion with the dog	3	81.25
WAKING UP	The cat wakes us up I am woken up by the cat	18	74.96
PREPARING	I prepare my dog for the day	49	54.05
LOOKING AFTER	I look after my dogs	21	52.15
SHOWERING	Shower the dog	3	49.17
PLAYING	I play with my dog I play with my cats	153	48.99
GROOMING	I help my wife to groom the dog	24	47.44
GIVING	I get up to give the kittens a bottle I give my dog care and his meal	52	43.96
FIRST NAME (= where a first name is used)	I come back from the sheep pen, playing with my little dog [first name] with her ball	45	42.21
LIFTING	I lift up the cat	7	32.90
NAPPING	I take a nap with my dog	3	22.14
CONVERSATION	TV conversation with my dog	1	19.30
BED	Breakfast in bed with my dogs	2	18.14
MINDING	I receive a visit from a friend who leaves me his cat to mind	1	16.35
COLLECTING	The neighbours came to collect their cat	6	13.94
PLACING	I place the dog in the car I place more drink for the dog	15	13.01
WASHING	I wash my dog	12	10.46
TAKING	I take the dog to drop off the mail	11	9.71
LEAVING	Leave to walk the dog	3	9.66
WAKING_UP	I cuddle the cat who wakes me up	1	9.32
MEAL	I serve the dogs' meal	128	8.76
LITTLE	Come back from the sheep pen playing with little dog [first name] with her ball	68	6.84
VISITING	Visit by the cat next door	5	6.80
ACTIVITY	Activities performed with the dog	1	5.18
SLEEPING	I sleep with my cats I sleep with my dog	7	5.02
PREPARING_MEAL	Preparation of the dogs' meal	97	4.60
DROPPING OFF	Dropping the dog off with my parents	7	3.80
KEEPING COMPANY	I keep my children's dog company at their home	3	3.48
TALKING	Talk a little with the dog	18	3.27
Terms typical of the vocabulary used for activities performed without animals (level 1/100)			
FEEDING	I feed the dog	23	2.62
BRUSHING	Brushing and meal for the cat I brush the dog	2	2.47
WAITING	Wait at the vet	3	2.43
Terms fairly typical of the vocabulary used for activities performed without animals (level 1/10)			
GOING_TO_BED	I go to bed with my dog	3	2.30
TAKING	Taking the dog to the vet	2	1.85
FINAL	Final time letting the dog out in the garden	4	1.84
TIME	Spend time with my dogs	3	1.72
RELAXING	Relaxing with my animals	1	1.72
PICKING UP	I go to pick up my dog from the vet	12	1.64

Notes: See Table 4-A.
Sources and coverage: INSEE, 1998 and 2010 *Emploi du temps* surveys, France excluding Mayotte, people living in a household for which the reference person is aged 18 or over, having reported at least one activity related to an animal, or one activity from the "Looking after the children" category.

generic terms, used in any context; but there are also terms typically reserved for animals, such as "feed" or even "give food". Speaking of "meals" would be indicative of a linguistic register more related to humans than animals.

Conversely, the term "cuddling" could, at first glance, be thought to refer to humans rather than animals, but the analysis of the corpus shows that it is, on the contrary, rather characteristic of activities with animals. It is therefore not included in our lists of "anthropomorphic" terms or terms "indicative of equating the animal to a child".

In addition to the two indicators mentioned above, we also explored other indicators that could reflect a way of expressing ourselves using terms far removed from those used mostly with animals, thus demonstrating a relationship with the animal that could be called "anthropomorphic": claiming that an activity is performed "with" a pet (for example, not "I walk my dog", but "I walk with my dog"); putting an animal on the same grammatical level as the human entourage ("I prepare my breakfast and my dog's breakfast", or "Looking after children and the dog"). We also consider saying "my animal", rather than "the animal" or "animal" (or rather than "the dog" or "dog", etc.), although it is important to be careful with the interpretation of such a linguistic sign, given that it is more legitimate for the animal's owner to say that than another member of the household (and therefore, it is in fact legitimate for a single person to say it).

3.3. Single People Use More Non-Animal Terms to Describe Activities Performed with Animals

With these indicators in mind, let us now return to the analysis of the corpus relating to people living in a household that owned at least one pet in 2010,[12] which contains the descriptions of their days by each respondent who reported at least one activity performed with an animal. Table 5 shows the proportion of people who have used one of the terms in the lists we have compiled or one of the specific terms or phrases described in the previous section at least once. Grammatical constructions that place animals and their human entourage on the same level are used by 4%, while between 20 and 25% use terms "indicative of equating the animal to a child" and 26% use the possessive term "my". Finally, about 12–13% use a term from the list that could be described as "anthropomorphic", or "non-animal".

