MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# CUADERNOS ECONÓMICOS

Número 104 • 2022/II

# La transición a sociedades descarbonizadas

# *The transition to a decarbonized society*

2022 CALIDAD REVISTAS CIENTÍFICAS ESPAÑOLAS
GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN | FECYT INNOVACIÓN
FECYT-457/2022
Fecha de certificación: 7ª convocatoria (2021)
Válido hasta: 22 de julio de 2023

**EDICIÓN Y REDACCIÓN**
Ministerio de Industria, Comercio y Turismo
Secretaría de Estado de Comercio
Paseo de la Castellana, 162. Planta 12. 28046 Madrid
Teléfonos 91 349 6053 / 91 349 2548

**DISTRIBUCIÓN**
Ministerio de Industria, Comercio y Turismo
Centro de Publicaciones
Calle Panamá, 1. Planta 0, despacho 3. 28036 Madrid
Teléfonos: 91 349 5129 / 91 349 5133 / 91 349 4335
CentroPublicaciones@mincotur.es
*www.revistasice.com*

Esta publicación se encuentra en las siguientes bases de datos bibliográficas:
*REBIUN, ECONLIT, DIALNET, LATINDEX, DICE, InDICES CSIC e ISOC*.
*Sus índices de impacto aparecen en IN-RECS*.



Editor: S.G. de Estudios y Evaluación de Instrumentos de Política Comercial. Secretaría de Estado de Comercio
Diseño de cubierta: TexTec
Composición y maquetación: TexTec
Impresión y encuadernación: Centro de Impresión Digital y Diseño de la Secretaría de Estado de Comercio
Papel:
Exterior: estucado mate ecológico (250 g)
Interior: offset ecológico FSC/TCF (80 g)
ECPMINCOTUR: 1.ª ed./200/1222
PVP: 18 € + IVA
DL: M 22392-1977
NIPO: 112-19-008-4
e-NIPO: 112-19-009-X
ISSN: 0210-2633
e-ISSN: 2340-9037

**Catálogo general de publicaciones oficiales:**
**https://cpage.mpr.gob.es/**

# *CUADERNOS ECONÓMICOS DE ICE*

MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO

*NÚMERO 104 • 2022/II*

## *SUMARIO*

# Presentación
# La transición a sociedades descarbonizadas

Xavier Labandeira
Universidade de Vigo

Era difícil imaginar a comienzos de 2021, cuando recibí la invitación para coordinar este monográfico sobre transición a la descarbonización, los profundos cambios que se producirían en los ámbitos energético y climático antes de que el número viese la luz. En aquel momento se apreciaban algunas tensiones menores en los mercados energéticos, que se exacerbarían en la segunda mitad del año y explotarían tras la invasión de Ucrania. Desde entonces la deriva energética está generando una gran alarma social, al afectar de lleno al sector productivo y a los hogares en gran número de países, y ha llevado a muchos gobiernos del planeta a aplazar acciones contra el cambio climático e incluso a introducir medidas inconsistentes con la descarbonización. Tampoco habíamos sufrido entonces los eventos climáticos extremos de 2022, generalizados en el hemisferio norte y particularmente en España durante el verano, que causaron importantes impactos socioeconómicos en muchos territorios y apuntan a la gravedad de los fenómenos, aún incipientes, asociados al cambio climático.

Otra novedad relevante del último año es la presentación del ciclo completo de informes de evaluación del IPCC (Grupo Intergubernamental de Cambio Climático, por sus siglas en inglés), que apunta a la creciente preocupación sobre los impactos del cambio climático y a la urgencia de acelerar su mitigación y la adaptación de nuestras sociedades. El tercer grupo de trabajo, principalmente dedicado a las cuestiones tecnológicas y socioeconómicas vinculadas a la mitigación del cambio climático, recoge en su informe el continuo crecimiento de las emisiones de gases de efecto invernadero a la vez que apunta la alta heterogeneidad e insuficiente intensidad de las políticas aplicadas para su control. Su mensaje, en cualquier caso, no es derrotista: si durante esta década se aplican políticas climáticas adecuadas será posible reducir sustancialmente las emisiones y alinearse con los objetivos del Acuerdo de París.

A pesar de que, a más de un año vista, la selección de participantes y contenidos no podía obviamente contemplar un contexto tan diferente, creo que las aportaciones de este monográfico permiten abordar bastantes de las cuestiones candentes a las que se enfrentan actualmente las sociedades ante un cambio tan intenso y acelerado del marco energético y climático. Desde la búsqueda de soluciones globales efectivas a la mitigación del cambio climático, hasta el diseño y evaluación de medidas específicas aplicables en el ámbito energético-ambiental sobre diversos sectores y agentes. Por ello, debo agradecer a los autores que participan en este número especial por sus interesantes, útiles y «duraderas» aportaciones. Agradecimiento que extiendo a los evaluadores externos que han contribuido al afine y mejora de los trabajos que a continuación presento y, por supuesto, a la editora de la revista por haber escogido este tema y darme total libertad para su desarrollo.

El primero de los trabajos que reseño, escrito por **Humberto Llavador, John Roemer** y **Thomas Stoerk**, suministra sugerencias sobre cómo progresar en la actuación contra el cambio climático ante las dificultades apuntadas con anterioridad en los recientes informes del IPCC. El artículo emplea un modelo estilizado de la economía mundial en el que los países acuerdan un presupuesto de carbono, no muy lejos por tanto de la arquitectura actual, aunque la decisión sobre el nivel de emisiones está descentralizada por el uso de un precio por emitir cuyos ingresos se destinan a un fondo global que se reintegra a los ciudadanos del planeta en función de cuotas nacionales establecidas *ex-ante*. El trabajo muestra que, en este contexto, se obtiene un equilibrio globalmente Pareto eficiente. Posteriormente los autores calibran el modelo utilizando datos de RICE *(Regional Integrated Model of Climate and the Economy)*, obteniendo el presupuesto global de carbono acumulado que acordarían los países y los impactos climáticos, el precio de carbono y los flujos financieros internacionales asociados.

Por su parte, **Alberto Antonioni, Antonio Cabrales, Francesca Lipari** y **Anxo Sánchez** proponen en su artículo emplear aproximaciones experimentales e incentivos al cambio de comportamiento individual y colectivo para avanzar en la mitigación del cambio climático. En particular, se centran en dos ejemplos: la aplicación del «club climático» de Nordhaus para conseguir que los países contribuyan de forma efectiva a la reducción de las emisiones de gases de efecto invernadero, y la interacción entre la percepción del riesgo de catástrofes climáticas y las normas sociales que se derivan del comportamiento de los agentes e influyen en este. En su artículo indican que estas aproximaciones pueden ayudar a avanzar, frente a las estrategias convencionales aplicadas hasta el momento (voluntarismo de países o imposición correctora sobre los contaminadores) que han sido poco efectivas por diseño o por enfrentarse a una fuerte oposición social. Los autores sugieren así la conveniencia de intervenciones conductuales que faciliten la aplicación en la práctica de políticas de reducción de emisiones, además de justificar el uso de la regulación financiera por las potenciales consecuencias sistémicas de las crisis climáticas.

**Lara Lázaro** y **Gonzalo Escribano** firman otro de los artículos del monográfico que se preocupa por la limitada progresión global de la mitigación climática, si bien en su caso se centran en el papel que las políticas de inversión pública (asociadas hoy a los planes de recuperación post-Covid y los denominados pactos verdes) pueden jugar para desbloquear la situación. Para ello realizan una revisión de la literatura para evaluar si los distintos programas de reactivación e inversión pública aplicados desde principios de siglo han permitido un desarrollo económico compatible con la contención del cambio climático. Su conclusión es que, aunque la legislación y los paquetes de recuperación económica en muchos países se han «reverdecido», no está claro que vayan a permitir una transición justa en la que las emisiones de gases de efecto invernadero puedan desvincularse del crecimiento económico global.

Tres artículos del monográfico se ocupan del diseño y evaluación de medidas específicas para la transición a la descarbonización sobre distintos sectores y en diferentes contextos.

En el primero de ellos, **Xavier Fageda** y **Jordi Teixidó** se interesan por los efectos del mercado europeo de comercio de emisiones (EU ETS, por sus siglas en inglés) sobre las emisiones de la aviación en España. Este es un sector crucial para la descarbonización, al contribuir de forma creciente a las emisiones globales sin contar apenas con alternativas limpias para su operación. El EU ETS aspira a moderar dicho crecimiento de emisiones y, sobre todo, fomentar el desarrollo e implantación de tecnologías compatibles con la reducción de emisiones a gran escala. Los autores aplican así una metodología empírica de diferencias en diferencias para mostrar que el EU ETS llevó a mayores reducciones de emisiones de la aviación en España que en otros países europeos. El trabajo apunta a la reducción de la oferta de vuelos como causante de este fenómeno, lo que parece explicarse por la competencia intermodal y el gran peso del turismo.

Otra aplicación al caso español, la de **Mikel González-Eguino, Xaquin García-Muros, Iñaki Arto** y **Cristina Pizarro**, se preocupa del análisis de los impactos ambientales y socioeconómicos de distintas alternativas para la financiación de los costes regulados de las energías renovables en el sector eléctrico. Se trata de unos abultados costes, fruto de políticas muy intensas en la promoción de estas opciones renovables durante los primeros años del siglo que, entre otros objetivos, buscaban acelerar la madurez de tecnologías que contribuyesen de forma decisiva a la mitigación climática. Sin embargo, la transmisión de estos costes sobre los precios de la electricidad ocasionó importantes efectos distributivos y sobre la competitividad en nuestro país. El trabajo suministra alternativas a dicha transmisión a los precios de la electricidad y las evalúa mediante la integración de un modelo de equilibrio general para la economía española con otro de microsimulación que permite evaluar los efectos sobre los hogares. Sus resultados muestran impactos macroeconómicos positivos, aunque muy reducidos, e impactos progresivos en todos los escenarios considerados. No obstante, los impactos a nivel sectorial o en las emisiones dependen del mecanismo elegido. Así, aunque la financiación vía presupuestos generales del estado aumenta la progresividad, el uso de impuestos energéticos o sobre emisiones de $CO_2$ favorece la transición energética.

En su artículo, **Xavier Labandeira, José María Labeaga, Xiral López-Otero** y **Thomas Sterner** también se ocupan de la evaluación ambiental, socioeconómica y distributiva de la fiscalidad sobre el $CO_2$, aunque su análisis se refiere a México. Este es un país muy relevante para el progreso global de la mitigación climática, al contar con importantes reservas de hidrocarburos y con políticas de precios históricamente favorables a su consumo. Como en el caso de otras sociedades de ingresos medios, tanto las aplicaciones prácticas como la evidencia académica existente sobre políticas de mitigación climática son limitadas y dicha ausencia puede obstaculizar el progreso de la lucha global contra el cambio climático. En este sentido, el artículo suministra la estimación de un sistema de demanda y la simulación de un impuesto sobre las emisiones de carbono, prestando una atención especial al uso de los ingresos públicos con objetivos redistributivos. Los resultados de la aplicación de un impuesto sobre el carbono en México apuntan a reducciones de demanda energética y emisiones asociadas y un impacto progresivo sobre el bienestar (si bien incrementaría la pobreza y el bienestar). Sin embargo, estos efectos podrían revertirse completamente de dirigir solo parte de la recaudación adicional a los hogares más pobres.

El último trabajo que recoge este monográfico, el de **Manuel Bueno** y **J. Alberto Aragón**, comparte con muchos de los anteriores artículos la búsqueda de aproximaciones incentivadoras para reforzar la sostenibilidad, aunque centrándose en un asunto relativamente poco explorado: la influencia del capital humano en el progreso ambiental del mundo empresarial. En particular, los autores analizan si la orientación competitiva de los trabajadores de una empresa, reflejada en sus carreras profesionales, se relaciona con los avances ambientales de dicha organización. Para ello utilizan información pública para realizar un análisis detallado de toda la vida laboral de miles de personas que trabajan en empresas cotizadas, utilizando la experiencia en los distintos rangos jerárquicos como un indicador de la mentalidad competitiva. Mediante modelos de ecuaciones estructurales multinivel, el trabajo muestra que las empresas mejoran su proactividad ambiental si cuentan con un mayor número de empleados con experiencia en niveles jerárquicos altos y con una mayor dispersión salarial. En suma, existe una relación positiva entre la competitividad interna entre trabajadores y los progresos ambientales de la empresa.

Solo me queda agradecer de nuevo a los autores de este monográfico sus aportaciones teóricas y empíricas que, si bien muestran una elevada heterogeneidad (buscada expresamente en la selección temática y de participantes), comparten la búsqueda de soluciones viables al problema del cambio climático. Espero que los lectores disfruten tanto como yo de su lectura y que las contribuciones desde tan ricas y diversas perspectivas sirvan para orientar a los decisores políticos y empresariales en sus necesarios empeños en este campo.

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# Global unanimity agreement on the carbon budget*

# *Acuerdo global por unanimidad sobre el presupuesto de carbono*

Humberto Llavador
Universitat Pompeu Fabra and Barcelona School of Economics

John Roemer
Yale University

Thomas Stoerk
National Bank of Belgium and London School of Economics

**Abstract**

*This paper analyzes a stylized model of the global economy in which countries must agree on the carbon budget while the decision on the level of carbon emissions is decentralized, with firms treating their emissions as a production input for which a uniform price is charged. The revenue accumulates in a global fund and is returned to global citizens according to national shares that are announced ex ante. The vector of country shares for the distribution of the carbon revenue assures that countries agree by unanimity on the carbon budget. The equilibrium exhibits the following desired features: (1) the global emissions level is set by unanimous agreement; (2) the demand to emit carbon is decentralized and, hence, there is no need to determine the distribution of permits; and (3) the equilibrium is Pareto efficient. We explore the implication of the model in an application based on RICE-2010.*

***Keywords:*** *international environmental agreement, climate economics, climate policy, carbon price.*

***JEL classification:*** *Q54, Q56, Q58, F53, F64.*

**Resumen**

*Este artículo analiza un modelo estilizado de la economía mundial en el que los países deben acordar el presupuesto de carbono mientras que la decisión sobre las emisiones de carbono está descentralizada, y las empresas tratan sus emisiones como un input en su producción por el que han de pagar un precio uniforme. La recaudación se acumula en un fondo mundial y se devuelve a los ciudadanos de todo el mundo según las cuotas nacionales que se anuncian ex ante. El vector de cuotas nacionales para la distribución de los ingresos del carbono garantiza que los países se pongan de acuerdo por unanimidad sobre el presupuesto del carbono. El equilibrio presenta las siguientes características: (1) el nivel global de emisiones se fija por unanimidad; (2) la demanda de emisiones de carbono está descentralizada y, por tanto, no es necesario determinar la distribución de permisos; y (3) el equilibrio es eficiente en términos de Pareto. Exploramos las implicaciones del modelo en una aplicación basada en RICE-2010.*

***Palabras clave:*** *acuerdo internacional, economía del cambio climático, política del cambio climático, precio del carbono.*

* Humberto Llavador acknowledges financial support from the Spanish Agencia Estatal de Investigación (AEI), through the Severo Ochoa Programme for Centres of Excellence in R&D (Barcelona School of Economics CEX2019-000915-S) and grants AEI/FEDER, UE-PGC2018-096370-B-I00 and PID2020-115044GB-I00//AEI/10.13039/501100011033. Stoerk's contribution to this research does not necessarily reflect the opinion of the National Bank of Belgium or the Eurosystem.


DOI: https://doi.org/10.32796/cice.2022.104.7491
Recibido: Abril 2022 · Aceptado: Septiembre 2022

The global emissions problem exhibits the tragedy of the commons (Barrett, 2018), which is simply a dramatic way of saying that, in the emissions "game", the Nash equilibrium is (massively) Pareto inefficient, and that countries must cooperate if they want to avoid this bad equilibrium. Although a climate agreement to reduce emissions has been proved difficult to achieve, the Climate Change Conference (COP) meetings are venues that should be understood as attempts to build trust and solidarity among nations, so a cooperative solution that is Pareto efficient can be achieved (Keohane & Victor, 2016).

In this paper we present a stylized model of the global economy with countries agreeing on the carbon budget, while the decision on the level of carbon emissions is decentralized to the regional level, where firms treat their emissions as a production input for which a price is charged (Weitzman, 2014). The revenues from these charges accumulate in a global fund, and are returned to global citizens according to national shares that are announced *ex ante*. The vector of country shares for the distribution of the carbon revenue assures country unanimity of agreement on the carbon budget. Hence, our model can be viewed as one in which each country's firms demand permits to emit carbon, for which they pay a common price, and the vector of country shares for the distribution of the carbon fund assures countries' unanimity agreement on what the number of carbon permits globally should be. Because firms decide upon their emissions as part of a profit-maximizing plan, no firm has an incentive to emit more than it demands. Because, in choosing its desired global level of carbon emissions, each country maximizes the utility of its representative citizen considering the benefits from consumption, the damages from the global emissions level and the impact of the carbon permits, no country has an incentive to propose a different carbon budget. It is worth emphasizing that, once the mechanism is accepted, there is no need to negotiate the allocation of permits among countries, keeping the instrument of negotiation one dimensional centered on the global carbon budget, which, we argue, is a useful way of framing the climate mitigation challenge and a much easier issue to agree upon than the allocation of emission permits.[1]

In our stylized global economy there is a single good, produced in all countries according to nationally specific production functions, which use labor and capital as inputs, and emit according to country specific carbon intensities with respect to output. The markets for capital and output are standard. The market for carbon emissions is not. As mentioned, the demands for carbon emissions of countries are set by the profit-maximizing firms in each country, which must pay for standard inputs and proposed emissions. The supply of global emissions is unanimously agreed upon by countries. In equilibrium, all markets clear: in particular, all countries agree upon the desired global carbon budget, which equals (in equilibrium) the sum total of the demands for carbon emissions of the world's firms.

---

[1] Total emissions are, in our opinion, a natural focal point in international negotiations of climate change. Notice that agreeing on a carbon budget is similar to agreeing on a temperature change target (headline statement D.1 in IPCC, 2022).

The virtues of the equilibrium are the following: (1) the global emissions level is not set by negotiations but by unanimous agreement of the national citizenries of the world; (2) the demand to emit carbon is decentralized to the firm level; (3) the equilibrium is globally Pareto efficient – there is no feasible allocation of capital, the good, and emissions that could make all countries better off. Of course, accepting the mechanism implies that the shares according to which the global carbon revenues are returned to nations must appear to be fair, for if they are not accepted, then unanimity on the global emissions level will dissolve. The shares are not negotiated but determined internally by the mechanism.

The mechanism satisfies all three properties that, according to Weitzman (2014), any instrument for negotiating climate change should satisfy, namely, "cost effectiveness, a natural one-dimensional focal point, and a built-in self-enforcement mechanism that internalizes the externality". While the countervailing force that internalizes the externality in the mechanism works in a similar fashion as in Weitzman (2014),[2] a notable difference is that unanimity agreement is more powerful than the Condorcet winner proposed there. Moreover, our proposal differs substantially in that our focal point is the remaining cumulative carbon budget rather than the carbon price, which has the advantage of drawing on climate science rather than the more uncertain economic climate impacts literature needed to estimate the social cost of carbon. We do, however, share Weitzman's spirit of seeing this proposal as an exploration into the solution rather than a concrete policy proposal.

## *1.1. Related literature*

Our proposal is not the first to analyze the question of how to induce international collaboration in climate policy. Starting with Chander and Tulkens (1997), this literature has used game theoretic approaches to study the stability of climate policy coalitions under different assumptions. Our work follows in this tradition: abatement is coordinated, and financial transfers are part of our proposal, though they are not explicitly negotiated. In the standard literature, depending on the specific policy setup and assumptions about the behaviour of non-coalition countries, coalitions can be larger or smaller in equilibrium (Ray & Vohra, 2001), leading to a positive amount of climate action. However, calibrations typically find the resulting mitigation to fall short of greenhouse gas emissions cuts required to reach the 1.5 °C objective of the Paris Agreement.[3] Eyckmans and Tulkens (2006), for instance, find resulting warming of close to 4 °C in the most optimistic scenario using a calibration based on the RICE model. Our proposal differs from this literature in substantive terms: if the unanimity equilibrium is implemented, it leads to Paris-compatible levels of

[2] The desire to set total emissions at low levels thereby reducing climate change damages, countervails the wish of each country to increase their production, and hence their individual emissions.

[3] Models based on bargaining (e.g., Caparrós (2016)) and mechanism design approaches (e.g., Martimort & Sand-Zantman (2016)) generally find qualitatively similar results.

warming. This idea is closest in spirit to the study of self-enforcing agreements, in particular Heitzig et al. (2011) which builds on earlier, more pessimistic literature, e.g. Dutta and Radner (2004).

Our proposal, furthermore, returns to an earlier focus on the importance of transfers to sustain international climate action. Carraro et al. (2006) and Lessmann et al. (2015), for instance, both highlight the importance of using transfers to ensure the stability of a climate coalition. At the same time, real world climate action as negotiated in COP26 agrees to the need for raising US$100 billion per year to provide climate financing to low- and middle-income countries. Our proposal takes this seriously and addresses it.

The remainder of this article is organised as follows: in Section 2, we describe the stylized model, define the unanimity equilibrium and prove its properties. Section 3 illustrates the implications of the mechanisms by simulating a 12-region world that, in the spirit of the Paris Agreement, must agree on the carbon budget until 2050 with the compromise of zero-emissions afterwards. Finally, Section 4 concludes.

## 2. A global unanimity equilibrium

In this section, we describe the model and study its properties. There are $n$ countries, each endowed with labor, capital, and a technology for producing a single good. Country $j$ is represented by an agent with a quasi-linear utility function

$$u_j(x, E) = x - h_j(E) \qquad [1]$$

where $x$ represents the GDP per capita of the country, $h_j$ is a convex damage function, and $E$ is the global cumulative greenhouse gas emissions. Each country $j$ has an increasing and concave aggregate production function

$$y = G_j(K) \qquad [2]$$

where $y$ is output of the single good and $K$ is capital. It is assumed that $G_j'(0) \rightarrow +\infty$ for all $j$, and that labor is immobile across countries, but capital is mobile. Therefore, the production function $G_j$ assumes full employment of the country's labor supply, which is implicit in equation [2]. Besides its labor supply, country $j$ is endowed with capital in the amount $\bar{K}_j$.

Emissions are assumed to be proportional to production (Nordhaus, 2018).

$$E_j = \eta_j y_j \qquad [3]$$

We start by deriving the conditions of Pareto efficiency.

**Definition 1.** An allocation of output and emissions $((x_1, E_1), ..., (x_n, E_n))$ is *globally feasible* if there is an allocation of capital $K_1, ..., K_n$ and output $y_1, ..., y_n$ such that:

$$y_j = G_j(K_j),\ \ E_j = \eta_j y_j,\ \ \sum x_j = \sum y_j,\ \text{ and }\ \sum K_j = \sum \bar{K}_j, \qquad [4]$$

**Definition 2.** A globally feasible allocation is *Pareto efficient* if there is no other feasible allocation that gives at least one country higher utility and no country lower utility.

**Proposition 1.** *The necessary first-order conditions for an allocation to be Pareto efficient are*:

$$\begin{array}{lll} (i) & \forall j & \eta_j \sum_l (h_l)'(E) < 1 \\ (ii) & \forall i,j & \dfrac{(G_i)'(K_i)}{(G_j)'(K_j)} = \dfrac{1-\eta_j \sum_l (h_l)'(E)}{1-\eta_i \sum_l (h_l)'(E)} \end{array} \qquad [5]$$

where $E = \sum_j E_j$.

**Proof.** The conditions for Pareto efficiency are given by solving the following program:

$$\left.\begin{array}{ll} \max x_j - h_j(E) & \\ s.t. & \\ \forall i \neq j,\ x_i - h_i(E) \geq k_i & (\lambda_i) \\ \sum G_i(K_i) \geq \sum x_i & (\alpha) \\ \sum (\bar{K}_l) \geq \sum K_i & (\beta) \\ E \geq \sum \eta_i G_i(K_i) & (\gamma) \end{array}\right\} \text{Program (PE)}$$

The program is not convex, because of the last constraint (the $\{G_j\}$ are concave functions). Therefore, the Kuhn-Tucker conditions are necessary but not sufficient for the solution of (PE). Define $\lambda_1 = 1$. Then the Kuhn-Tucker conditions are:

$$\begin{array}{ll} (\partial x_i) & \lambda_i = \alpha \quad \text{for all } i \\ (\partial K_i) & \alpha(G_i)' - \beta - \gamma\, \eta_i (G_i)' = 0 \\ (\partial E) & -\sum\limits_i \lambda_i (h_i)'(E) = 0 \end{array}$$

We deduce that $\lambda_i = 1 = \alpha$ for all $i$; $\gamma = \sum_l (h_l)'(E)$ and

$$\beta = (G_i)'\left(1 - \eta_i \sum_l (h_l)'\right)$$

From this last equation, and using $(G_i)'(0) \rightarrow +\infty$, we have the conditions:

$$(\forall i) \qquad 1 > \eta_i \sum_l (h_l)'(E)$$

$$(\forall i, j) \qquad \frac{(G_i)'}{(G_j)'} = \frac{1 - \eta_j \sum_l (h_l)'(E)}{1 - \eta_i \sum_l (h_l)'(E)}$$

These are the stated conditions in the proposition. ■

We now describe how the economy works. There are three markets: for the produced good, whose price will be denoted $p$; for capital, whose interest rate is $r$; and for carbon emissions, whose price is $c$. The firm in each country will demand capital to maximize profits:

$$\Pi_j = pG_j(K_j) - c\,\eta_i G_j(K_j) - rK_j \qquad [6]$$

where it must pay the carbon price for the emissions it creates. All profits, which here include wages because labor is implicit in the production function, are returned to the population of the country. Carbon pricing revenues are deposited in an international fund, and will be distributed to countries as demogrants, where country $j$ will receive back a fraction $a_j$ of total revenues. Thus, along with the price vector $(p, c, r)$, countries observe a vector of shares $(a_1, ..., a_n) \in \Delta^{n-1}$, where $\Delta^{n-1}$ is the unit simplex in $\Re^{n-1}$.

The income of country $j$ will be:

$$I_j = \Pi_j + r\bar{K}_j + a_j cE \qquad [7]$$

where $E$ is global emissions, and so $cE$ is the value of the carbon revenues. Each country supplies its entire capital endowment to the market.

It is clear there is a supply and demand for capital, and there is also a supply and demand for the good, because each country will demand the good in amount $I_j/p$.

The demand for emissions is determined by the firms' profit-maximizing choices, but we have yet to determine the supply of emissions (the carbon budget), which will be set by a unanimous agreement among countries. Note that the preferences of country $j$ over carbon budgets is given by the indirect utility function:

$$V_j(E) = \frac{\Pi_j + r\bar{K}_j + a_j cE}{p} - h_j(E) \qquad [8]$$

For country $j$, the optimal level of global emissions, $E$, is therefore given by the first-order condition:

$$(V_j)'(E) = 0 \quad \text{or} \quad a_j \frac{c}{p} = (h_j)'(E) \qquad [9]$$

We close the model by requiring that the $n$ countries *unanimously agree* on the value of $E$, the cumulative carbon budget. Thus, country representatives "supply" the emission permits *in toto* to firms.

We summarize the equilibrium of the economy as follows.

**Definition 3.** A *global unanimity equilibrium* is a price vector ($p$, $c$, $r$), a share vector $(a_1, ..., a_n) \in \Delta^{n-1}$, an allocation $(x_1, ..., x_n, K_1, ..., K_n, E_1, ..., E_n)$, and a global supply of emission permits $E$ equalling the global cumulative carbon budget such that:

a) for each country $j$, $(K_j, E_j)$ maximizes firm profits $\Pi_j = pG_j(K_j) - cE_j - rK_j$, subject to the constraint $E_j = \eta_j G_j(K_j)$;
b) for each country $j$, $E$ maximizes its utility

$$V_j(E) = \frac{\Pi_j + r\bar{K}_j + a_j cE}{p} - h_j(E) \; ;$$

c) country $j$'s demand for the good is

$$x_j = \frac{\Pi_j + r\bar{K}_j + a_j cE}{p} \; ; \text{ and}$$

d) all markets clear:

$$\sum \bar{K}_j = \sum K_j, \;\; \sum E_j = E, \;\; \text{and} \;\; \sum x_j = \sum G_j(K_j)$$

The following proposition shows that the global unanimity equilibrium is Pareto efficient and that it allocates the carbon pricing revenue proportional to marginal damages.

**Proposition 2**

A. *Any global unanimity equilibrium satisfies the first-order conditions for Pareto efficiency.*
B. *In equilibrium, the share of global carbon pricing revenue that country j receives is proportional to its marginal damages* $(h_j)'(E)$.

**Proof.** The first order conditions for profit maximization are, for all countries $j$:

$$(G_j)'(K_j)(p - c\eta_j) = r \quad \text{or} \quad (G_j)'(K_j)\left(1 - \frac{c}{p}\eta_j\right) = \frac{r}{p} \qquad [10]$$

The first order conditions for the unanimous agreement on the level of the cumulative global carbon budget $E$ are, for all $j$:

$$(h_j)'(E) = a_j \frac{c}{p} \qquad [11]$$

from which it follows that $\sum(h_j)'(E) = c/p$. Substituting this into equation [5] gives, for all $j$: $(G_j)'(K_j)(1 - \eta_j \sum(h_j)'(E)) = r/p$. Conditions (i) and (ii) of Proposition 1 follow immediately, proving claim A.

Claim B follows immediately from equation [11]. ■

Observe that the global unanimity equilibrium is a species of Lindahl equilibrium. As mentioned earlier, the virtues of the solution are global Pareto efficiency, unanimity of agreement on global cumulative greenhouse gas emissions and a clear distribution of carbon pricing revenue.

## 3. An application

We use the data from the Regional Integrated model of Climate and the Economy (RICE) to simulate a 12-region world whose regions negotiate, in the spirit of the Paris Agreement, a carbon budget for their next 40 years (2015-2055), with the assumption of zero emissions afterwards.[4] RICE provides the necessary regional disaggregation for the current analysis. The twelve regions correspond to United States (US), the European Union (EU), Japan, Russia, Eurasia, China, India, Middle East, Africa, Latin America, Other High Income countries (OHI), and Other Asian countries. To approximate the dynamic situation, we endow each region with an annual stock of capital, an annual population, and a carbon intensity parameter that represent annual average values for the period under consideration. Utility is measured by the present value (in international $) of the average annual consumption net of climate change damages. Finally, climate change damages are computed as the monetized present value (also in international $) of warming costs to the end of the century associated to cumulative emissions. Details are provided in the next subsection.

### *3.1. Calibration*

We use the data from the baseline run in RICE, representing a business-as-usual scenario.[5] Here we explain in detail the adjustment of the model proposed above to the data in RICE. We describe utility and production functions, carbon intensities, and endowments (stocks of capital and population) for each of the twelve regions.

**Utility** is measured as the present value of average annual consumption $v(x_j)$, net of climate damages $h_j(E)$ related to annual greenhouse gas emissions $E$,

$$u_j(x_j, E) = v(x_j) - h_j(E) \qquad [12]$$

[4] Since we will use the quasi-linear relationship between temperature change and cumulative emissions, negotiating a carbon budget is equivalent to setting a temperature change target.

[5] More specifically, we obtain the data from the RICE-2010 Excel spreadsheet version 4.012510.

Both consumption and damages are measured in trillions of international US dollars. For a discount factor $\rho$ and a period of $N$ years, the present value of consumption is simply

$$v(x_j) = \sum_{t=1}^{N} \rho^t x_j = \frac{\rho - \rho^{N+1}}{1-\rho} x_j \quad [13]$$

We construct region-specific climate damage functions in three steps. First, we calibrate an exponential function mapping warming to annual climate damages reported in RICE. Secondly, we exploit the nearly-linear relationship between warming an global cumulative emissions to write annual damages as a function of cumulative emissions. Finally, we calculate the present value to obtain total climate damages.

*Step 1*. Define the region-specific exponential function that maps temperature increases to annual climate damages:

$$d_j(\Delta T) = \alpha_{1j} e^{\alpha_{2j} \Delta T} \quad [14]$$

where damages are measured in annual trillions of international dollars, and temperature change $\Delta T$ is in degrees centigrade above pre-industrial levels. We choose the parameters to calibrate the functions to the damage costs in the baseline run of RICE-2010 for the period 2005-2215.[6] Figure 1 shows the fit for the twelve regions. The value of the parameters are reported in the last two columns of Table 1. It is important to notice that economic climate damage are almost surely underestimated in RICE (see, e.g. on tipping points, to name but one reason).[7] With this caveat in mind, our parametrization of [14] provides a good fit to RICE's damages, as shown in Figure 1.