12. We established lists of "non-animal" terms based on activity descriptions from 1998 and 2010, but the analysis can only cover 2010, the only year for which we know if people were living in a household that has at least one pet.

Table 5 – **The use of atypical terms in the language used to describe activities performed with animals**

As a %

	Use of the possessive adjective MY (animal)	Use of the preposition WITH (animal)	Human/non-human grammatical identity	Use of "anthropomorphic" vocabulary			Use of vocabulary typical of child care		
				At the limit of 1 per 1,000	At the limit of 1 per 100	At the limit of 1 per 10	At the limit of 1 per 1,000	At the limit of 1 per 100	At the limit of 1 per 10
Population as a whole	26.1	17.9	4.0	11.7	12.0	13.3	19.6	22.4	24.3
Female	28.3	17.6	5.0	14.7	15.2	16.9	24.9	27.9	28.7
Male	23.3	18.4	2.6	7.8	8.0	8.8	12.8	15.3	18.6
Single person	39.2	20.6	6.4	21.6	21.7	22.9	28.0	33.4	34.4
Single parent	26.1	6.3	6.8	3.9	3.9	6.7	13.4	13.4	15.5
Spouse in a couple without children	25.4	17.9	3.3	10.6	10.9	12.3	19.6	22.0	23.6
Spouse in a couple with at least one child	16.5	13.8	5.4	10.5	10.5	10.9	18.1	21.1	21.7
Child of a couple or single parent family	35.0	23.4	2.5	3.3	5.1	5.1	18.0	20.8	29.9
Other type of complex household circumstances	16.6	18.1	1.5	10.7	10.7	13.5	14.0	14.8	15.2

Reading note: Among people included in the coverage who have spoken about their pet(s) at least once in the diary they have completed, or in at least one of the two diaries when they have completed two, 26.1% used the expression "my animal" (or "my dog", etc.) at least once.
Sources and coverage: INSEE, 2010 *Emploi du temps* survey, France excluding Mayotte, people aged 18 or over living in a household that owns at least one pet and who mentioned an animal in the description of the day.

These figures show that the lists of "anthropomorphic" words or words "indicative of equating the animal to a child" that we have constructed include words used by a significant proportion of the population: the text analysis software has not designated these ways of expressing oneself in relation to animals as atypical of the way of talking about activities performed with animals because they are very rare, but because they are much more common when not talking about animals than when talking about them.

Beyond these averages, women use more "non-animal" terms or constructions to talk about animals than men do, across almost all indicators. This is also true of single people more than others, while people aged 65 to 74, who could be described as young retirees, as well as young people aged 18 to 24 are more likely to use terms "typical of child care".

The fact that single people use "non-animal" language significantly more than others when talking about activities performed with animals could lean towards confirming the hypothesis that they have a greater attachment to their animals than other people because they are alone. However, single people are also more likely to be women and are more often elderly, categories that also use this "non-animal" language more than others.

3.4. Other Characteristics Being Equal, Single People Do Not Exhibit Signs of a Stronger Attachment to the Animal

Working on a large sample makes it possible to put things into perspective, which is generally not possible for social psychology studies, the findings of which align with ours, based on more sophisticated indicators. It also makes it possible

Box 4 – **Probit Model with Selection Taken into Account**

We find that the tendency for a person to behave towards an animal as though it were a human can be explained by a set of factors such as gender, household type and socio-professional category.

As this tendency is not directly observable, the dependent variable is a dichotomous variable with a value of 1 if the person used a term from an anthropomorphic register to describe an activity performed with their animal or a value of 0 otherwise:

$$anthro_i = \begin{cases} 1 \text{ if } \beta_0 + \beta_1 x_i + u_i > 0 \\ 0 \text{ otherwise} \end{cases}$$

where x_i represents all the characteristic variables of the individual i that might explain their tendency to behave towards their animal as they would towards a human and u_i represents an error term.

This simple regression model assumes that the explanatory variables are independent of the error term. It is generally assumed that x_i is exogenous, that is to say that $E(u_i|x_i) = 0$.

The above equation is estimated for the sample of owners who mentioned their pet at least once in the description of their day's activities. We do not actually see the use of the anthropomorphic register for all people with a pet, but only a selection of them; those who mentioned their pet. We estimate the following system of equations in order to take into account this selection, which can distort the results:

$$anthro_i = \begin{cases} 1 \text{ if } \beta_0 + \beta_1 x_i + u_i > 0 \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

$$parleranimal_i = \begin{cases} 1 \text{ if } \gamma_0 + \gamma_1 x_i + \gamma_2 z_i + v_i > 0 \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

where equation (2) takes account of selection. The selected variable z_i, referred to as the exclusion variable, is a variable with ten options, combining the quintile of the number of lines completed in the diary with the number of completed diaries. In order to create it, we first defined the quintiles for the distribution of the number of lines of those who completed a diary, then the quintiles for the distribution of the number of lines of those who completed two diaries; then we combined these results into a single variable with five options. Thus, regardless of the number of diaries completed, being in the first quintile means that a person was not very precise in the description of their day (compared to the other people who described a day), or not very precise in the description of the two days (compared to the people who described two days), etc. In addition, distinguishing between people based on the number of diaries completed makes it possible to retain this information, which remains important for explaining whether or not the person mentioned their pet in the description of the day or days.

The variable obtained in this manner is closely correlated with the person mentioning their animal in the diary: we note that the more detailed the diary is, the higher the probability of the person referring to their pet. We assume that the number of lines completed in the diary has no direct effect on the person using anthropomorphic vocabulary when talking about their animal.

to take into account socio-demographic characteristics that are known to affect the way people express themselves, such as socio-professional category. It is also possible to take into account that not all animal owners report performing at least one activity with their animal when describing their day; in particular, single people are systematically over-represented among those who do report performing an activity, because they are unable to share those activities with other household members (Box 4).

We estimated two models for the use of an "anthropomorphic" term on the one hand, and a term "indicative of equating the animal to a child", on the other,[13] together with three models explaining the use of the other linguistic signs mentioned above (Table 6).

13. The two models presented here are based on the use of a term from the lists significant at the 1‰ level; those based on the use of a term from the lists significant at the levels of 1% and 10% are presented in the Online Appendix (link at the end of the article). They provide similar results.

Table 6 – **Models explaining the use of atypical terms in the language used to describe activities performed with animals**

	Variable explained: use (over the course of a day) of at least...				
	... a term from a register that is highly atypical of the register used with animals and typical of the one used for...		... one time...		
	... other activities performed without animals...	... child care...	... the possessive adjective MY (animal)	... the preposition WITH (animal)	... a human/ non-human grammatical identity
	... in the list of terms with significant specificity at the level of 1 per 1,000				
Constant	−0.39 (0.32)	0.10 (0.25)	−0.66** (0.29)	−1.10*** (0.33)	0.08 (0.36)
Age					
18 to 24	−0.10 (0.24)	0.39** (0.16)	0.31* (0.17)	0.06 (0.19)	−0.05 (0.31)
25 to 64	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
65 or over	0.28*** (0.10)	0.19** (0.09)	−0.06 (0.09)	0.03 (0.09)	0.22* (0.13)
Gender					
Male	−0.22*** (0.08)	−0.23*** (0.07)	−0.13* (0.07)	0.05 (0.07)	−0.04 (0.11)
Female	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Status in the household					
Single person	0.05 (0.17)	−0.16 (0.14)	0.49*** (0.16)	0.10 (0.17)	−0.34* (0.19)
Single parent	−0.16 (0.30)	−0.05 (0.24)	−0.18 (0.26)	−0.26 (0.32)	0.10 (0.30)
Spouse in a couple without children	−0.12 (0.13)	−0.10 (0.11)	0.13 (0.12)	0.14 (0.13)	−0.50*** (0.15)
Spouse in a couple with at least one child	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Child of a couple or single parent family	−0.12 (0.36)	0.16 (0.24)	0.09 (0.26)	0.43* (0.26)	0.12 (0.33)
Other type of complex household circumstances	0.01 (0.15)	−0.16 (0.12)	0.06 (0.13)	0.17 (0.14)	−0.42** (0.19)
Pets owned by the household					
Cat(s) only	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Dog(s) only	−0.39*** (0.12)	−0.50*** (0.10)	0.17 (0.12)	0.33** (0.14)	−0.59*** (0.13)
Other configurations	−0.31*** (0.10)	−0.38*** (0.09)	0.01 (0.10)	0.14 (0.12)	−0.52*** (0.13)
rho	−0.50*** (0.12)	−0.57*** (0.09)	−0.17 (0.13)	−0.38*** (0.13)	−0.76*** (0.09)

Notes: The robust standard errors are shown in brackets. *estimated coefficient significant at the 10% level; **significant at the 5% level; ***significant at the 1% level. Instrumental variable that is "explanatory" of the way people talk about their animals: ten options that combine the quintiles for number of lines completed and number of diaries completed (one or two). The other variables included in the models are social group (9 options), geographical area of birth (6 options), limitations in daily life (3 options), size of the urban area (6 options), whether or not there is a garden, the number of rooms in the dwelling (2 options), the number of diaries completed and the presence of a "Stiglitz column".
Sources and coverage: INSEE, 2010 *Emploi du temps* survey, France excluding Mayotte, people aged 18 or over living in a household with at least one pet.