*Step 2*. We use the nearly-linear relationship between cumulative global emissions and warming (Matthews et al., 2009, 2018; IPCC, 2022) to write

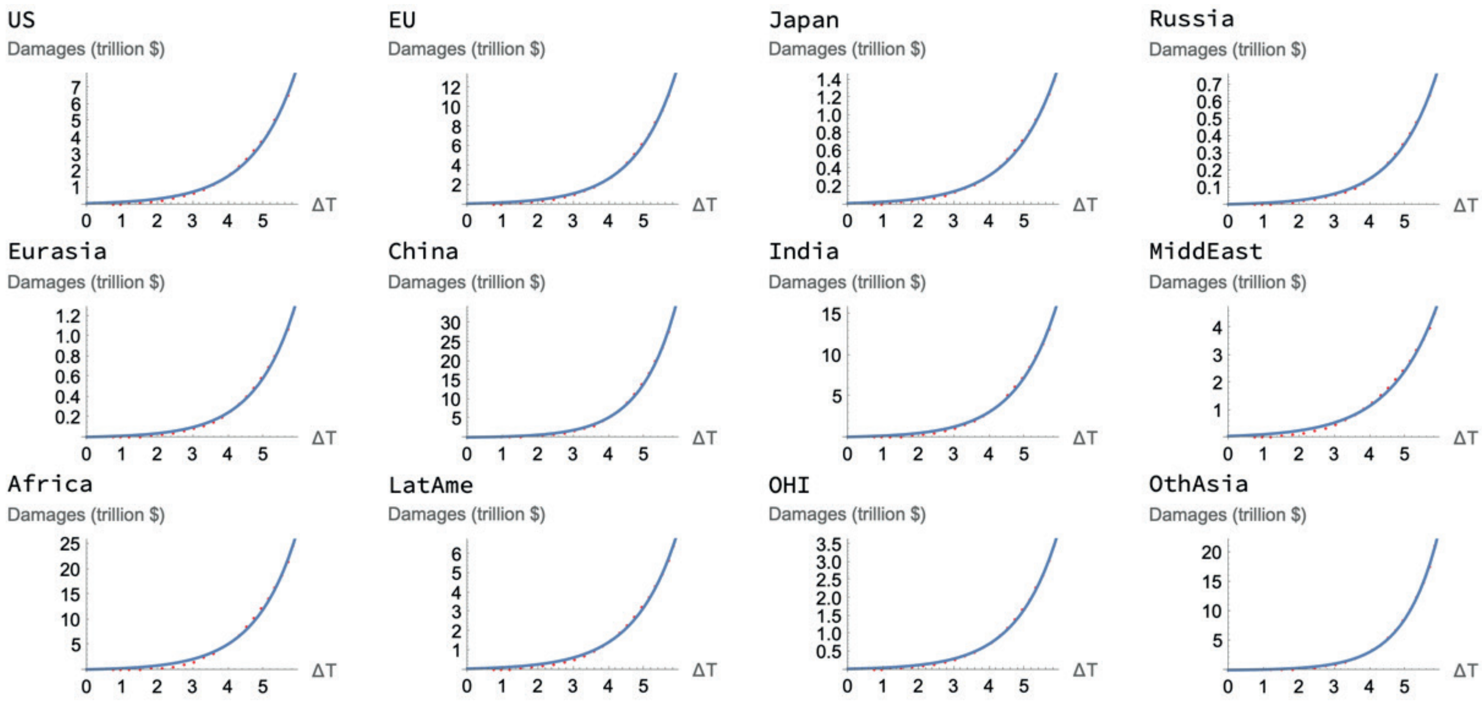
$$\Delta T_t = \varphi 10^{-3} E_t^{cum} \quad [15]$$

where $\varphi$ is the ratio of warming to cumulative $CO_2$ emissions in °C/Tt$CO_2$, known as the Transient Climate Response to Emissions (TCRE), and $E_t^{cum}$ are cummulative anthropogenic emissions in GtCO.[8] We take $\varphi$ = 0.45 (°C per 1000 Gt$CO_2$) as the best estimate reported in the last IPCC report (D.1.1 in IPCC, 2022).

[6] The period 2005-2215 corresponds to temperature increases under 6 °C. See Table A.1 in the Appendix.
[7] A robustness check in the Appendix shows that larger damages result in qualitatively similar, but more extreme, outcomes.
[8] For computational simplicity, we opt to ignore the short delay between cumulative emissions and the onset of associated temperature change shown in Dietz and Venmans (2019).

**FIGURE 1**

**ESTIMATED ANNUAL DAMAGE FUNCTIONS (BLUE SOLID LINE), AND ACTUAL POINT DATA IN RICE-2010 BASELINE RUN (RED DOTS).**




NOTE: Damages measured in trillions of annual international-dollars.
**SOURCE:** Own elaboration.

Combining [14] and [15], region $j$ climate damages in year $t$ from global cumulative emissions $E_t^{cum}$ are

$$\hat{D}_j(E_t^{cum}) = \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3} E_t^{cum}} \qquad [16]$$

Finally, let $E_0^{cum}$ represent historical cumulative $CO_2$ emissions for the period 1850 to 2015 –amounting to 2296.5 $GtCO_2$–, and let average annual emission be $E$ for the next $N$ years, and zero afterward. Then, the present value of total climate damages in region $j$ for $\hat{N} > N$ years is[9]:

$$p \times h_j(E) = \sum_{t=1}^{\hat{N}} \rho^t D_j(E, t) = \sum_{t=1}^{N} \rho^t \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0 + tE)} + \sum_{t=N+1}^{\hat{N}} \rho^t \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0 + NE)} \qquad [17]$$

where $D_j(E, t)$ are damages (in monetary terms) at year $t$ in region $j$ from average annual emission $E$.

Combining equations [13] and [17], we can write the utility of region $j$ as a function of average consumption and average total annual emissions:

$$u_j(x_j, E) = \frac{\rho - \rho^{N+1}}{1-\rho} x_j - \sum_{t=1}^{N} \rho^t \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0 + tE)} - \sum_{t=N+1}^{\hat{N}} \rho^t \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0 + NE)} \qquad [18]$$

Utility represents the present discounted value of consumption net of warming costs from climate change.

**Production** is represented by a Cobb-Douglas function of labor and capital,

$$G_j(K) = A_j(L_j)^{1-\gamma} K^{\gamma} \qquad [19]$$

where $\gamma = 0.33$ is the elasticity of output with respect to capital. Total factor productivity (TFP) $A_j$ is calibrated to the average values of output, capital and population in the baseline run of RICE for the period 2016-2055.[10] Defining $\kappa_j = A_j(L_j)^{1-\gamma}$, the production function can be expressed as

$$G_j(K) = \kappa_j K^{\gamma} \qquad [20]$$

The values of $\kappa$ are presented in column 2 of Table 1.

Finally, average annual capital stock $\bar{K}_j$ (in trillions of international \$) and carbon intensity $\eta_j$ (in $GtCO_2$/trillion \$) are calculated as the average values in the baseline run of RICE-2010 for the period 2016-2055. (Columns 3 and 4 in Table 1).

[9] Cumulative emissions until year $t$ are $E_t^{cum} = E_0^{cum} + tE$ if $t \leq N$, or $E_t^{cum} = E_0^{cum} + NE$ if $t \leq N$. Therefore, from equation [16], $D_j(E, t) = \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0^{cum} + tE)}$ for $t \leq N$, and $D_j(E, t) = \alpha_{1j} e^{\alpha_{2j}\varphi 10^{-3}(E_0^{cum} + NE)}$ for $t \geq N$.

[10] Figure A1 in the Appendix shows that these estimated TFPs are very close to the average of the reported TFP values in RICE-2010.

**TABLE 1**

**CALIBRATED VALUES BASED ON THE DATA FROM THE BASELINE RUN OF RICE-2010**

| | Production parameter $\kappa_j$ | Stock of capital $\bar{K}_j$ (trillion \$) | Carbon intensity $\eta_j$ ($GtCO_2$/trillion\$) | Damage function parameters | |
|---|---|---|---|---|---|
| | | | | $\alpha_{1j}$ | $\alpha_{2j}$ |
| **Region** | | | | | |
| US | 8.0926 | 63.5154 | 0.2761 | 0.0672 | 0.8080 |
| EU | 8.3429 | 66.1483 | 0.2024 | 0.0867 | 0.8564 |
| Japan | 2.7546 | 13.5586 | 0.1887 | 0.0134 | 0.7970 |
| Russia | 1.8737 | 7.7646 | 0.5044 | 0.0052 | 0.8470 |
| Eurasia | 1.8338 | 7.5898 | 0.4563 | 0.0075 | 0.8750 |
| China | 7.4834 | 55.6930 | 0.4790 | 0.1019 | 0.9876 |
| India | 4.8316 | 30.3280 | 0.2878 | 0.1003 | 0.8595 |
| MiddEast | 3.2878 | 17.3715 | 0.4318 | 0.0580 | 0.7484 |
| Africa | 5.0156 | 32.0531 | 0.2540 | 0.1717 | 0.8525 |
| LatAme | 5.5100 | 36.9398 | 0.2068 | 0.0528 | 0.8247 |
| OHI | 3.2531 | 17.0958 | 0.3497 | 0.0235 | 0.8559 |
| OthAsia | 4.7999 | 30.3416 | 0.2516 | 0.0501 | 1.0333 |

**SOURCE:** Own elaboration.

Summarizing, each region is characterized by a utility function with region specific damages from climate change, a production function with region specific TFP, population, stock of capital, and a carbon intensity parameter. All calibrated values are collected in Table 1.

### *3.2. Computing the Global Unanimity Equilibrium*

We proceed as follows to solve for the Global Unanimity Equilibrium as described in Definition 3. First, write $r = 1-p-c$, using that the price vector $(p, c, r)$ is restricted to the unit simplex $\Delta^2$, to obtain the demand of capital as a function of prices from the first-order conditions for the profit maximization of the firms:

$$K_j = (G_j)^{-1}\left(\frac{1-p-c}{p-c\eta_j}\right)\left(\frac{\gamma}{1-c-p}(p-c\eta_j)\kappa_j\right)^{\frac{1}{1-\gamma}} \quad [21]$$

Plug equation [21] into the market clearing conditions of capital and emissions to obtain:

$$\sum_j \bar{K}_j = \sum_j Kj \Rightarrow \left(\frac{\gamma}{1-c-p}\right)^{\frac{1}{1-\gamma}} \sum_{j=1}^{12} (\kappa_j \eta_j (p-c\eta_j))^{\frac{1}{1-\gamma}} = \sum_{j=1}^{12} \bar{K}_j \; ; \tag{22}$$

$$\sum_j \eta_j G_j(K_j) = E \Rightarrow \left(\frac{\gamma}{1-c-p}\right)^{\frac{\gamma}{1-\gamma}} \sum_{j=1}^{12} \eta_j \kappa_j ((p-c\eta_j)\kappa_j)^{\frac{\gamma}{1-\gamma}} = E \tag{23}$$

The first order condition of the unanimity equilibrium implies $\sum_j (h_j)'(E)p/c = \frac{\rho-\rho^N}{1-\rho}$, which, using equation [17] and after some manipulation, becomes:

$$\sum_{j=1}^{12} \alpha_{1j}\hat{\alpha}_{2j}\theta_{0j}\left(\frac{N(\rho-\rho^{-N+\hat{N}+1})(\theta_{1j}(E))^N}{1-\rho} + \left(\frac{\theta_{1j}(E)}{1-\theta_{1j}(E)}\right)^2 (1-(\theta_{1j}(E))^N)\right) +$$
$$+\sum_{j=1}^{12} \alpha_{1j}\hat{\alpha}_{2j}\theta_{0j}\frac{\theta_{1j}(E)(1-(N-1)(\theta_{1j}(E))^N)}{1-\theta_{1j}(E)} = \frac{(\rho-\rho^{-N})c}{1-\rho} \tag{24}$$

where $\hat{\alpha}_{2j} := \frac{\varphi\alpha_{2j}}{10^3}$ and $\theta_{0j}(E) := \rho e^{\hat{\alpha}_{2j}E}$.

Walras's Law assures us that the good's market clears. Equations [22]-[24] represent a system of three equations with three unknowns. We program Mathematica (v.12.3) to solve for the price of output $p^*$, the price of emissions permits $c^*$, and the total level of emissions $E^*$. Other values are obtained as follows:

- $K_j^*$, the stock of capital for region $j$, follows from equation [21];
- the price of capital is $r^* = 1-p^*-c^*$;
- total revenue from emission permits equals $c^* \times E^*$;
- the share of total revenue for region $j$ follows from equation [24]:

$$a_j^* = \frac{1-\rho}{\rho-\rho^N}\frac{p^*}{c^*}(h_j)'(E^*);$$

- emissions of region $j$ equal $E_j^* = \eta_j\kappa_j(K_j^*)^\gamma$;
- income of region $j$ is $I_j = \rho\kappa_j(K_j^*)^\gamma + r^*(\bar{K}_j - K_j^*) - c^*E_j^* + a_j^*c^*E^*$; and
- the net contribution of region $j$ is $c^*E_j^* - a_j^*c^*E^*$.

### 3.2. *Results*

We derive two sets of results in equilibrium: the global cumulative carbon budget that countries would agree on as well as the associated temperature implications; and the carbon price and the associated international financial flows. Results are summarized in Figure 2 and in Tables 2 and 3.

### 3.2.1. The carbon budget and its temperature implications

Global average emissions are 50.3 $GtCO_2$ for the period 2016-2055, and zero afterwards. Therefore, total cumulative emissions since the beginning of the industrial revolution amount to 4,307 $GtCO_2$, which, according to equation [15] would result in a temperature increase by 2100 around 1.9 °C above pre-industrial levels. Observe that the analysis is conservative in assuming the (almost surely underestimated) costs in RICE and in ignoring any abatement policy beyond the energy efficiency trend embedded in the baseline run of RICE model.

### 3.2.2. Revenue and its distribution

At equilibrium, emission permits are priced at 54.5$/$tCO_2$, yielding an average global revenue of 2.74 trillion dollars per annum.

The following points are worth emphasizing:

1. Africa, China and India receive the largest shares of total revenue, receiving over half of total revenue (first column in Table 2). This is because they are the regions with the highest marginal costs of warming according to RICE-2010.
2. However, when we account for the contribution to the global fund, China becomes the second largest net contributor, with a net payment of 130.5 billion dollars, only after the 220.3 billion dollars of net contribution by the USA (Figure 2 and first column in Table 3). The net contributions of these two regions alone amount to nearly 60 % of the total amount supplied by those regions who are net contributors.
3. Africa, India and the small less developed countries in Asia are the only net recipients from the global fund. Africa, with 394 billion dollars per annum, is by far the largest net recipient, obtaining close to three-fold the amount received by India (141 billion $). The net annual payment to India, Africa and Other Asia ($643 billion per annum) is six and a half times the $100 billion commitment to the developing world agreed upon in Paris at COP21 and, subsequently, COP26.
4. Although the mechanism does not have any explicit built-in redistributive objective, inequality is reduced compared to 2015 values. For instance, while the US per capita income is 14 times that of Africa in 2015, it reduces to only 8.4 times on average for the period 2016-2055 (columns three and four in Table 3). This equalizing effect originate in the negative relationship between income and climate change costs. Poorer regions are more intensively affected by climate change than richer regions, receiving a larger share of total revenue, hence reducing income differences.

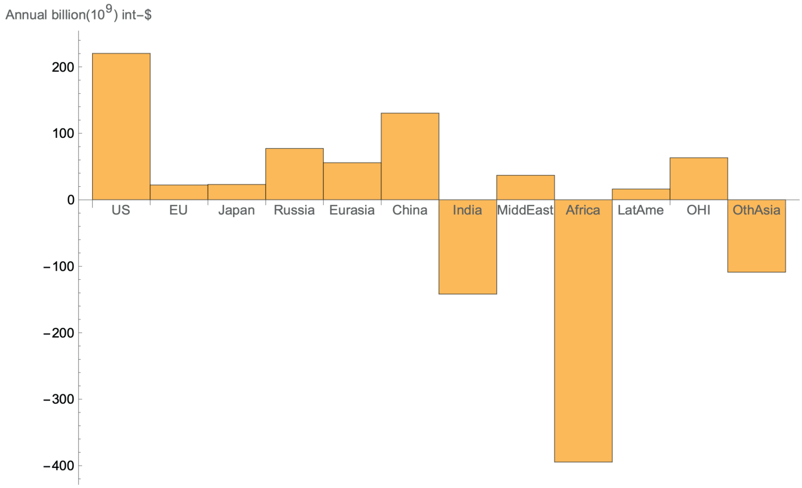
## TABLE 2
## ALLOCATION OF PERMITS' CLAIMS AND REVENUES

| | Share of total revenue | | | Revenue: $a_j^* \times (c \times E^*)$ | | |
|---|---|---|---|---|---|---|
| Region | $a_j^*$ | $\frac{a_j^*}{\text{Pop}_j\text{share}}$ % | $\frac{a_j^*}{\text{Pop}_j}$ Per million person | Total (billion $) | $ per capita | As % of GDP |
| US | 0.074 | 1.653 | 0.195 | 201.804 | 534.01 | 0.866 |
| EU | 0.110 | 1.626 | 0.192 | 301.593 | 525.03 | 1.230 |
| Japan | 0.014 | 1.094 | 0.129 | 38.958 | 353.33 | 0.777 |
| Russia | 0.006 | 0.444 | 0.052 | 17.550 | 143.25 | 0.622 |
| Eurasia | 0.010 | 0.439 | 0.052 | 27.502 | 141.81 | 0.996 |
| China | 0.190 | 1.128 | 0.133 | 520.733 | 364.44 | 2.507 |
| India | 0.129 | 0.732 | 0.086 | 352.493 | 236.47 | 3.095 |
| MiddEast | 0.053 | 1.465 | 0.173 | 144.696 | 473.08 | 2.247 |
| Africa | 0.216 | 1.094 | 0.129 | 590.794 | 353.41 | 4.817 |
| LatAme | 0.061 | 0.732 | 0.086 | 166.847 | 236.45 | 1.228 |
| OHI | 0.030 | 1.866 | 0.220 | 81.804 | 602.70 | 1.296 |
| OthAsia | 0.106 | 0.666 | 0.079 | 291.329 | 215.22 | 2.582 |

NOTE: The shares of total revenue are endogenously determined in equilibrium according to $a_j^* = \frac{(1-\rho)}{(\rho-\rho^N)} \frac{p^*}{c^*} (h_j)'(E^*)$. Each country receives revenue equal to $a_j^*(c^* \times E^*)$, where $(c^* \times E^*)$ is total revenue from emission permits. GDP is the average value for the region in 2016-2055, the period under consideration.

**SOURCE:** Own elaboration.

## FIGURE 2
## NET CONTRIBUTIONS TO THE GLOBAL FUND




NOTE: Bars represent the difference between the amount contributed and the amount received by each region from the global fund. Only India, Africa and Other Asian (representing Asian small developing countries) are net recipients –they receive from the global fund more than what they contribute from buying pollution permits. USA, China and Russia are the main net contributors. Quantities are in billions of international dollars.