As regards the use of "anthropomorphic" terms or terms "indicative of equating the animal to a child", these models show that women use such terms more often, as do people aged 65 or older. This type of vocabulary is also used significantly more by managers in the private sector and people with a garden. These aspects are more difficult to interpret, but they are found in all models. The only result for which all models are not aligned is age: the youngest people, those aged 18 to 24, use terms indicative of "equating the animal to a child" even more than older people, but that is not the case regarding the use of "anthropomorphic" terms.

Our data do not allow us to systematically determine which type of animal people are talking about when describing their activities, whether it is a cat, a dog or another animal. However, it can be determined in some cases, when the person has only cats or dogs. All other things being equal, the various signs of anthropomorphisation are found more often when the household has only cats. The only notable exception is that performing an activity "with" a pet is reported much more frequently when the household has only dogs. On this basis, it will be concluded that this indicator is not like the others, but serves as a reminder that we do not necessarily develop the same type of bond with different types of pets (Doré *et al.,* 2019), even though we cannot take this into account in our study.

Finally, assuming that all other things are equal, particularly gender, age, social group and where the respondent lives, living alone does not increase the probability of using a term included on these lists.[14]

* *
*

Our study is a reminder that single people have a pet less often than others, but it also shows that single people who do have a pet spend more time with it, including playing or long walks. In addition, they are more likely than others to use vocabulary from a register that could be characterised as "anthropomorphic" to describe the activities they perform with animals in their daily lives. However, we also show that women and older people use this "anthropomorphic" linguistic register more than others. The fact that women and the elderly are more likely to be single explains why those groups use "anthropomorphic" language more than others. Our data therefore do not confirm the theory that people living alone have a greater attachment to their animal.

The literature addresses the question of people's attachment to their pet from an emotional angle, linking it in particular to whether or not a person lives alone. Our results suggest that it is more of a gender issue. Therefore, this reframes the subject as one that falls into the division of domestic work, which is still more often performed by women, including when they are single. This suggests in particular that our study could contribute to the field of studies on care by including time dedicated to pets. □

14. Leaving aside the notion of all other things being equal, saying "my" animal is more common for single people: the reasons for this are obvious.

Link to the Online Appendix:
www.insee.fr/en/statistiques/fichier/8260969/ES543_Brousse-Bodier_OnlineAppendix.pdf

BIBLIOGRAPHY

Archer, J. (1997). Why Do People Love Their Pets? *Evolution and Human Behavior*, 18(4), 237–259. https://doi.org/10.1016/S0162-3095(99)80001-4

Arluke, A. B. (1988). Sacrificial Symbolism in Animal Experimentation: Object or Pet? *Anthrozoös*, 2(2), 98–117. https://doi.org/10.2752/089279389787058091

Arluke, A. (1990). Moral evaluation in medical research. *Advances in Medical Sociology*, 1, 189–204. https://pubmed.ncbi.nlm.nih.gov/11660597/

Becker, G. S. (1973). A Theory of Marriage: Part I. *Journal of Political Economy*, 81(4), 813–846. http://www.jstor.org/stable/1831130

Becker, G. S. (1974). A Theory of Marriage: Part II. *Journal of Political Economy*, 82(2), S11–S26. http://www.jstor.org/stable/1829987

Brousse, C. (2015). La vie quotidienne en France depuis 1974. Les enseignements de l'enquête *Emploi du temps*. *Économie et Statistique*, 478-480, 79–117. https://doi.org/10.3406/estat.2015.10559

Brousse, C. & Bodier, M. (2024). La place des animaux dans la vie quotidienne : une lecture à travers les enquêtes Emploi du temps. Insee, *Document de travail*.

Claidière, N. & Guillo, D. (2016). Comment articuler les sciences de la vie et les sciences sociales à propos des relations humains / animaux ? Un modèle interactionniste et évolutionniste. *L'Année sociologique*, 66, 385–420. https://doi.org/10.3917/anso.162.0385

Digard, J.-P. (1998). *Les Français et leurs animaux*. Paris : Fayard.