**SOURCE:** Own elaboration.

**TABLE 3**

**ANNUAL NET PAYMENT FROM EMISSION PERMITS AND ANNUAL INCOME**

| | Annual net payment | | Annual per capita income | |
|---|---|---|---|---|
| | Per capita (thousand of $) | Share of GDP (% of GDP) | Initial per capita (thousand of $) | Annual per capita (thousand of $) |
| **Region** | | | | |
| US | 220.313 | 0.95 | 48.969 | 61.644 |
| EU | 22.271 | 0.09 | 31.041 | 42.685 |
| Japan | 23.076 | 0.46 | 35.054 | 45.473 |
| Russia | 77.212 | 2.74 | 16.267 | 23.024 |
| Eurasia | 55.754 | 2.02 | 8.459 | 14.237 |
| China | 130.461 | 0.63 | 8.595 | 14.539 |
| India | –141.948 | –1.25 | 3.658 | 7.641 |
| MiddEast | 36.824 | 0.57 | 14.204 | 21.049 |
| Africa | –394.583 | –3.22 | 3.509 | 7.337 |
| LatAme | 16.098 | 0.12 | 11.508 | 19.262 |
| OHI | 63.323 | 1.00 | 35.146 | 46.513 |
| OthAsia | –108.800 | –0.96 | 3.828 | 8.336 |

NOTE: Income is measured as gross firm revenues plus net income from capital minus the net payment for emission permits $Income_j = [p\kappa_j(K_j(p, \mathrm{c}))^{\gamma}] + [r(\bar{K}_j - K_j(p, \mathrm{c}))] - [cE_j(p, c) - a_j cE]$. Population is the average population in 2016-2055.

**SOURCE:** Own elaboration.

## 4. Conclusion

The model we have presented has much less detail in it than many of the models in the climate-change literature. We have presented this reduced form because our analysis focuses on showing that if nations agree to cooperate, there are mechanisms leading to a satisfactory solution to the massive challenge we all face. In that sense, the global unanimity equilibrium presents a mechanism that contrasts with regimes of punishments that would support a Nash (non-cooperative) equilibrium among nations. We believe that the COP meetings, and in particular COP21 that led to the signing of the Paris Agreement in 2015 Paris, exhibit both the desire and the feasibility for nations to cooperate. A key practical question is the applicability of large cross-border financial transfers. As shown in Figure 2, in our calibration, net financial flows across countries exceed 500 billion $ per year. While this is a large number, COP26 led to commitments of 100 billion US$ of annual climate finance to be provided to middle and lower income countries. Our proposal is, therefore, within the ballpark of the latest climate policy negotiations in the real world. However, our analysis does not pretend to offer a solution to the problem of achieving a deeper global cooperation, except in so far as the attractiveness of the global unanimity equilibrium is an advertisement for the cooperation that could bring it about. However, we think that research in climate economics continues to have a direct bearing on climate policy and that, as Karp and Sakamoto (2021) show, economic insights affect beliefs, which in turn matter for the possibility of climate cooperation in the real world.

## References


Barrett, S. (2018). Choices in the climate commons. *Science*, *362*(6420), 1217-1217.

Caparrós, A. (2016). Bargaining and international environmental agreements. *Environmental and Resource Economics*, *65*(1), 5-31.

Carraro, C., Eyckmans, J., & Finus, M. (2006). Optimal transfers and participation decisions in international environmental agreements. *The Review of International Organizations*, *1*(4), 379-396.

Chander, P., & Tulkens, H. (1997). The core of an economy with multilateral environmental externalities. *International Journal of Game Theory*, *26*(3), 379–401.

Dietz, S., & Venmans, F. (2019). Cumulative carbon emissions and economic policy: in search of general principles. *Journal of Environmental Economics and Management*, *96*, 108-129.

Dietz, S., Rising, J., Stoerk, T., & Wagner, G. (2021). Economic impacts of tipping points in the climate system. *Proceedings of the National Academy of Sciences*, *118*(34), e2103081118.

Dutta, P. K., & Radner, R. (2004). Self-enforcing climate-change treaties. *Proceedings of the National Academy of Sciences*, *101*(14), 5174-5179.

Eyckmans, J., & Tulkens, H. (2006). Simulating Coalitionally Stable Burden Sharing Agreements for the Climate Change Problem. In P. Chander, J. Drèze, C.K. Lovell and J. Mintz, *Public Goods, Environmental Externalities and Fiscal Competition*, Chapter 11 (218–249). Springer.

Heitzig, J., Lessmann, K., & Zou, Y. (2011). Self-enforcing strategies to deter free-riding in the climate change mitigation game and other repeated public good games. *Proceedings of the National Academy of Sciences*, *108*(38), 15739-15744.

IPCC, Intergovernmental Panel of Climate Change. (2021). Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32.

Karp, L., & Sakamoto, H. (2021). Sober optimism and the formation of international environmental agreements. *Journal of Economic Theory*, *197*, 105321.

Keohane, R. O., & Victor, D. G. (2016). Cooperation and discord in global climate policy. *Nature Climate Change*, *6*(6), 570-575.

Lessmann, K., Kornek, U., Bosetti, V., Dellink, R., Emmerling, J., Eyckmans, J., ... & Yang, Z. (2015). The stability and effectiveness of climate coalitions. *Environmental and Resource Economics*, *62*(4), 811-836.

Martimort, D., & Sand-Zantman, W. (2016). A mechanism design approach to climate-change agreements. *Journal of the European Economic Association*, *14*(3), 669-718.

Matthews, H. D., Zickfeld, K., Knutti, R., & Allen, M. R. (2018). Focus on cumulative emissions, global carbon budgets and the implications for climate mitigation targets. *Environmental Research Letters*, *13*(1), 010201.

Matthews, H. D., Gillett, N. P., Stott, P. A., & Zickfeld, K. (2009). The proportionality of global warming to cumulative carbon emissions. *Nature*, *459*(7248), 829-832.

Nordhaus, W. (2018). Evolution of modeling of the economics of global warming: changes in the DICE model, 1992–2017. *Climatic change*, *148*(4), 623-640.

Nordhaus, W. D., & Boyer, J. (2003). *Warming the world: economic models of global warming*. MIT press.

Ray, D., & Vohra, R. (2001). Coalitional power and public goods. *Journal of Political Economy*, *109*(6), 1355-1384.

Weitzman, M. L. (2014). Can negotiating a uniform carbon price help to internalize the global warming externality?. *Journal of the Association of Environmental and Resource Economists*, *1*(1/2), 29-49.

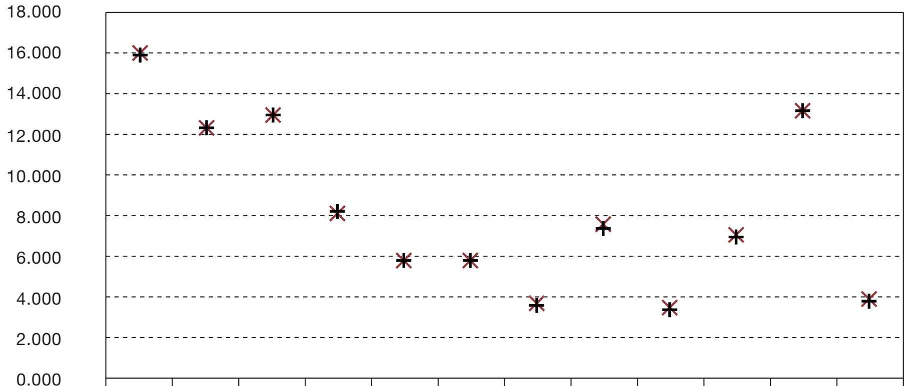
# APPENDIX

## A.1. Estimated total factor productivity

Figure A1 shows that our estimated values of total factor productivity are very similar to total factor productivity when averaging the values for 2016-2055 reported in the baseline run of RICE-2010.

**FIGURE A1**

**AVERAGE 2015-2055 TOTAL FACTOR PRODUCTIVITY IN RICE-2010 (TFP), AND ESTIMATED TOTAL FACTOR PRODUCTIVITY (eTFP)**




| | US | EU | Japan | Russia | Eurasia | China | India | MiddEast | Africa | LatAme | OHI | OthAsia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| × Estimated TFP | 15.993 | 12.299 | 12.894 | 8.146 | 5.781 | 5.829 | 3.654 | 7.534 | 3.500 | 7.033 | 13.165 | 3.883 |
| + Average TFP | 15.901 | 12.272 | 12.967 | 8.182 | 5.767 | 5.811 | 3.588 | 7.415 | 3.385 | 6.963 | 13.124 | 3.790 |

**SOURCE:** Own elaboration.

## A.2. Temperature change and climate change damages in RICE-2010

Table A1 reports temperature increases and the associated climate change damages as reported in the baseline run of RICE-2010.

**TABLE A1**
**CLIMATE CHANGE DAMAGES (IN TRILLIONS OF INTERNATIONAL $) AND TEMPERATURE CHANGE (IN °C WITH RESPECT TO 1850) IN NORDHAUS' RICE-2010 MODEL**

| | | Annual climate change damages (trillions of international $ per annum) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Temperature Change (°C)** | **US** | **EU** | **Japan** | **Russia** | **Eurasia** | **China** | **India** | **MiddEast** | **Africa** | **LatAme** | **OHI** | **OthAsia** |
| 2005 | 0.73070 | 0.00935 | 0.01173 | 0.00334 | 0.00104 | 0.00086 | 0.00663 | 0.00994 | 0.00554 | 0.00746 | 0.00529 | 0.00278 | 0.00571 |
| 2015 | 0.94387 | 0.02021 | 0.04350 | 0.00694 | 0.00230 | 0.00198 | 0.05589 | 0.02590 | 0.01397 | 0.02321 | 0.01262 | 0.01269 | 0.01340 |
| 2025 | 1.20613 | 0.04275 | 0.08144 | 0.01310 | 0.00461 | 0.00443 | 0.11603 | 0.05726 | 0.02905 | 0.05599 | 0.02786 | 0.02381 | 0.03226 |
| 2035 | 1.49926 | 0.08173 | 0.14601 | 0.02251 | 0.00835 | 0.00886 | 0.21457 | 0.11373 | 0.05521 | 0.12313 | 0.05556 | 0.04273 | 0.07008 |
| 2045 | 1.80860 | 0.14257 | 0.24230 | 0.03468 | 0.01394 | 0.01609 | 0.36262 | 0.20658 | 0.09644 | 0.24630 | 0.10035 | 0.07029 | 0.13798 |
| 2055 | 2.12340 | 0.22888 | 0.37414 | 0.05178 | 0.02174 | 0.02681 | 0.56957 | 0.34241 | 0.15431 | 0.43964 | 0.16554 | 0.10706 | 0.24547 |
| 2065 | 2.43529 | 0.34364 | 0.54447 | 0.07454 | 0.03195 | 0.04173 | 0.85110 | 0.52974 | 0.23210 | 0.71822 | 0.25557 | 0.15344 | 0.40420 |
| 2075 | 2.73901 | 0.49175 | 0.75753 | 0.10223 | 0.04455 | 0.06139 | 1.21812 | 0.78225 | 0.33548 | 1.11831 | 0.37518 | 0.21066 | 0.63192 |
| 2085 | 3.03226 | 0.67684 | 1.01552 | 0.13472 | 0.05954 | 0.08622 | 1.67934 | 1.11025 | 0.46909 | 1.67328 | 0.52815 | 0.27922 | 0.94567 |
| 2095 | 3.31449 | 0.90387 | 1.33649 | 0.17220 | 0.07684 | 0.11661 | 2.29977 | 1.52496 | 0.64049 | 2.44189 | 0.71828 | 0.36502 | 1.37078 |
| 2105 | 3.58611 | 1.17354 | 1.73935 | 0.21926 | 0.09920 | 0.15535 | 3.11989 | 2.03508 | 0.83575 | 3.37014 | 0.95002 | 0.47306 | 1.91334 |
| 2115 | 3.84052 | 1.48180 | 2.24197 | 0.27819 | 0.12807 | 0.20397 | 4.20694 | 2.64044 | 1.04171 | 4.39468 | 1.22266 | 0.60890 | 2.57415 |
| 2125 | 4.08099 | 1.82910 | 2.82489 | 0.34466 | 0.16105 | 0.26050 | 5.54053 | 3.34469 | 1.27361 | 5.57047 | 1.53693 | 0.76794 | 3.38989 |
| 2135 | 4.30983 | 2.24344 | 3.51536 | 0.42419 | 0.20161 | 0.32873 | 7.13854 | 4.16637 | 1.52997 | 6.95919 | 1.89814 | 0.95238 | 4.34411 |
| 2145 | 4.52899 | 2.69988 | 4.29612 | 0.51156 | 0.24680 | 0.40564 | 9.03139 | 5.09463 | 1.81019 | 8.52319 | 2.30084 | 1.16177 | 5.48729 |
| 2155 | 4.73957 | 3.20350 | 5.17183 | 0.60746 | 0.29706 | 0.49174 | 11.24380 | 6.13336 | 2.11460 | 10.26080 | 2.74639 | 1.39769 | 6.84170 |
| 2165 | 4.94229 | 3.75892 | 6.14886 | 0.71250 | 0.35278 | 0.58736 | 13.79650 | 7.28525 | 2.44322 | 12.17060 | 3.23556 | 1.66184 | 8.42941 |
| 2175 | 5.13764 | 4.37029 | 7.23282 | 0.82715 | 0.41424 | 0.69272 | 16.70780 | 8.55200 | 2.79579 | 14.24810 | 3.76866 | 1.95579 | 10.27340 |
| 2185 | 5.32595 | 5.04153 | 8.42873 | 0.95179 | 0.48172 | 0.80796 | 19.99370 | 9.93456 | 3.17187 | 16.48650 | 4.34563 | 2.28099 | 12.39750 |
| 2195 | 5.50748 | 5.77645 | 9.74115 | 1.08672 | 0.55541 | 0.93309 | 23.66830 | 11.43330 | 3.57083 | 18.87690 | 4.96610 | 2.63881 | 14.82580 |
| 2205 | 5.68233 | 6.57305 | 11.18160 | 1.23266 | 0.63481 | 1.07006 | 27.79340 | 13.12190 | 4.01303 | 21.53380 | 5.65569 | 3.03141 | 17.67680 |
| 2215 | 5.85083 | 7.43195 | 12.76010 | 1.39022 | 0.71966 | 1.22012 | 32.42670 | 15.05060 | 4.51102 | 24.53710 | 6.43059 | 3.46086 | 21.05990 |

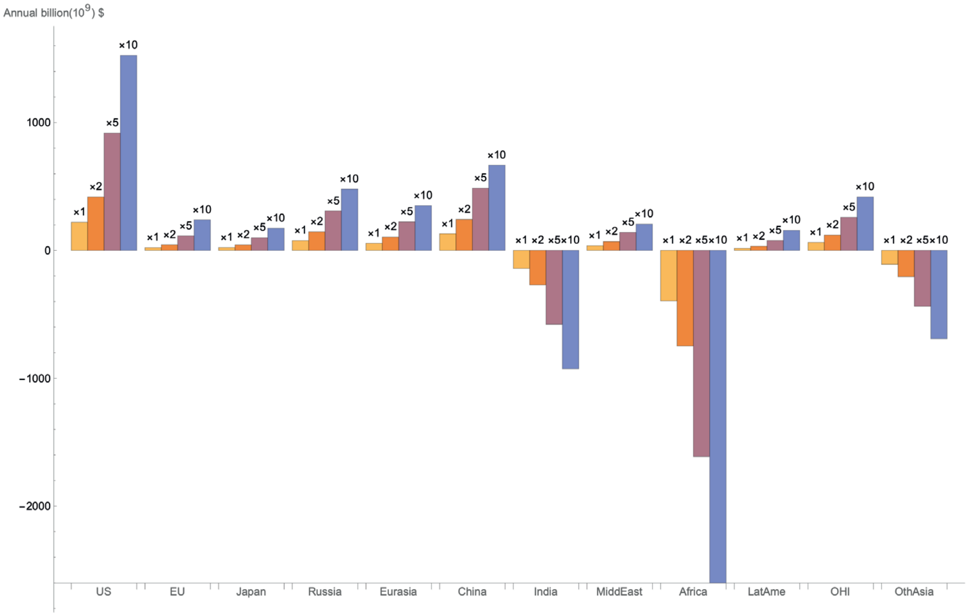
**SOURCE:** RICE-2010 Excel spreadsheet version 4.012510-baselin run.

## A.3. Sensitivity analyses to climate damages

Climate damages in RICE are almost surely underestimated. We repeat the analysis for a range of much larger damages, finding a similar pattern in the allocation of net recipients, with magnitudes increasing with the cost of climate change. Figure A2 shows net contributions for a range of much larger damages. In particular, we study allocations for damages 2, 5, and 10-fold those used in RICE-2010 (that is, we consider $2 \times \alpha_{1j}$, $5 \times \alpha_{1j}$ and $10\alpha_{1j}$ in equation [16]). These allocations show a similar pattern to our main calibrated model. If anything, differences between net recipients and net contributors exacerbate with the increase in damages.

**FIGURE A2**

**NET CONTRIBUTIONS AND RECIPIENTS AS INCREASES IN TEMPERATURE ENTAIL LARGER DAMAGES**




NOTE: The bars shown correspond to the net contribution of each region for damages that are × 2, × 5 and × 10 those in RICE's baseline. A negative value means that the region is a net recipient of global carbon pricing revenue.