Doré, A., Michalon, J. & Líbano Monteiro, T. (2019). Place et incidence des animaux dans les familles. *Enfances Familles Générations*, 32. http://journals.openedition.org/efg/6980

Epley, N., Akalis, S., Waytz, A. & Cacioppo, J. T. (2008). Creating Social Connection Through Inferential Reproduction: Loneliness and Perceived Agency in Gadgets, Gods, and Greyhounds. *Psychological Science*, 19(2), 114–120. https://doi.org/10.1111/j.1467-9280.2008.02056.x

Gilbey, A. & Tani, K. (2015). Companion Animals and Loneliness: A Systematic Review of Quantitative Studies. *Anthrozoös*, 28(2), 181–197. https://doi.org/10.1080/08927936.2015.11435396

Guillo, D. (2009). *Des chiens et des humains*. Coll. « Mélétè ». Paris : Le Pommier.

Héran, F. (1987). Les animaux domestiques. Insee, *Données sociales*, 417–423.

Héran, F. (1988). Comme chiens et chats : Structures et genèse d'un conflit culturel. *Ethnologie Française*, 18(4), 325–337. http://www.jstor.org/stable/40989067

Herpin, N., Grimler, G. & Verger, D. (1991). Les Français et leurs animaux familiers : des dépenses en forte hausse. *Economie et Statistique*, 241, 53–63. https://doi.org/10.3406/estat.1991.5554

Herpin, N. & Verger, D. (1992). Sont-ils devenus fous ? La passion des Français pour les animaux familiers. *Revue Française de Sociologie*, 33(2), 265–286. https://doi.org/10.2307/3321997

Herpin, N. & Verger, D. (2016). La possession d'animaux de compagnie en France : une évolution sur plus de vingt ans expliquée par la sociologie de la consommation. *L'Année sociologique*, 66, 421–466. https://doi.org/10.3917/anso.162.0421

Hirsh-Pasek, K. & Treiman, R. (1982). Doggerel: Motherese in a New Context. *Journal of Child Language*, 9(1), 229–237. https://doi.org/10.1017/S0305000900003731

Lafon, P. (1980). Sur la variabilité de la fréquence des formes dans un corpus. *Mots*, 1, 127–165. https://doi.org/10.3406/mots.1980.1008

Lemel, Y. (1982). Activités primaires et secondaires : analyse de contenu des dossiers de l'enquête Emploi du temps : 1974-1975. Insee, *Document de travail*.

Mondémé, C. (2018). Comment parle-t-on aux animaux ? Formes et effets pragmatiques de l'adresse aux animaux de compagnie. *Langage et société*, 163, 77–99. https://doi.org/10.3917/ls.163.0077

Morand, E. & de Singly, F. (2019). Sociologie d'une forte proximité subjective au chat, au chien. *Enfances, Familles, Générations*, 32. https://doi.org/10.7202/1064510ar

Ponthieux, S. (2015). Introduction. Les enquêtes *Emploi du temps* : une source majeure pour l'étude des inégalités sociales et de genre. *Économie et Statistique*, 478-479-480, 59–77. https://doi.org/10.3406/estat.2015.10558

Sanders, C. R. (1993). Understanding dogs: Caretakers' Attributions of Mindedness in Canine-Human Relationships. *Journal of Contemporary Ethnography*, 22(2), 205–226. https://doi.org/10.1177/089124193022002003

Scoresby, K. J., Strand, E. B., Ng, Z., Brown, K. C., Stilz, C. R., Strobel, K., Barroso, C.S. & Souza, M. (2021). Pet Ownership and Quality of Life: A Systematic Review of the Literature. *Veterinary Sciences*, 8(12), 332. https://doi.org/10.3390/vetsci8120332

Stewart, J. (2013). Tobit or not Tobit*? Journal of Economic and Social Measurement*, 38(3), 263–290. https://content.iospress.com/articles/journal-of-economic-and-social-measurement/jem00376

Stiglitz, J., Sen, A. & Fitoussi, J.-P. (2009). Rapport de la Commission sur la mesure des performances économiques et du progrès social. https://medias.vie-publique.fr/data_storage_s3/rapport/pdf/094000427.pdf

Yonnet, P. (1983). L'homme aux chats : Zoophilie et déshumanisation. *Le Débat*, 27, 111–126. https://doi.org/10.3917/deba.027.0111

N° 542 (2024)