**SOURCE:** Own elaboration.

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# Behavior, decisions and ecological transition: experimental approaches with policy implications

# *Comportamiento, decisiones y transición ecológica: aproximaciones experimentales con implicaciones para las políticas*

Alberto Antonioni
Antonio Cabrales
Francesca Lipari
Anxo Sánchez
Universidad Carlos III de Madrid

***Abstract***

*One key aspect of the ecological transition has to do with individuals' and collective behavior and its impact on climate change and decarbonization. We will describe how these questions can be studied by proper experimental designs by focusing on two examples: the implementation of Nordhaus's climate club idea for making countries contribute to climate change mitigation, and the interplay between the perception of the risk of a climatic catastrophe and the social norms arising from, and influencing, individual behavior. We will draw conclusions of the outcome of the experiments that can be relevant for policy making.*

***Keywords:*** *climate clubs, behavioral experiments, social norms.*
***JEL codes:*** *D9, Q5.*

***Resumen***

*Un aspecto clave de la transición ecológica tiene que ver con el comportamiento individual y colectivo y su impacto en el cambio climático y la descarbonización. Describimos cómo pueden estudiarse estas cuestiones mediante diseños experimentales adecuados, centrándonos en dos ejemplos: la aplicación de la idea de los clubes climáticos de Nordhaus para hacer que los países contribuyan a la mitigación del cambio climático, y la interacción entre la percepción del riesgo de una catástrofe climática y las normas sociales que se derivan de, y que influyen en, el comportamiento individual. En las conclusiones discutimos cómo este tipo de experimentos pueden ser relevantes para la elaboración de políticas.*

***Palabras clave:*** *clubs climáticos, experimentos conductuales, normas sociales.*

Cuadernos Económicos de ICE n.º 104 · 2022/II
DOI: https://doi.org/10.32796/cice.2022.104.7505
Recibido: Abril 2022 · Aceptado: Septiembre 2022

## 1. Introduction

According to Masson-Delmotte et al. (2021), each of the last four decades has been successively warmer than any decade that preceded it since 1850, and global surface temperature in the period 2001-2020 was around 1 °C higher than 1850-1900. Only in the last few years a clear majority, ranging from 83% in USA to 95 % in Germany in the nine countries surveyed by Eichhorn et al. (2020), of Europeans and US-Americans have finally become aware that the climate is changing, and also that human activity is an important cause of climate change (from 79 % in USA to 90 % in Italy). In Spain, 97 % of people surveyed by Lázaro Touza et al. (2019) agreed that climate change exists, and 92 % of them agreed that it is caused by human activity.

In the UN Climate Change Conference (COP21) in Paris, in 2015, the participant countries reached a historic agreement, an internationally binding treaty to address this crisis. The agreement established, among other things, a set of *Nationally Determined Contributions* that committed the countries to a fixed level of abatement of emissions. They also committed to establish long-term strategies towards achieving net zero emissions. Interestingly, from this point of view, the latest Intergovernmental Panel on Climate Change (IPCC, 2022) report claims that "Collective action and strengthened networked collaboration, more inclusive governance, spatial planning and risk-sensitive infrastructure delivery will contribute to reducing risks." That is, there exists a growing realization that social issues are a key consideration to deal with this problem.

Such is the approach we take in this paper. Climate change is a serious collective action problem. No one single individual or even country, however powerful, can deal with it alone. This means that strategic interaction is inevitable when addressing mitigation efforts. Another important characteristic of the problem is that we cannot really do many experiments in the field. As the saying goes: "there is no planet B." Both strategic interaction and the difficulty of doing field experiments suggests that laboratory experimentation with games is one of the few good empirical models to understand factors affecting behavioral mitigation efforts.

The usefulness of experiments arises from different reasons. First, the orthodox economics models that regulators and policymakers use to understand the effect of various mitigation policies usually ignore that humans are boundedly rational and have systematic cognitive biases, plus social motivations. This can mean, for example, that a standard policy, such as a Pigouvian tax may not be as effective as regulators expect. Citizens may have difficulty adjusting energy consumption, because of *status quo* bias, or reject it because they feel it is unfair. Experiments can be used to predict these "policy failures" and propose alternatives.

At the same time, the alternatives can also be proposed using behavioral approaches and tested experimentally. For example, social norms have been found to be theoretically relevant and empirically useful to guide behavior. Then experiments have been used to test interventions based on those social norms. People are more willing to make energy savings efforts, or take public transportation, if others are also doing those efforts.

Another area where experiments can help is in the design of novel global institutions to address climate change. A particular case study we have emphasized is that of climate clubs, an original proposal of William Nordhaus that club members commit to lower emissions, and at the same time to have lower tariff barriers towards members than non-members. One important feature of this proposal is its vulnerability to equilibrium multiplicity. Experiments have been used successfully to figure out the factor affecting the probability of different equilibria arising in coordination games. That wealth of information can be brought to bear and help design experiments that address the challenges faced in this specific case.

In the rest of the paper, we present first, in section 2, the ways in which economists have approached the issue of climate change historically, and how the behavioral sciences and the study of social norms have made that approach evolve. In section 3 we review theories and experimental results on how to model social dilemmas and to induce behavior change that have implications for climate mitigation. In section 4 we present the regulatory side, i.e. the strand of institutional design literature, in which we provide a review of different models proposed during the years and our critical standpoint on the existing literature and regarding its future evolution. Section 5 concludes.

## 2. The standard approach to climate change and the contributions of behavioral science

The proper way to address climate change is that of global public goods: goods whose impacts are indivisibly spread around the entire globe (Faunce, 2012). Clearly, climate is a global public good and climate change is probably the most difficult collective action problem in human history (Barrett, 2018). Collective action problems are also known as social dilemmas[1] and specifically, when the definition is applied to common pool resources, as the climate, they are presented as the "Tragedy of the Commons" (Hardin, 1968). Climate change is a social dilemma in which people must choose between their short-term own self-interest and the longer-term interest of the entire population, operating at multiple scales (individual, national, international).

As a global social dilemma, fighting climate change requires global cooperation at both international and domestic level. At the international level, countries are involved in international agreements which, after rounds of negotiation, bind their actions through mitigation pledges, such as the nationally determined contributions in the Paris Agreement. Yet, the large number and diversity of stakeholders involved in those negotiations makes it difficult to come to an agreement on a policy proposal defining the pledges.

[1] According to Olson (1965), a social dilemma is a situation in which actions that are individually rational can lead to outcomes that are collectively irrational. In other words, is a situation in which individuals would be better off cooperating but fail to do so because of conflicting.

At the national level, each government will need to transform those pledges into a mitigation policy whose success will depend on individuals' behavior and their willingness to cooperate. In order to achieve citizen cooperation in climate commons, policymakers need to understand the reasons that will induce individuals to change their choice, behaviors and lifestyles.

In this framework, it turns out that climate change mitigation can be promoted by resorting to two basic mechanisms: working on social preferences or, in other words, changing players' behaviors and motivations, and creating institutions, by modifying the rules of the game or introducing new ones. In what follows, we give examples of each one of them.

Economists tend to start discussions about climate change and other environmental problems by pointing at public policy (institutional) interventions. These are the systems of laws, regulatory measures, and other actions that governments and parliaments design and implement in response to the problems faced by their citizens seeking to improve their well-being. In a certain way, the objective of public policies can be defined as seeking to limit the social suboptimality of decisions taken "optimally" at the individual level and correct their effects. However, the success of public policies crucially depends on the response of citizens to them. That is, the acceptance, understanding and degree of compliance that citizens make of the measures applied to them. However, there is ample evidence that human beings do not always optimize and, therefore, our decisions often do not result in our own benefit or that of the society to which we belong.

To be concrete, let us start by providing an example. The typical introductory economics textbook reaction to the climate change problem is to suggest the imposition of a "Pigouvian" tax.[2] Such tax increases the price of unclean externality-creating energy sources. If correctly set, at a rate that equalizes the social and individual marginal cost, it would eliminate the social distortion, by aligning the individual and social optimal consumption levels. However, is it really the case that environmental taxes work? A recent meta-analysis by Zhou et al. (2018) shows that "residential electricity demand is almost price-inelastic and income-inelastic in the short-term." This means that a well-meaning environmental tax will not reduce consumption immediately. It will create revenue for the government, and maybe even increase inequality, since energy is a larger fraction of expenditure in poorer households. Does that mean that Pigouvian prices and other standard public policy approaches should be abandoned? Certainly not; following with the same example, Cialani and Mortazavi (2018) show that industrial electricity demand is elastic to price changes. And even Zhou et al. (2018) show that long-term price elasticity is significant.

The previous discussion highlights that society should take a three-pronged approach to address the challenge of climate change. First, we need to intervene to

[2] This is true even at modern/enlightened textbooks such as The Economy by the Core Project. See its unit 12: https://www.core-econ.org/the-economy/

correct wedges between individual and social interests. Second, we need to tackle the individually suboptimal decisions that arise out of a lack of cognitive resources to address a very complex world. And, finally, we need to figure out creative ways to address the global commons problem, which makes climate change so intractable. Since the first path is the common one in Economics, we will concentrate our discussion in this paper in the other two, namely behavior change, and novel proposals to address global commons.

In the last fifty years, behavioral social sciences have successfully shown that many of the actions of human beings are not always governed by the principle of rational optimization. In the pioneering work of Kahneman and Tversky (1974), they show that our decision-making process is often based on automatic decisions ("biases" or "heuristics"), influenced in turn by our emotions, our inability to process information, our behavior in the face of uncertainty or simply because we do not know exactly what is best for us, either in the short or long-term. Behavioral science has therefore based part of its success on taking as its starting point what individuals actually do, rather than a "theoretical" idealization of how they behave (or should behave).

The application of behavioral economics to climate change policy has been considered extensively. Carlsson and Johansson-Stenman (2012), for example, note that the departures from standard ways of thinking take three main forms:

1. Behavior is not motivated just by own material payoffs. Distributional concerns are an important driver of behavior (see Cabrales and Ponti, 2015).
2. Human act in a social context: social approval, norms and status are key motivators (Cole et al., 1992).
3. People have cognitive limitations and therefore sometimes make seemingly irrational decisions. (Simon, 1955).

These considerations suggest margins of action that we will explore in what follows. Thus, Cai et al. (2010) and Svenningsen and Thorsen (2020) have explored the impact of distributional concerns, between and within generations, on the willingness to pay for abatement. It must be remembered at this point that the negative reaction from a part of the French population to a green tax (the *gilet jaunes* movement) was heavily influenced by a perception that the consequences of the tax were not evenly distributed.

Social norms have also been used extensively to modify consumption decisions. Alcott (2011) reports on the OPOWER experiment, where a consulting company, working in conjunction with power utilities in the US used the power of social norms to decrease energy consumption. They sent its letters called "Household Energy Reports" (HERs) with a "social comparison module" and a normative indication as to whether the home is "very good," "good" or "below average." They obtained significant consumption reductions over time. Importantly, they were maintained over time, which indicates that the informational intervention served to assuage cognitive limitations as well.

The final lever of interest is that of innovative proposals to mitigate emissions. The global commons suffer from the standard problem of a social dilemma. If individuals observe that others do not contribute to a public good (and some will surely not contribute) then global contributions will decline over time. There is significant evidence about this for multiple societies (Herrmann et al., 2008).

In principle, the fact that the climate game is repeated can theoretically provide a solution, using the threat of "bad equilibrium reversion" to get cooperation. This is an intriguing, decentralized solution. The trouble is that we have not seen any evidence of it happening in the half century since climate change has become evident; and there are good reasons for this. In a context with many countries, the efficient theoretical equilibrium is too vulnerable to partial agreements between several countries. In a very precise sense, it is not stable against deviations from "coalitions". Perhaps more importantly, from the point of view of human behavior, punishments are difficult to implement because they not only hurt the punished, but also the punisher; and when "this hurts me more than you" it is easy for a group to find a less painful way out.

An obvious solution is to have international agreements where countries commit to reduce emissions. One problem with this approach is its vulnerability to "carbon leakage", the displacement of production and emissions from states with more to less stringent climate policy commitments. One way to deal with this problem is carbon adjustment taxes. All goods entering a trading zone (say, the European Union) will need to pay a tax that is equivalent to the local cost of carbon abatement inside the zone. This neutralizes the perverse incentives to displace production to less regulated areas. This could face limitations because of international trade agreements, but Mehling et al. (2019) show they could be addressed with a careful design. Winchester et al. (2011) show that although the direct effect of carbon border adjustments may be small (and they are a costly way to implement leakage reductions), they can be a useful coercion strategy for countries to implement policies that reduce emissions more cheaply. An evolution of this tool is the one called "climate clubs" proposed in Nordhaus (2015), about which we discuss at length in this paper.

Another potential set of abatement alternatives works through a deeper understanding of the inter-relationship between fiscal and financial climate policies. The financial system's network structure means that climate-induced shocks can spread quickly, but also suggest that the impact of financial policies to fight climate change may spread with the same speed across agents and boundaries, bolstered by the evolution of social norms. The tools of the existing framework (economic, social, legal) for financial stability are sufficiently powerful to change the incentives for firms and reduce significantly their carbon footprints. In upcoming work, Cabrales and Gottardi (2022) explore the impact of misaligned incentives on financial network formation and on social welfare, and Ramos et al. (2022) explore the legal feasibility and opportunity of financial regulatory tools.

## 3. Experiments on individual behavior

The IPCC, in its Special Report on 1.5 degrees, assumes “behavioral and lifestyle changes” as a vital climate change mitigation strategy complementary to technological measures. According to the IPCC ambitious changes, like how we use fuel, land and other natural resources (Intergovernmental Panel on Climate Change, 2018, 2019) are a priority.

Such an ambitious plan will require a large-scale change that needs to incorporate both the demand (consumers) as well as the supply (firms and politics) side of the society (Alló & Loureiro, 2014). Citizens’ responses do not come with negligible resistance. Even policy solutions that focus on technology or structural changes often require behavioral components to succeed, such as the adoption of new technologies or participation in energy-efficiency programs. Ultimately, people must adhere to policies for them to succeed.

Hence the question is: why people fail to engage in behaviors necessary to mitigate climate change? The answer is related to the well-known gap between environmental attitudes and actions that enable a change of behavior. In the literature, we find that the gap between attitudes and behaviors depends on both structural barriers and decision-making barriers. Structural barriers, such as poverty, ill-suited public transportation and services or climate-averse infrastructure, may be lowered with social programs and infrastructure improvements. According to Drew and Van den Bergh (2016), who review the sociopsychological factors underlying the (un)popularity of carbon taxes, the barriers of individuals’ decision-making display at both individual level, such as lack of knowledge, ill-oriented motivation, wrong perception about climate change and the effectiveness of mitigation policy, self-efficacy of agents, as well as at the social level, such as generalized trust and social norms and expectations and lack of enabling institutions. Finally, decision making is highly heterogeneous and as such the literature, usually, presents the two barriers as separate, but there exist spillovers effects from structural barriers to psychological barriers.

The scope of this section is to shed light on the barriers that hamper individuals’ decision making to enact the behavior change that the climate change mitigation policies address. In the rest of the section, we present how behavior change has been addressed in the literature and the underlying assumptions of individual’s decision making which justify the use of top-down or bottom-up interventions. Then, we examine how social norms impact people’s ability to cooperate with climate change mitigation. Finally, capitalizing on the previous sections, we present experiments concerning many social dilemma situations that have implications for climate mitigation.

### *3.1. Behavior change in economic models*

If society decides that it has an interest in changing people’s behaviors away from unsustainable ones, economic theory has identified four basic options to change behavior: (1) impose regulations that constrain individual's actions (strategy spaces, in the language of game theory); (2) tax (or subsidize) the undesired (desired) behavior (changing the payoffs, in the language of game theory); (3) other forms of incentivizing (changing the payoffs of) the desired behavior; or (4) provide information.

Neoclassical economists confined themselves to the study of beliefs and incentives, strictly assuming that decision makers are fully rational, self-interested, benefits maximizing, and costs minimizing individuals with stable preferences. Modern behavioral economists relax the homo economicus assumptions when investigating beliefs and incentives and study adaptation of preferences and the role of boundedly rational learning rules.

Given these premises, the approaches to behavioral change of these two literatures need not be viewed as antipodes, but they should reveal the need for effective integration as the IPCC Sixth Assessment Report (IPCC, 2019) suggests and recommends.

We revise the policy mitigation strategies considering both neoclassical and behavioral theory in order to highlight such integration.

1) The first approach to behavioral change consists in drafting regulations, such as bans and restrictions to the use of the harmful alternative. Regulations, such as bans or restrictions, can be implemented more easily and equitably than taxes or incentives. Yet regulations face the problem of needing to be enforced. That is, placing a regulation on an activity does not change the basic internal calculus concerning the individual's actions. If individuals prefer private transportations over public ones, for example, then a law that bans the sale of cars is not likely to be effective unless it appeals to another value (e.g., being a good member of society, adhering to social norms) or there is some enforcement mechanism to ensure adherence.

2) A second approach suggests the use of taxes and subsidies. The rationale behind the use of taxes as instrument for behavioral change rests on the standard economic remedy for internalizing external costs, which is a Pigouvian tax on the pollutant. In this case, what is called for is a carbon tax, levied on carbon-based fossil fuels in proportion to the amount of carbon associated with their production and use. Will such a tax amounts affect people's driving or home heating habits very much, or impact industry's use of fuels? This depends on the elasticity of demand for these fuels and on its regressive effect.