ÉCONOMIE DE LA SANTÉ / HEALTH ECONOMICS

• Introduction – De la théorie à la pratique et vice versa ou comment les économistes contribuent à comprendre et à améliorer le système de santé / *Introduction – From Theory to Practice and Vice Versa or How Economists Contribute to Understanding and Improving the Healthcare System* – Thomas Barnay & David Crainich

INÉGALITÉS ET VULNÉRABILITÉ / INEQUALITIES AND VULNERABILITY

• La répartition géographique des internes en médecine générale : un outil de régulation des lieux d'installation ? / *Geographical Distribution of Interns in General Practice: A Tool for Regulating Place of Settlement?* – Julien Silhol

• Comment prendre en compte le coût supplémentaire lié au handicap dans la mesure du niveau de vie des ménages en France ? / *How Can the Additional Cost Due to Disability Be Taken Into Account When Measuring the Standard of Living of Households in France?* – Thomas Blavet

• Le reste à charge en santé nuit-il à l'équité dans le financement des soins ? Une comparaison des systèmes de santé en Europe / *Do Out-Of-Pockets Undermine Equity in Healthcare Financing? A Comparison of Healthcare Systems in Europe* – Florence Jusot & Adèle Lemoine

CONSOMMATION DE SOINS ET PRÉVENTION / HEALTH CARE CONSUMPTION AND PREVENTION

• L'impact d'un programme social sur la consommation de soins des travailleurs indépendants âgés en France / *The Impact of a Social Programme on the Healthcare Consumption of Elderly Self-Employed Workers in France* – Estelle Augé & Nicolas Sirven

• Impact d'Internet haut débit sur les comportements préventifs en matière de santé au Sénégal / *Impact of Broadband Internet on Preventive Healthcare Behaviors in Senegal* – Pauline Kergall & Jean-Baptiste Guiffard

EHPAD ET HÔPITAL / EHPADs AND HOSPITAL

• Effet de l'aide informelle fournie par leurs enfants sur la santé des personnes âgées en maison de retraite / *The Effect of Informal Care Provided by Children on Health in Nursing Homes* – Quitterie Roquebert

• Inciter à prescrire des médicaments biosimilaires : évaluation d'une expérimentation de partage de gains entre les hôpitaux et l'Assurance maladie en France / *Biosimilar Prescribing Incentives: Results of a French Pilot of Gainsharing Between Hospitals and the National Health Insurance* – Vincent Attia, Mathilde Gaini, Edouard Maugendre & Catherine Pollak

N° 541 (2023)

• Discriminations dans l'accès à l'emploi : les effets croisés du genre, de l'origine et de l'adresse / *Discrimination in Access to Employment: The Combined Effects of Gender, Origin and Address* – Sylvain Chareyron, Yannick L'Horty & Pascale Petit

• La régulation des prix des alcools en France : quel scénario de réforme pour une politique proportionnée aux objectifs de santé publique et d'équité fiscale ? / *Alcohol Price Regulation in France: Choosing a Reform Scenario to Achieve Public Health and Tax Fairness Objectives* – Sébastien Lecocq, Valérie Orozco, Christine Boizot-Szantai, Céline Bonnet & Fabrice Etilé

• Les stéréotypes de genre en Europe / *Gender Stereotypes in Europe* – Clotilde Coron

• La non-imposition des loyers imputés : un cadeau pour Harpagon ? Une estimation dans le cas de la France / *Non-Taxation of Imputed Rent: A Gift to Scrooge? Evidence from France* – Montserrat Botey & Guillaume Chapelle

N° 540 (2023)

• Qui est mieux classé que ses parents dans l'échelle des revenus ? Une analyse de la mobilité intergénérationnelle en France / *Who Climbs Up the Income Ladder? An Analysis of Intergenerational Income Mobility in France* – Michaël Sicsic

• Les délocalisations jouent-elles encore un rôle dans le déclin de l'emploi industriel ? / *Does Offshoring Still Play a Role in the Decline in Manufacturing Employment?* – Camille Beaurepaire & Victor Lavialle

• Aides publiques et performances des entreprises nées mondiales / *Public Aid and the Performance of Born Globals* – Flora Bellone, Catherine Laffineur & Sophie Pommet

• Brexit et exportations agricoles et alimentaires bretonnes / *Brexit and Breton Agricultural and Food Exports* – Angela Cheptea, Marilyne Huchet & Lucile Henry

N° 539 (2023)

• Au-delà du PIB : une évaluation de la croissance du bien-être monétaire dans 14 pays européens et aux États-Unis / *Beyond GDP: A Welfare-Based Estimate of Growth for 14 European Countries and the USA Over Past Decades* – Jean-Marc Germain