Along with purely economic reasons, interventions such as carbon taxes are shadowed by perils like the lack of public support. Carattini et al. (2018) surveys the literature on qualitative and experimental work highlighting several factors affecting public support. Concerns over carbon taxes stem from overestimation (underestimate) of the costs (benefits) of the tax (Alberini et al., 2018; Heres et al., 2017; Carattini et al., 2018; Odeck & Bråthen, 2002), to equity and pro-social preferences (Bristow et al., 2010; Brännlund & Persson, 2012; Gevrek &

Uyduranoglu, 2015) and to concerns over the implementation and efficacy of the policy (Klok et al., 2006; Steg et al., 2006; Baranzini & Carattini, 2017; Carattini et al., 2017; Hsu et al., 2008; Kallbekken & Aasen, 2010; Kallbekken & Sælen, 2011). In many of the studies above the respondents consider low-carbon subsidies to be a more powerful way to reduce greenhouse gas emissions, especially if the cost of switching from consuming high-carbon goods to low-carbon goods is considered high and given that price elasticity of demand for carbon-intensive goods was considered close to zero. The support for subsidies against the tax can be explained by the loss aversion hypothesis.

A subsidy is environmentally motivated if it reduces directly or indirectly the use of something that has a proven, specific negative impact on the environment. It can take many forms: Value-Added Taxes exemptions on electric cars, feed-in tariffs on renewable energy generation, tax credits for environmentally relevant investment, or provision of public funds for nature conservation projects. Yet all these instruments are not seen as appealing by everyone. The same issues of behavioral biases (Allcott & Rogers, 2014) and bounded rationality (Pollitt & Shaorshadze, 2013) in consumer decision-making prevail.

3) A third approach to behavior change involves providing financial incentives or disincentives for engaging in the desired behavior that are not taxes or subsidies. There are several challenges with using incentives to spur behavioral change.

People's reference points matter in considering a monetary incentive as binding. Whether using incentives as a reward for positive behavior or as a penalty for bad behavior it may be useful to consider loss aversion (the phenomenon that individuals prefer to avoid losses than acquiring gains). It is likely that sanctions, such as fines, are likely to be more effective when framed as losses. On the other hand, ambitious climate-protection goals would require new investments (physical and intellectual) in climate-friendly technologies. These investments are essentially irreversible and people might suffer from the sunk cost fallacy.

Providing monetary incentives raises the total amount that individuals can spend and thus could lead to an increase of consumption of both climate friendly and polluting goods. A further drawback of incentive is their crowding-out effect. It is claimed that monetary compensation can lead to feelings that an activity is not worthy by itself ("intrinsic" motivations) being "crowded out" or partially destroyed. Another problem related to incentives is that the choice over a sustainable behavior might have not only an economic attribute but it could enclose social or symbolic values.

In this regard, individuals are endowed by what Manski (2000) called "preference interactions". Individuals' preference ordering over the alternatives in a choice set depends on the actions chosen by other agents. Such everyday ideas as conformism, jealousy, and paternalism suggest forms of preference interaction. Preference orderings expressed in terms of symbolic values entail attitude, beliefs and identity.

Values influence behavior indirectly by activating norms, thereby creating a feeling of moral obligation to act pro-environmentally (Nordlund & Garvill, 2003). Values generally influence pro-environmental behavior through three different channels: by the perceived importance and likelihood of behavioral consequences, by norm activation and via environmental self-identity (Van der Werff et al., 2014).

4) The fourth approach is based on informational interventions. In reality, all individuals are not endowed with access to the same amount of information or have the same capacity to manipulate the same piece of information: what will be the tool to coordinate them to a new sustainable alternative? In this case, provision of information should cause the individual to realize that the values of the attributes of the promoted sustainable (brown) alternative is better (worse) than they initially believed. Yet lasting behavior change can only occur when informational campaigns provide new information that produces lasting changes in how people view the attributes. There are several impairments to the re-evaluation of the attributes.

The first limitation, given that climate change is a complicated phenomenon, even when people understand and endorse the goal of mitigation policies they may not know which of the many personal changes will be more effective. Attari et al. (2010) shows that within a familiar context like home energy conservation, people often do not know which strategy, between curtailment (e.g., turning off lights, driving less) and efficiency improvements (e.g., installing more efficient light bulbs and appliances), was more *consequential* to achieving energy efficiency. Moreover, the efficient use of energy is a cognitively challenging task and involves trading off short-term versus long-term benefits and costs, and it is unlikely that all consumers can perform the necessary calculations and to arrive at an individually optimal result.

The second obstacle is that even if people know how to act effectively, they may not be motivated to do so. Motivations are linked to how much the climate change problem, with its related costs or losses, is perceived immediate and concrete in both time and space. In order to fight global warming, we ask individuals to make an immediate costly effort to regulate their behavior today (e.g., to drive less, to consume local, to use an alternative energy resource) but the rewards from these efforts, e.g., in form of better environmental conditions, are only realized in the future. Such self-regulatory problems are very difficult to address (Weber, 2006), even in a context in which individual's self-interest is clearly at stake (e.g., increasing healthy eating to promote long-term health, Hall and Fong, 2006). A simple informational strategy would not be effective.

The third hurdle is related to the idea that people have rational expectations about the consequences that one action will produce given the informational set available at the time of the decision. Yet, neoclassical economics also assumes that people would form such expectations from observational learning, i.e. from observation of the actions chosen and outcomes experienced by others. Observational learning is highly heterogeneous in reality. If it is true that people learn from what they observe, people living in the same city but in different residential areas would have a different glimpse of the reality. General information about how society at large adopts more sustainable behaviors might not have the same effect as information based on the behavior of local communities. Any information colliding with such experiential window would be discarded. For example, Allcott and Mullainathan (2010), Allcott (2011), and Allcott and Rogers (2014) show how the power of social comparison in home energy reports (HER) are a cost-effective climate policy intervention to push people towards sustainable energy consumption or providing households with tailored information regarding their energy use reduces their energy use (Abrahams et al., 2007). In contrast, direct repeated information about the causes of climate change does not lead to a reduction of carbon consumption (King et al., 2009).

Hence, the nature and the saliency of the information delivered, and the mode of information delivery is relevant. Chetty et al. (2009) finds that consumer reactions to taxes depends on the visibility and salience of the tax. By the same token, assuming that any type of information will be accounted for in the decision process is highly unrealistic too. In behavioral economics there exists a phenomenon called information avoidance (Golman et al., 2017) which refers to situations in which people choose not to obtain knowledge that is freely available. Active information avoidance includes physical avoidance, inattention, the biased interpretation of information (see also confirmation bias) and even some forms of forgetting. Alcott (2011), for example, indicates that 40% of US consumers do not consider vehicle gasoline when they face the decision to purchase a vehicle.

To date, the literature on behavioral approaches to mitigation policy has focused its attention on how to correct all the previous behaviors labeled as far from the neoclassical assumption, but none on understanding whether individuals' competences are up to the challenge of behavioral change (Kolle, 2015). The literature, so far, looks at the individual as a boundedly rational, boundedly self-interested being who suffers from lack of willpower (Thaler & Sunstein, 2008; Halpern, 2015). Consequently, the policy approach that has been used is the one of nudging such as default option (Allcott & Kessler, 2019; Bernheim et al., 2015).

Psychological barriers are not only based on limited cognition or on social interactions. There are individual psychological barriers that need to be added in the analysis to really assess people's motivation to take part to the climate change battle. The inertia of people to change their behavior emerges, not only as a consequence of increasing returns to conformity but also because of the way in which individual self-views evolve. If most members of the population do not believe in their abilities to change the *status quo* they are more likely to unquestionably follow the standing behavioral rule (Olson, 1965). For instance, perceived lack of control predicts the choice between public transportation and driving (Kaiser & Gutscher, 2003; Heath & Gifford, 2002). Thus, when individuals perceive little control over the problem of climate change, they may fail to act. Specifically, there is evidence that low-income individuals are more likely to respond to curtailment policy and to stick to default choices (Ghesla et al., 2020). In particular, investigating electricity contract choices

Hortacsu et al. (2017) find that households with lower income and lower education are less likely to switch their electricity contract.

In addition, the policy approach changes if we consider individuals only as cognitively and socially bounded actors or if we take into consideration also their competences. In fact, by addressing only individual's cognitive deficiencies, policymakers can steer (nudge) individuals' behavior toward behaviors that are consistent with their ultimate goals or preferences – and that result in better outcomes than would otherwise be obtained (Rebonato, 2012; Thaler & Sunstein, 2008). In doing so, the architect does not aim to foster people's competences for making better choices. Hertwig and Grüne-Yanoff (2017) propose a different type of intervention to complement the nudges, what the authors called boosts. Boost interventions target competences and capabilities rather than immediate behavior. By fostering existing competences or developing new ones, boosts are designed to enable specific behaviors. Furthermore, they have the goal of preserving personal agency and enabling individuals to exercise that agency. Therefore, in order to improve one's judgment boost interventions aim to train and strengthen the cognitive system by promoting, for example, (i) statistical, energy, and financial literacy[3], (ii) deliberative skills, or (iii) the use of evidence-based guidelines. For example, Kalmi et al. (2020) show that energy-related financial literacy might guide consumers' decisions toward energy efficiency and conservation.

### *3.2. Behavior change and social norms*

As recently argued by Fehr and Schurtenberger (2018), a large variety of behavioral regularities with regard to human cooperation can be explained by a significant share of individuals adhering to a social norm of conditional cooperation (see Kimbrough and Vostroknutov, 2016; Kölle et al., 2020; Szekely et al., 2021) for direct evidence on the importance of norm-following for cooperation).

Prior work has shown that harnessing social norms can be instrumental in addressing large-scale social dilemmas (Ostrom, 2000; Bicchieri, 2005; Biel & Thogersen, 2007). People's understanding of collective action problems does not occur in a vacuum because its interpretation is influenced by values and beliefs shared in groups for which they feel a sense of belonging. Hence, the first psychological barrier derives by the presence of social norms. Social norms are generally understood to be shared rules of conduct that are partly sustained by approval and disapproval (Elster, 1989) or ideal form of behavior to which individuals in a social group try to

[3] This competence can be achieved through (a) graphical representations (Lusardi et al., 2017); (b) experienced-based (as opposed to purely description-based) representations (e.g., Kaufmann et al., 2013); (c) representations that avoid biasing framing effects (Spiegelhalter et al., 2011); (d) training in transforming opaque representations (e.g., single-event probabilities) into transparent ones (e.g., frequency-based representations, Sedlmeier and Gigerenzer, 2001); and (e) training of general math skills (e.g., Berkowitz et al., 2015).

conform (Young, 2015; Burke & Young, 2011). They form as the unexpected result of individuals' interactions that, through learning, specify "what is acceptable and what is not in a society or group" (Muldoon et al., 2014). Moreover, social norms are self-enforcing at the group level because people adhere to certain norms of behavior if these norms make them better off, or meet their needs, but also if they expect others to adhere as well.

In a coordination game, a social norm corresponds to a pure equilibrium of the game that is played repeatedly by members of a population with or without a punishment of the deviants. The relevant point is that the equilibrium holds at the population level, inducing common expectations and behaviors for an interaction that is repeated over time by members of a social group. In Manski's words (Manski, 2000), a social norm would be the result of people's interactions colliding in a dynamic of expectation coordination.

At the same time, social norms do not only coordinate people's expectations and, eventually, judgement, but also people's preferences (Manski, 2000; Bicchieri, 2005). In other words, an agent's utility may derive simultaneously from his personal and idiosyncratic preference for a particular action, and from his preference for conformity to the actions of his reference group (Akerlof & Kranton, 2010). Norms and personal preferences are also highly intertwined, as norms can shift motivations; and even in cases where norms do not shift personal beliefs, they still can have a substantial impact on personal behavior (e.g., Paluck, 2009a). Moreover, according to Paluck (2009b), it is often easier to impact perceptions of social norms than directly shift people's attitudes or beliefs on a topic. Consequently, an agent with such preferences would react to incentives that are norm-based, or will follow taxes that are in agreement with the local social norms, or will accept information that are salient with the features of the norms.

We could look at social norms as the solution of global social dilemma. Coordination of expectations is extremely important in global dilemma, such as the climate change, where uncertainty and ambiguity related to the effectiveness of agents' effort is a hurdle to overcome. At the same time, coordination of expectation reduces agents' worries for the free-riding of others and align people's incentives (whatever those are).

In fact, if we analyze the expectations features of the social norms, we soon realize that norms exists if two kinds of expectations are formed in the mind of people. According to Carattini et al. (2020), social norms have different levels of visibility.

Empirical expectations[4], that are the most visible ones, are expectations about what people do. By observing other people cooperating, agents start forming expectations about the fact that cooperation is a widespread behavior in the social reality in which agents live (Allcott & Rogers, 2014). Normative expectations, the less visible ones, are those related with what people should do in respect of the context, the reference group and the decision to take. Normative expectations make people's beliefs

[4] Bicchieri (2006) calls empirical expectations what Cialdini (2003) descriptive norms.

converge towards what is perceived as the socially right behavior to have (Schultz et al., 2007; Szekely et al., 2021). For Bicchieri (2006, 2016) both types of expectations are necessary to see the emergence of social norms.

For all of these features and dynamics, norms are likely to be an apt solution to addressing climate change because they are a robust source of influence (Ostrom, 2000; Bicchieri, 2002; Biel & Thogersen, 2007; Bolsen et al., 2013; Nyborg et al., 2016; Huber et al., 2018). Of course, to be part of the solution to climate change and not its hurdle, new green and sustainable social norms need to be created or helped to emerge within the society. And to do that, many policy instruments are needed.

Examples of how empirical expectations induce behavioral change are the following. In Allcott and Mullainathan (2010), Allcott (2011) and Allcott and Rogers (2014) comparison in home energy reports (HER) works as signal of the behavior of others pushing people towards the creation of empirical expectation on sustainable energy consumption. Baranzini et al. (2017a) find that Swiss consumers are more likely to adopt solar panels if neighbors have already done so. Such diffusion is driven by imitation of conspicuous consumption and communication of positive information. The same effect in the adoption of rooftop photovoltaic technology has been identified in California (Bollinger & Gillingham, 2012), Connecticut (Graziano & Gillingham, 2015) and Germany (Rode & Weber, 2016). All of the above confirm the fact that rooftop solar photovoltaic panels were visible, they convey information about the behavior of others in a given community (i.e., the local social norm). Even though there were also financial incentives driving the adoption, the literature suggest that the recurrent view of the panel worked as a reminder of the widespread social behavior.

Empirical expectations do not suffice, by themselves, to sustain a change of behavior for a long time. Normative expectations are necessary too. In fact, as found in Székely et al. (2021) individuals' cooperative behavior is primarily sustained by both empirical and normative expectations of cooperation, which are formed through individuals' social interaction. Also, Schultz et al. (2007) apply this approach to a field experiment on household energy consumption in California finding that when interventions are based on both empirical expectations and normative ones, people tend to replicate the behavior of the more cooperative individuals in their local context.

Social norms have also been highlighted as a means for overcoming the limit faced by regulations in achieving behavior change. In fact, social norms help in building public support for climate policy (for a review, see Alló and Loureiro, 2014; Sparkman et al., 2021). Furthermore, social norms have been shown to influence one's policy attitudes, even when those norms are contrary to one's initial personal beliefs (Todorov & Mandisodza, 2004). Norms also shape support for climate change policy measures among policy-makers themselves (Nilsson et al., 2004). Beyond policy support, social norms have been shown to impact whether citizens are likely to engage in political action on climate change, such as contacting government officials, voting for "green" candidates and protesting (Doherty & Webler, 2016).

The next section describes how climate change can be modelled with specific experimental setups and how social norms could be used as instruments to steer people's mitigating behavior.

### *3.3. An experiment on behavior change for climate mitigation*

For years the experimental literature on social dilemma has focused on using standard public good games to study how to sustain cooperation. Standard public good games are concerned with the creation of a collective gain (Sturm & Weimann, 2006; Fehr & Gächter, 2000; Fischbacher & Gachter, 2010). Even though climate change is considered an example of a global public good, it has specific characteristics that require a different representation than standard public good games. In fact, climate change is more about avoiding an uncertain public bad, rather than the creation of a collective gain.

The literature about sustaining cooperation for addressing climate change is divided into two strands of literature: the static repeated games and the dynamic social dilemma.

In the set of static repeated games, we find games that model climate change as a collective-risk social dilemma, i.e., a problem of sustaining cooperation when facing an emission threshold that may result in a catastrophe (Milinski, 2008), while others model it with an incremental damage from pollution (Ghidoni et al., 2017).

This "collective-risk social dilemma," is a threshold public good game of loss avoidance played with sequential contributions to a fund aimed at avoiding a probabilistic loss arising if the target is missed (Milinski et al., 2006; Dreber & Nowak, 2008; Chakra et al., 2018).

This model belongs to a larger set of dilemmas also known as threshold public global good (Pacheco et al., 2009). At the start of the game, participants are each given an endowment, and they must decide whether to contribute, up to a predefined amount, to the common good over a fixed number of rounds. If the joint contributions of all the participants over those rounds are equal or above a certain threshold, then the disaster is averted, and they receive as a reward the remainder of the endowment (hence the dilemma). On the contrary, if the target is not reached, there is a probability that a disaster may occur, resulting in an economic loss for all the participants (they lose the remainder of their endowment). In the experiments, people only tend to contribute to avoid the disaster if they perceive the risk to be high (Hagel et al., 2016; Milinski et al., 2008). Moreover, even when the risk is high, theoretical models indicate that players should delay their contributions until the moment when the disaster is known (Abou-Chakra & Traulsen, 2012; Hilbe et al., 2013).

The phenomenon of climate change is very well depicted through the features of the collective-risk social dilemma. The risk parameters, the threshold, and the loss avoidance construct, which make the game non-linear and the collective benefit uncertain as it is only achievable in the future. For this reason, the game has shed new light on the issue.