• Produits numériques gratuits et mesures agrégées de l'activité économique / *Free Digital Products and Aggregate Economic Measurement* – Diane Coyle & David Nguyen

TÉLÉTRAVAIL ET PRODUCTIVITÉ / TELEWORK AND PRODUCTIVITY

• Les liens entre télétravail et productivité pendant et après la pandémie de Covid-19 / *The Role of Telework for Productivity During and Post COVID-19* – Chiara Criscuolo, Peter Gal, Timo Leidecker, Francesco Losma & Giuseppe Nicoletti

• Télétravail et productivité avant, pendant et après la pandémie de Covid-19 / *Telework and Productivity Before, During and After the COVID-19 Crisis* – Antonin Bergeaud, Gilbert Cette & Simon Drapala

• Commentaire – Télétravail et productivité trois ans après les débuts de la pandémie / *Comment – Telework and Productivity Three Years After the Start of the Pandemic* – Pierre Pora

N° 538 (2023)

VIEILLISSEMENT ET RETRAITE / AGEING AND RETIREMENT

• Vieillissement, retraites et dépendance – Introduction / *Ageing, Pensions and Dependency – Introduction* – Didier Blanchet

• Dynamique du processus de perte d'autonomie dans les populations vieillissantes / *Dynamic of the Disablement Process in Ageing Populations* – Mahdi Ben Jelloul, Antoine Bozio, Elsa Perdrix, Audrey Rain & Léa Toulemon

• Le recours aux établissements pour personnes âgées en France (2008-2015) : le rôle de l'entourage familial / *Institutional Long-Term Care Use in France (2008-2015): The Role of Family Resources* – Amélie Carrère, Emmanuelle Cambois & Roméo Fontaine

• Effets sur la consommation de soins d'un report de l'âge de départ à la retraite annoncé en fin de carrière / *The Health-Consumption Effects of Increasing Retirement Age Late in the Game* – Eve Caroli, Catherine Pollak & Muriel Roger

• Le droit à l'information sur la retraite introduit par la réforme de 2003 rend-il les Français mieux informés et moins inquiets quant à leur future retraite ? / *Does the Right to Information on their Pension Introduced by the 2003 Reform Make the French Better Informed and Less Concerned about their Future Pension?* – Luc Arrondel, Loïc Gautier, Aurélie Lemonnier & Laurent Soulat

• Les perspectives financières du système de retraite et du niveau de vie des retraités à l'horizon 2070 / *Financial Outlook for the Pension System and the Standard of Living of Pensioners by 2070* – Frédérique Nortier-Ribordy

N° 536-37 (2022)

DOSSIER THEMATIQUE / THEMATIC SECTION

• Travail domestique et parental au fil des confinements en France : comment ont évolué les inégalités socio-économiques et de sexe ? / *Housework and Parenting during the Lockdowns in France: How Have Socio-Economic and Gender Inequalities Changed?* – Ariane Pailhé, Anne Solaz, Lionel Wilner & l'équipe EpiCov

• Les couples pendant le confinement : « La vie en rose » ? / *Couples in Lockdown: "La vie en rose"?* – Hugues Champeaux & Francesca Marchetta

• *Commentaire* – La crise du Covid-19 a-t-elle contribué à modifier la division du travail selon le genre au sein des familles ? / Comment – *Did the COVID-19 Crisis Contribute to a Change in the Gender-Based Division of Work within Families?* – Hélène Couprie

• Migrations résidentielles et crise de la Covid-19 : vers un exode urbain en France ? / *Residential Migration and the COVID-19 Crisis: Towards an Urban Exodus in France?* – Marie-Laure Breuillé, Julie Le Gallo & Alexandra Verlhiac

• Covid-19 et dynamique des marchés de l'immobilier résidentiel en France : une exploration / *COVID-19 and Dynamics of Residential Property Markets in France: An Exploration* – Sylvain Chareyron, Camille Régnier & Florent Sari

• Une analyse territoriale de l'impact de la crise sanitaire de 2020 sur la masse salariale du secteur privé : effets structurels et effets locaux / *Regional Analysis of the Impact of the 2020 Health Crisis on the Private-Sector Wage Bill: Structural and Local Effects* – Mallory Bedel-Mattmuller, Fadia El Kadiri & Lorraine Felder Zentz

ARTICLE

• Le déficit protéique français – Une analyse prospective / *Protein Deficit in France – A Prospective Analysis* – Alexandre Gohin & Alice Issanchou

Economie et Statistique / Economics and Statistics

Objectifs généraux de la revue

Economie et Statistique / Economics and Statistics publie des articles traitant de tous les phénomènes économiques et sociaux, au niveau micro ou macro, s'appuyant sur les données de la statistique publique ou d'autres sources. Une attention particulière est portée à la qualité de la démarche statistique et à la rigueur des concepts mobilisés dans l'analyse. Pour répondre aux objectifs de la revue, les principaux messages des articles et leurs limites éventuelles doivent être formulés dans des termes accessibles à un public qui n'est pas nécessairement spécialiste du sujet de l'article.

Soumissions

Les manuscrits doivent être adressés au secrétariat de la revue (redaction-ecostat@insee.fr), de préférence en format MS-Word. Il doit s'agir de travaux originaux, qui ne sont pas soumis en parallèle à une autre revue. Les articles peuvent être soumis en français ou en anglais. Le texte d'un article standard fait environ 11 000 mots en français (y compris encadrés, tableaux, figures, annexes et bibliographie, non compris d'éventuelles annexes en ligne). Aucune proposition initiale de plus de 12 500 mots (11 500 mots pour les soumissions en anglais) ne sera examinée.

La soumission doit comporter deux fichiers distincts :

- Un fichier d'une page indiquant : le titre de l'article ; les prénom, nom, affiliations (maximum deux) et adresses e-mail et postale de chaque auteur ; un résumé de 160 mots maximum (140 mots pour les soumissions en anglais) qui doit présenter très brièvement la problématique, indiquer la source et donner les principaux axes et conclusions de la recherche ; les codes JEL et quelques mots-clés ; d'éventuels remerciements.
- Un fichier anonymisé du manuscrit complet (texte, illustrations, bibliographie, éventuelles annexes) indiquant en première page uniquement le titre, le résumé, les codes JEL et les mots-clés.

Les propositions retenues sont évaluées par deux à trois rapporteurs (procédure en « double-aveugle »). Les articles acceptés pour publication devront être mis en forme suivant les consignes aux auteurs (accessibles sur https://www.insee.fr/fr/information/2410168). Ils pourront faire l'objet d'un travail éditorial visant à améliorer leur lisibilité et leur présentation formelle.

Publication

Les articles sont publiés en français dans l'édition papier et simultanément en français et en anglais dans l'édition électronique. Celle-ci est disponible, en accès libre, sur le site de l'Insee, le jour même de la publication ; cette mise en ligne immédiate et gratuite donne aux articles une grande visibilité. La revue est par ailleurs accessible sur le portail francophone Persée, et référencée sur le site international Repec et dans la base EconLit.

Main objectives of the journal

Economie et Statistique / Economics and Statistics publishes articles covering any micro- or macro- economic or sociological topic, either using data from public statistics or other sources. Particular attention is paid to rigor in the statistical approach and clarity in the concepts and analyses. In order to meet the journal aims, the main conclusions of the articles, as well as possible limitations, should be written to be accessible to an audience not necessarily specialist of the topic.

Submissions

Manuscripts should be sent to the editorial team (redaction-ecostat@insee.fr), preferably in MS-Word format. The manuscript must be original work and not submitted at the same time to any other journal. It can be submitted either in French or in English. The standard length of an article is of about 10,000 words (including boxes if any, tables, figures, appendices, bibliography, but not counting online appendices if any). Manuscripts of more than 11,500 words will not be considered. Submissions must include two separate files:

- A one-page file providing: the title of the article; the first name, name, affiliation-s (at most two), e-mail et postal addresses of each author; an abstract of maximum 140 words, briefly presenting the research question, data and methodology, and the main conclusions; JEL codes and a few keywords; acknowledgements if any.
- An anonymised manuscript (including the main text, illustrations, bibliography and appendices if any), mentioning only the title, abstract, JEL codes and keywords on the front page.

Proposals that meet the journal objectives are reviewed by two to three referees ("double-blind" review). The articles accepted for publication will have to be presented according to the guidelines for authors (available at https://www.insee.fr/en/information/2591257). They may be subject to editorial work aimed at improving their readability and formal presentation.

Publication

The articles are published in French in the printed edition, and simultaneously in French and in English in the online edition. The online issue is available, in open access, on the Insee website the day of its publication; this immediate and free online availability gives the articles a high visibility. The journal is also available online on the French portal Persée, and indexed in Repec and EconLit.

N° 543 - 2024

Economie ET Statistique

Economics AND Statistics

ISBN 978-2-11-162445-0 - ISSN 0336-1454 - ECO 543
Parution octobre 2024 - PRIX : 22 €