Yet, in a real-world scenario both the amount (threshold) as well as the timing when it has to be achieved are uncertain, as they are based on predictions and thus inherently suffer from uncertainties. Prior work on uncertainty about what amount (threshold) should be achieved in such games and more so in case of ambiguity (Barrett & Dannenberg, 2012, 2014; Dannenberg et al., 2015) has shown that the level of cooperation, i.e., the willingness to contribute in both games, is negatively affected. Uncertainty about the timing in which a predetermined target yields benefits decreases cooperation (Jacquet et al., 2013; Kolle & Lauer, 2020).[5]

Moreover, the challenge of this game is coordination. Players are best off when synchronizing contributions in the face of multiple equilibria. The game therefore calls for an instrument able to facilitate such coordination. Some authors use communication as an instrument for coordination. Tavoni et al. (2011) show that income inequality and the ability to communicate also affect the frequency of avoiding a catastrophe: success is more likely in groups making choices that reduce inequality and are able to communicate.

Other authors use social norms as a coordination mechanism. Szekely et al. (2021) design a repeated threshold public goods game with elicitation of social norms and social norms strength showing the causal evidence that social norms change in response to threat variants and that stronger norms increase social coordination. To do so the experiment lasted for 30 days to allow social norms of cooperation to emerge and to be enforced. During the experimental days, the agents' expectations (both empirical and normative) were elicited and agents' social norms strength was computed. Agents were exposed to two different threats where the risk of a catastrophe was either high or low. Social norms associated with the two risk scenarios were the tools driving people cooperation.

The main conclusions of the experiment can be summarized as follows: The authors find that in the scenario where the risk was high, social norms strength was higher, pushing agents to cooperate more. The positive relation between social norm strength and risk answers the daunting question of how to address cooperation in uncertain collective-risk social dilemma. Moreover, such relationship would persist in time: the paper results show that in a high-risk scenario the effect of higher social norms strength would persist also when the risk lowered. Finally, social norms were not only endorsed by agents, via increasing cooperation, but they were also enforced by the latter, leading to punishment actions against the norm-breakers.

[5] These results hold true also when treatment in delayed payment is not present and they hold true in both the lab(oratory) as well as in the field. Fehr and Leibbrandt (2011) find that time preferences measured in the lab predict cooperation behavior outside the lab in a situation that entails an intertemporal component. In particular, they find that more patient fisherman use more sustainable fishing instruments that are less likely to exploit the collectively used fishing grounds. Similar evidence is provided by Boonmanunt et al. (2020) who show that time preferences elicited in the lab predict replenishment behavior in the field.

The above experiment aligns with the studies of dynamic setups that have been carried out recently. Climate change externalities are dynamic because they depend on the stock of pollution accumulated in the atmosphere and not just on the yearly flow. Cooperation in dynamic set-ups appears more difficult than in static ones. The two main references in this area are Battaglini et al. (2016) and Calzolari et al. (2018).

As Battaglini et al. (2016) point out, there are two main differences in dynamic public good problems with respect to static ones. First, there is now a “dynamic free-rider” problem, where an increase in the contribution of one agent in the present triggers a decrease in the contribution of others in the future. The other problem is that there may be a large number of dynamic equilibria. The paper offers a number of important methodological contributions. However, from our point of view, the main result is on the equilibrium selection. The “good” equilibria where player use strategies that react to actions other than the accumulated level of the public good is not observed in the data. Instead, the Markov perfect equilibrium (usually Pareto inefficient) is the typical observed outcome.

Calzolari et al. (2018) uses a more specific dynamic public good game that mimics climate change more closely. Their main observation for our purposes relates to a situation where conditions are close to the ones in reality: the stocks of the harmful action are long-lasting. In this case they observe that participants in the experiment cooperate strongly at the beginning of the game, but then it decreases in a very significant way.

In summary, the insights obtained from the dynamic models corroborate those already found in the static games, to a large extent, but emphasize just how difficult is to obtain cooperation in dynamic situations.

## 4. Institution design

### *4.1. The role of institutions in climate change*

Since the last quarter of the 20th century, there has been quite some research on the theory and modeling of global public goods that, as we have discussed above, is the way climate change should be addressed. Among this large body of literature, quite a few papers discuss the game theory and modeling of coalitions (e.g., of institutions) of countries. While a thorough review of this literature is beyond the scope of this paper, we here summarize the most important results along this line to provide a proper context for our focus paper, namely Nordhaus (2015). A general survey on treaties about global public goods preceding Nordhaus work can be found in Barrett (2003).

Prior to Nordhaus’ work, a first relevant contribution was that of Carraro and Siniscalco (1993), who analyzed the problem of free-riding within international agreements for global public goods. Their key finding was that only a small number of countries would take part in the agreements as they were designed, and only if it was possible to make and enforce binding commitments. This result would arise also from many other studies, leading to Nordhaus calling it the "small coalition paradox". Subsequently, Chandler and Tulkens (1995) and Chandler (2007) showed that transfers between participants are needed in general to have stable cooperative equilibria, although in a few special cases such transfers might not be necessary. However, they assumed that any single defection is enough to break the coalition, something like a doomsday scenario, to prevent defections from participation. The drawback is that this strategy works against the punisher as well as the punished, and hence the agreement is not very appealing (technically, they are not renegotiation-proof). Along these lines, Yang (1999, 2008) considered how transfers could improve the overall abatement, finding that it requires substantial transfers from North to South to induce cooperation.

Bosetti et al. (2012) studied the problem using the WITCH (World Induced Technical Change Hybrid) integrated-assessment model (Bosetti et al., 2006), a global dynamic model integrating the interactions between the economy, the technological options, and climate change (it is worth mentioning that WITCH is an open-source model available for any further studies and still running today, see https://www.witchmodel.org). Their main finding is that only a global coalition of all regions is able to control the amount of greenhouse gas in the atmosphere, but unfortunately, such a global coalition turns out to be unstable even with monetary transfers. The small coalition paradox showed up again as they also found that smaller coalitions can be stable but cannot lead to efficient climate change mitigation.

Related results have been found in Finus et al. (2005), who showed that no non-trivial coalition is stable if membership is open, and by Weikard et al. (2009) who also noticed stability problems that cannot be prevented by transfers, and that bargaining over them can generate coalition instability.

In 2015, Nordhaus' paper was published, proposing a mechanism to allow this kind of institutions to work without resorting to unrealistic assumptions, which we discuss in detail below. A lot of discussion ensued, leading to recent commentary papers such as Tagliapietra and Wolff (2021), where it is claimed that if the three biggest economies would agree on a carbon tax on imports, their agreement would catalyze global climate.

As for more academically oriented literature, several papers are particularly relevant. Thus, Vogt (2016) considered a situation with heterogeneous actors that at the same time are inequality averse. They applied their results, estimating empirically some of their model parameters, to the problem of climate mitigation policies using the twelve world regions from Nordhaus' RICE (Regional Integrated Climate-Economy) model. Their conclusion aligned with the instability problems of coalitions, as they found that wealthy countries have economic incentives to leave a coalition, even taking into account a preference for advantageous inequality, whereas poor countries also improve their welfare leaving, as both their absolute payoff increases and their disutility from disadvantageous inequality is reduced. As in previous research, suitable transfer schemes can stabilize coalitions formed by economically divergent members.

Another issue that has been considered in the literature is the fact that it is often the case that belonging to one or another group is not a completely voluntary choice. In this context, Dannenberg and Barrett (2018) showed that learning within a group takes place slowly in time, hindering the emergence of cooperation. Indeed, groups can fail to implement an efficient institution because of expectations that it would not work, or, if the institution is implemented, when not enough members realize its advantage, the institution eventually breaks down. This leads to further pessimism and causes groups to accept their fate. Heitzig and Kornek (2018) studied a related situation, in which countries expect that if they do not take part in a coalition, others might, showing that this implied once again poor prospects for collaboration. However, they also show that in a dynamic setting, an efficient coalition is achieved when players are sufficiently far-sighted or there is an immediate coordination caps right after market linkage.

More recently, Nordhaus himself has revisited the problem, including now a repeated game perspective. In Nordhaus (2021), the author extends the one-shot approach to many periods, introducing an approach that deals with "supportable policies" in a scenario of multiperiod clubs. An additional novelty of his study is that he considers interaction between club effectiveness and rapid technological change, neither of which will allow to attain the objectives of international climate policy on its own. Trade sanctions will be too costly to produce deep abatement in the absence of accompanying, rapid technological innovation, while innovation alone is still subject to countries free riding. Interestingly, he shows that when the two factors work together, international climate goals can be achieved.

In addition, Karatayev et al. (2021) address the problems of large-scale negotiations, when commitment to mitigation is costly and uncommon, and demonstrate that a well-timed policy shift from local to global legally binding agreements is much more effective than using only local, only global, or both agreement types simultaneously. The reason is that local agreements foster commitment and mitigation in early adopting groups, and subsequently global agreements bring in late-adopting groups.

As can be seen from the above, necessarily brief, summary, the idea of coalitions and similar institutions to fight climate change, in which Nordhaus proposal of climate clubs is framed, has been the subject of much theoretical research. However, the question naturally arises as to the real applicability of all those results, particularly because more often than not, results are negative (meaning that coalitions either do not form or are unstable) and because many mechanisms proposed to deal with these issues have not been tested at all. Here is where experiments are needed and are, in fact, the only way to bring these proposals closer to implementation. In the next section we discuss how experiments are actually informing the alternatives available for climate change abatement policies.

### *4.2. Some background on experimental approaches to institutions*

One of the first questions that was experimentally studied in this context was the effect of inequity aversion. In McEvoy and Stranlund (2016) the problem of coalition-forming in the presence of players that are averse to payoff inequality between coalition members and outsiders was considered. Their laboratory experiments showed that the bigger the gap in payoffs, the less likely coalitions between members and freeriding non-members are. Importantly, they designed their experiment in order to prevent confounding effects arising from the interplay of inequality and the smallest size for profitable coalitions. The main conclusion is then that controlling for the participation threshold size, coalition formation rates decay when the payoff gap between members and non-members increases, making it difficult for the coalition to hold for long.

Bosetti et al. (2017) addressed the issue of effort coordination between coalition members and non-members when they are threatened by a catastrophe. Agents interested in having the coalition formed may commit some of their investments to a climate change related project that offers smaller payoffs as a signal of their commitment. In their experimental design, externalities cannot be totally internalized by the countries joining the coalition, and second-movers' contributions are needed to avoid catastrophic losses. By modifying the returns of the two investments and the diffusion of the gains to second movers, they found that a sizeable coalition of early investors in the clean technology is more likely if benefits are appropriated by the members, and that in fact spillovers can bring in second-movers.

Schmidt and Ockenfels (2021) focused on a proposal by Weitzman (2014) to change the negotiation focus to a uniform common commitment (e.g., a minimum price for carbon) that would promote international cooperation. In their experiment, human subjects participate (voluntarily) in a public goods game and differ in benefits and costs. Irrespective of treaties being enforceable or self-enforcing, it turns out that negotiating a uniform common commitment is better than negotiating individual commitments (as in the Paris Agreement) to promote cooperation, and it is also better than commitments tailored to specific situation of each party (as was the case with the Kyoto Protocol). Finally, another very recent paper (Dong et al., 2021) analyzed the impact of a financial incentive for developing countries to reduce carbon emissions. They observe that such financial incentives lead to higher global contributions towards emissions reduction and effectively reduce emissions even without binding enforcement. This suggests that developed countries should devote some of their resources and incentivize developing countries to reduce their emissions.

These experimental results indicate that, indeed, tests of theoretical proposals to mitigate climate change through institutions can be done while, at the same time, indicate that experiments have to be designed very carefully if their conclusions are to shed light on the applicability of the proposed institutions. It is then worth to discuss a specific example in detail in order to better understand how the interplay between theory and experiments may be most fruitful, and this we do now by considering the case of Nordhaus' climate clubs.

### *4.3. Nordhaus' proposal of climate clubs*

Nordhaus' (2015) proposal arises from the realization that very many international conflicts have been solved through international agreements, even if international law, as arises from the 1648 Treaty of Westphalia, is an important obstacle. Indeed, the key feature of international law is that countries are all legally equal, and that they must join international treaties voluntarily. For the case of climate change, the temptation to free-ride on other countries' efforts to mitigate it is very clear, and there is little incentive in principle to join a treaty dealing with this issue.

To solve this dilemma, Nordhaus resorts to the theory of clubs (see Sandler and Tschirhart, 1980 for a review). According to this theory, clubs are voluntary groups that yield benefits for their members when there is a cost of producing a public-good-type resource that can be shared. For such an institution to be successful, it is necessary that the corresponding arrangement, including the dues, benefits all its members. In addition, non-members can be sanctioned and that these sanctions inflict a relatively low cost to members. Of course, for the club to work membership should also be stable, so members do not leave it. Examples of actually existing such clubs are international free-trade treaties or military alliances. In these two cases, there are costs, such as low trade barriers or the cost of sustaining an army and defending other members. Nordhaus's proposal is directly inspired by these examples. Still, he presents it as an idealized solution that will never exist in its pure form; the hope is that it opens a way to come up with a system that overcomes free-riding in the context of climate change mitigation.

The key idea behind the climate club is that members agree to undertake harmonized emissions reductions. For example, countries belonging to the club may commit to implement policies leading to a minimum domestic carbon emission price ($25 per ton of carbon dioxide in Nordhaus, 2015). The figure itself is not relevant for the discussion, but nowadays it is of course outdated and prices in the European Union at the time of writing are approaching $100 per ton of carbon dioxide. Countries would be at liberty to choose their own specific mechanisms (such as carbon tax, cap-and-trade, or hybrid designs).

Crucially, countries that are not members of the club are penalized. Nordhaus suggested that members could impose uniform percentage tariffs on the imports from non-members into the club territory. In this manner, a strategic situation is created so that countries acting in their self-interest will join the club assuming very high levels of emissions reductions. The advantage of Nordhaus' system is that countries that do not comply can expect a punishment that is credible, because the members of the club benefit from it. In his paper, Nordhaus examined in detail the club and then considered an empirical model to show that it could actually work. His simulated model, with parameters taken from climate models, allows him to investigate the characteristics of stable climate clubs for different emission reduction targets. The main result he obtains from the model is that significant reductions in emissions can be obtained with clubs that are stable.

When looking at the climate club design in detail, it turns out that one potential problem with it is that, in principle, multiple equilibria are possible. Indeed, if a country anticipates that no other country will join the club (or only a few, not really significant ones that can affect it with their tariffs), it has no interest in joining. Therefore, it is important to check how severe this problem can be, and here is where experiment can bring a substantial contribution to this literature, by studying whether or not clubs do form. The next section describes a proposal for an experimental design that could address this question.

### *4.4 An experiment on Nordhaus' climate clubs*

Our proposed design incorporates as much as possible the characteristics of the climate club idea. We believe that the design should contain at least two important aspects. One is the fact that in reality countries are heterogeneous. Some are bigger and/or wealthier than others are, and thus have a different impact on climate and on trade. The other is that Nordhaus did not specify the process by which the clubs form. There are many possibilities, and we know from past literature than the protocols for coalition formation are crucial to determine which coalitions actually form (see e.g. Rogna, 2019).

In the experimental setup we are proposing, participants play a number of rounds within a group always composed by the same six people. Within each group two participants are informed that their profile is A, while the other four participants have profile B (and they know it). The *profile* is a neutral word to convey the heterogeneity we mentioned before. The A-profile participants are the "wealthy/large" ones and will have a larger endowment than the B profile players will.

As mentioned, we believe the group formation is a critical part of the experiment. We describe now the general structure of the process and the different experimental treatments. Every round consists of several stages, beginning with a *pledging stage*, in which participants decide whether they want or not to make the pledge of joining the club. In fact, this design is the explicit form of what we believe is a process by which countries sign "expressions of interest" and then enter the club after observing others, as a cheap and effective way to implement the club. This pledge decision will remain in their history of pledge decisions over the entire experiment, and participants have the history of pledge decisions of groupmates available during the entire experiment. The same will occur with the rest of decisions participant have to make in a round. We note that at this stage, participants that make the pledge they are not yet committed to join the club during this round.

The next stage is the *implementation,* played only by participants who pledged to join the club in the previous stage, while the rest of the participants simply skip this stage. During the implementation stage, participants decide whether they want to ratify the pledge of joining the club, having information on the number and type of others who have made a positive pledge. This stage is crucial, and it can possibly take different forms. The club could be formed only if there is unanimous confirmation by pledgers. Alternatively, it can form only with those who confirm.

Finally, there is the *contribution stage*. If the club is formed in the previous stage, all participants within the club are forced to contribute their entire endowment to the common pool. If the club is not formed, they have to decide how many points of their endowment they contribute. Participants who did not join the club from the start also make their decisions to contribute at this point. Subsequently, the amount of the pool is multiplied by some factor and shared in proportion to the participant type/size; participants are informed of everybody's earnings and the next round begins.

To unveil the effects of the different elements of the club formation mechanism, we should consider four different treatments of the experimental design we have just summarized. Thus, in the baseline treatment T1, there is only the contribution stage, i.e., it is a (heterogeneous) public goods game, without any club. Treatment T2 allows clubs to be formed even if some of the members who initially pledged to join withdraw their pledge, whereas in treatment T3 clubs are only formed by unanimous ratification of all pledges. Both in T2 and T3 there are benefits to club members but no punishment to non-members. Treatment T4 introduces the punishment to non-members, and at the same time it keeps the unanimity rule. We note that this last treatment is the one that reflects closer the spirit of Nordhaus' proposal, so we will refer to it as the "climate club" treatment.

We have run the experiments and done some preliminary analysis of the results. There are several tentative conclusions that emerge from that analysis. One is all the institutions (T2, T3 and T4) deliver improvements in contributions with respect to the baseline T1. But, importantly, the full clubs treatment T4, which includes sanctioning, stabilises cooperation levels and make them resilient. It also provides strong incentives to form large clubs of highly committed participants.

A second important observation is that the effect of sanctions is more evident on highly endowed (wealthy) participants, which may suffer from the punishment when all the poorer subjects form clubs, leaving them alone. This hints at the idea that clubs could be a tool for poor countries to put pressure on rich ones. However, this conclusion should be taken with caution. The economic and power imbalance between developed and less developed nations in real world is very different than in our stylized version.

Finally, while high levels of cooperation can be reached without the rule of unanimity for clubs to form, when this rule is present the clubs are more robust and initial pledges to participate are almost always honored.

## 5. Conclusions

Cabrales et al. (2022) find an embarrassing disinterest in climate change by academic economists (measured by the total number of articles published in the so call "top-5" economic journals). This fact can be explained by the existence of a clear and well-understood set of policies. Namely, we have Pigouvian taxes and subsidies, regulations, and, if push comes to shove, markets for permits. If you want redistribution to compensate for the effects of those taxes, you can always do it through the tax and welfare system.

Perhaps the most important insight we can gather with this review is that policymakers and citizens have a useful tool to complement the existing ones in the pursuit of "safe and effective" policies for what is perhaps the defining problem of our age. We have shown first that there are good reasons why societies may oppose the standard tools economists want to use to address this problem. But, more hopefully, we show that there are other tools that may work as well. We have shown we can exploit the influence of the community through social norms. We can use behavioral interventions that promote the desirability of policies. We can also leverage the fact that climate shocks can have systemic financial consequences and use the mighty arm of financial regulation.

The other important insight is methodological. Theory and numerical simulations are of course complements and need to be used side by side with experiments, but they are not enough to get a good understanding of the challenges and threats we face in the future.

## References

Abou Chakra, M., Bumann, S., Schenk, H., Oschlies, A., & Traulsen, A. (2018). Immediate action is the best strategy when facing uncertain climate change. *Nature Communications*, *9*(1), 1-9.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology*, *27*(4), 265-276.

Akerlof, G. A., & Kranton, R. E. (2010). *Identity economics*. Princeton University Press.

Alberini, A., Ščasný, M., & Bigano, A. (2018). Policy-v. individual heterogeneity in the benefits of climate change mitigation: Evidence from a stated-preference survey. *Energy Policy*, *121*, 565-575.

Allcott, H., & Mullainathan, S. (2010). Behavior and energy policy. *Science*, *327*(5970), 1204-1205.

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*, *95*(9-10), 1082-1095.

Allcott, H., & Rogers, T. (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review*, *104*(10), 3003-37.

Allcott, H., & Kessler, J. B. (2019). The welfare effects of nudges: A case study of energy use social comparisons. *American Economic Journal: Applied Economics*, *11*(1), 236-76.
Alló, M., & Loureiro, M.L. (2014). The role of social norms on preferences towards climate change policies: A meta-analysis. *Energy Policy*, *73*, 563-574.
Attari, S. Z., DeKay, M. L., Davidson, C. I., & De Bruin, W. B. (2010). Public perceptions of energy consumption and savings. *Proceedings of the National Academy of Sciences*, *107*(37), 16054-16059.
Baranzini, A., & Carattini, S. (2017). Effectiveness, earmarking and labeling: testing the acceptability of carbon taxes with survey data. *Environmental Economics and Policy Studies*, *19*(1), 197-227.
Baranzini, A., Carattini, S., & Péclat, M. (2017). *What drives social contagion in the adoption of solar photovoltaic technology* (No. 270). Grantham Research Institute on Climate Change and the Environment.
Barrett, S. (2003). *Environment and statecraft: The strategy of environmental treaty-making: The strategy of environmental treaty-making*. OUP Oxford.
Barrett, S., & Dannenberg, A. (2012). Climate negotiations under scientific uncertainty. *Proceedings of the National Academy of Sciences*, *109*(43), 17372-17376.
Barrett, S., & Dannenberg, A. (2014). Sensitivity of collective action to uncertainty about climate tipping points. *Nature Climate Change*, *4*(1), 36-39.
Barrett, S. (2018). Choices in the climate commons. *Science*, *362*(6420), 1217.
Battaglini, M., Nunnari, S., & Palfrey, T. R. (2016). The dynamic free rider problem: A laboratory study. *American Economic Journal: Microeconomics*, *8*(4), 268-308.
Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Levine, S. C., & Beilock, S. L. (2015). Math at home adds up to achievement in school. *Science*, *350*(6257), 196-198.
Bernheim, B. D., Fradkin, A., & Popov, I. (2015). The welfare economics of default options in 401(k) plans. *American Economic Review*, *105*(9), 2798-2837.
Bicchieri, C. (2005). *The grammar of society: The nature and dynamics of social norms*. Cambridge University Press.
Bicchieri, C. (2016). *Norms in the wild: How to diagnose, measure, and change social norms*. Oxford University Press.
Biel, A., & Thøgersen, J. (2007). Activation of social norms in social dilemmas: A review of the evidence and reflections on the implications for environmental behaviour. *Journal of Economic Psychology*, *28*(1), 93-112.
Bollinger, B., & Gillingham, K. (2012). Peer effects in the diffusion of solar photovoltaic panels. *Marketing Science*, *31*(6), 900-912
Bolsen, T., Leeper, T. J., & Shapiro, M. A. (2014). Doing what others do: Norms, science, and collective action on global warming. *American Politics Research*, *42*(1), 65-89.
Boonmanunt, S., Lauer, T., Rockenbach, B., & Weiss, A. (2020). Field evidence on the role of time preferences in conservation behavior. *Journal of Environmental Economics and Management*, *104*, 102368.
Bosetti, V., Carraro, C., Galeotti, M., Massetti, E., & Tavoni, M. (2006). A world induced technical change hybrid model. *The Energy Journal*, Special Issue# 2.
Bosetti, V., Carraro, C., De Cian, E., Massetti, E., & Tavoni, M. (2012). *Incentives and stability of international climate coalitions: An integrated assessment*. FEEM Working Paper No. 97.2011

Bosetti, V., Heugues, M., & Tavoni, A. (2017). Luring others into climate action: coalition formation games with threshold and spillover effects. *Oxford Economic Papers*, *69*(2), 410-431.

Brannlund, R., & Persson, L. (2012). To tax, or not to tax: preferences for climate policy attributes. *Climate Policy*, *12*(6), 704-721.

Bristow, A. L., Wardman, M., Zanni, A. M., & Chintakayala, P. K. (2010). Public acceptability of personal carbon trading and carbon tax. *Ecological Economics*, *69*(9), 1824-1837.

Burke, M. A., & Young, H. P. (2011). Social norms. In K. J. Arrow, & M. D. Intriligator, *Handbook of Social Economics* (Vol. 1, pp. 311-338). North-Holland.

Cabrales, A., & Ponti, G. (2015). Social preferences. In P. Branas-Garza, A. Cabrales, *Experimental Economics* (Vol. 1, pp. 87-104). Palgrave Macmillan, London.

Cabrales, A., & Gottardi, P. (2022). *Network formation and heterogeneous risks* [in preparation].

Cabrales, A., García, M., Muñoz, D. R., & Sánchez, A. (2022). *The Interactions of Social Norms about Climate Change: Science, Institutions and Economics* [article submitted for publication].

Cai, B., Cameron, T. A., & Gerdes, G. R. (2010). Distributional preferences and the incidence of costs and benefits in climate change policy. *Environmental and Resource Economics*, *46*(4), 429-458.

Calzolari, G., Casari, M., & Ghidoni, R. (2018). Carbon is forever: A climate change experiment on cooperation. *Journal of Environmental Economics and Management*, *92*, 169-184.

Carattini, S., Baranzini, A., Thalmann, P., Varone, F., & Vöhringer, F. (2017). Green taxes in a post-Paris world: are millions of nays inevitable?. *Environmental and Resource Economics*, *68*(1), 97-128.

Carattini, S., Carvalho, M., & Fankhauser, S. (2018). Overcoming public resistance to carbon taxes. *Wiley Interdisciplinary Reviews: Climate Change*, *9*(5), e531.

Carattini, S., Levin, S., & Tavoni, A. (2020). Cooperation in the climate commons. *Review of Environmental Economics and Policy*, *13*(2).

Carlsson, F., & Johansson-Stenman, O. (2012). Behavioral economics and environmental policy. *Annual Review of Resource Economics*, *4*(1), 75-99.

Carraro, C., & Siniscalco, D. (1993). Strategies for the international protection of the environment. *Journal of Public Economics*, *52*(3), 309-328.

Chander, P., & Tulkens, H. (2006). A core-theoretic solution for the design of cooperative agreements on transfrontier pollution. In P. Chander, J. Drèze, C. Knox Lovell, J. Mintz, *Public goods, environmental externalities and fiscal competition* (pp. 176-193). Springer.

Chander, P. (2007). The gamma-core and coalition formation. *International Journal of Game Theory*, *35*(4), 539-556.

Chetty, R., Looney, A. & Kroft, K. (2009). Salience and taxation: Theory and evidence. *American Economic Review*, *99*(4), 1145-1177.

Cialani, C., & Mortazavi, R. (2018). Household and industrial electricity demand in Europe. *Energy Policy*, *122*, 592-600.

Cole, H. L., Mailath, G. J., & Postlewaite, A. (1992). Social norms, savings behavior, and growth. *Journal of Political Economy*, *100*(6), 1092-1125.

Dannenberg, A., Löschel, A., Paolacci, G., Reif, C., & Tavoni, A. (2015). On the provision of public goods with probabilistic and ambiguous thresholds. *Environmental and Resource Economics*, *61*(3), 365-383.
Dannenberg, A., & Barrett, S. (2018). Cooperating to avoid catastrophe. *Nature Human Behaviour*, *2*(7), 435-437.
Doherty, K. L., & Webler, T. N. (2016). Social norms and efficacy beliefs drive the alarmed segment's public-sphere climate actions. *Nature Climate Change*, *6*(9), 879-884.
Dong, Y., Ma, S., Zhang, B., Wang, W. X., & Pacheco, J. M. (2021). Financial incentives to poor countries promote net emissions reductions in multilateral climate agreements. *One Earth*, *4*(8), 1141-1149.
Dreber, A., & Nowak, M. A. (2008). Gambling for global goods. *Proceedings of the National Academy of Sciences*, *105*(7), 2261-2262.
Drews, S. & Van den Bergh, J. C. (2016). What explains public support for climate policies? A review of empirical and experimental studies. *Climate Policy*, *16*(7), 855–876.
Eichhorn, J., Molthof, L. & Nicke, S. (2020). *From climate change awareness to climate crisis action: Public perceptions in Europe and the United States*. Open Society Foundations. https://www.opensocietyfoundations.org/publications/from-climate-change-awareness-to-climate-crisis-action (last accessed September 2, 2021).
Elster, J. (1989). Social norms and economic theory. *Journal of Economic Perspectives*, *3*(4), 99-117.
Faunce, T.A. (2012). Global public goods. In R. Chadwick, *Encyclopedia of Applied Ethics, Second Edition*. Elsevier.
Fehr, E., & Gächter, S. (2000). Cooperation and punishment in public goods experiments. *American Economic Review*, *90*(4), 980-994.
Fehr, E., & Leibbrandt, A. (2011). A field study on cooperativeness and impatience in the tragedy of the commons. *Journal of Public Economics*, *95*(9-10), 1144-1155.
Fehr, E., & Schurtenberger, I. (2018). Normative foundations of human cooperation. *Nature Human Behaviour*, *2*(7), 458–468.
Fischbacher, U., & Gächter, S. (2010). Social preferences, beliefs, and the dynamics of free riding in public goods experiments. *American Economic Review*, *100*(1), 541-56.
Finus, M., Altamirano-Cabrera, J. C., & Van Ierland, E. C. (2005). The effect of membership rules and voting schemes on the success of international climate agreements. *Public Choice*, *125*(1), 95-127.
Gevrek, Z. E., & Uyduranoglu, A. (2015). Public preferences for carbon tax attributes. *Ecological Economics*, *118*, 186–197.
Ghesla, C., Grieder, M., & Schubert, R. (2020). Nudging the poor and the rich–A field study on the distributional effects of green electricity defaults. *Energy Economics*, *86*, 104616.
Ghidoni, R., Calzolari, G., & Casari, M. (2017). Climate change: Behavioral responses from extreme events and delayed damages. *Energy Economics*, *68*, 103-115.
Golman, R., Hagmann, D., & Loewenstein, G. (2017). Information avoidance. *Journal of Economic Literature*, *55*(1), 96-135.
Graziano, M., & Gillingham, K. (2015). Spatial patterns of solar photovoltaic system adoption: the influence of neighbors and the built environment. *Journal of Economic Geography*, *15*(4), 815-839.
Hagel, K., Abou Chakra, M., Bauer, B., & Traulsen, A. (2016). Which risk scenarios can drive the emergence of costly cooperation?. *Scientific Reports*, *6*(1), 1-9.

Hall, P. A., & Fong, G. T. (2007). Temporal self-regulation theory: A model for individual health behavior. *Health Psychology Review*, *1*(1), 6-52.

Halpern, D. (2015). *Inside the nudge unit: How small changes can make a big difference*. Random House.

Hardin, G. (1968). The Tragedy of the Commons: The population problem has no technical solution; it requires a fundamental extension in morality. *Science*, *162*(3859), 1243-1248.

Heath, Y., & Gifford, R. (2002). Extending the theory of planned behavior: Predicting the use of public transportation. *Journal of Applied Social Psychology*, *32*(10), 2154-2189.

Heitzig, J., & Kornek, U. (2018). Bottom-up linking of carbon markets under far-sighted cap coordination and reversibility. *Nature Climate Change*, *8*(3), 204-209.

Heres, D. R., Kallbekken, S., & Galarraga, I. (2017). The role of budgetary information in the preference for externality-correcting subsidies over taxes: a lab experiment on public support. *Environmental and Resource Economics*, *66*(1), 1-15.

Herrmann, B., Thoni, C., & Gachter, S. (2008). Antisocial Punishment Across Societies. *Science*, *319*(5868), 1362-1367.

Hertwig, R., & Grüne-Yanoff, T. (2017). Nudging and boosting: Steering or empowering good decisions. *Perspectives on Psychological Science*, *12*(6), 973-986.

Hilbe, C., Abou Chakra, M., Altrock, P. M., & Traulsen, A. (2013). The evolution of strategic timing in collective-risk dilemmas. *PloS ONE*, *8*(6), e66490.

Hortaçsu, A., Madanizadeh, S. A., & Puller, S. L. (2017). Power to choose? An analysis of consumer inertia in the residential electricity market. *American Economic Journal: Economic Policy*, *9*(4), 192-226.

Hsu, S. L., Walters, J., & Purgas, A. (2008). Pollution tax heuristics: An empirical study of willingness to pay higher gasoline taxes. *Energy Policy*, *36*(9), 3612–3619.

Huber, R. A., Anderson, B., & Bernauer, T. (2018). Can social norm interventions promote voluntary pro environmental action?. *Environmental Science and Policy*, *89*, 231-246.

IPCC, Intergovernmental Panel on Climate Change. (2018). *Global Warming of 1.5° C: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.*

IPCC, Intergovernmental Panel on Climate Change. (2019). *Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*

IPCC, Intergovernmental Panel on Climate Change. (2022). Technical Summary. In H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, *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. In Press.

Jacquet, J., Hagel, K., Hauert, C., Marotzke, J., Röhl, T., & Milinski, M. (2013). Intra-and intergenerational discounting in the climate game. *Nature Climate Change*, *3*(12), 1025-1028.

Kaiser, F. G., & Gutscher, H. (2003). The proposition of a general version of the theory of planned behavior: Predicting ecological behavior. *Journal of Applied Social Psychology*, *33*(3), 586-603.

Kallbekken, S., & Aasen, M. (2010). The demand for earmarking: Results from a focus group study. *Ecological Economics*, *69*(11), 2183–2190.

Kallbekken, S., & Sælen, H. (2011). Public acceptance for environmental taxes: Self-interest, environmental and distributional concerns. *Energy Policy*, *39*(5), 2966–2973.

Kalmi, P., Trotta, G., & Kažukauskas, A. (2021). Energy–related financial literacy and electricity consumption: Survey–based evidence from Finland. *Journal of Consumer Affairs*, *55*(3), 1062-1089.

Karatayev, V. A., Vasconcelos, V. V., Lafuite, A. S., Levin, S. A., Bauch, C. T., & Anand, M. (2021). A well-timed shift from local to global agreements accelerates climate change mitigation. *Nature Communications*, *12*(1), 1-7.

Kaufmann, C., Weber, M., & Haisley, E. (2013). The role of experience sampling and graphical displays on one's investment risk appetite. *Management Science*, *59*(2), 323-340.

Kimbrough, E. O., & Vostroknutov, A. (2016). Norms make preferences social. *Journal of the European Economic Association*, *14*(3), 608-638.

Klok, J., Larsen, A., Dahl, A., & Hansen, K. (2006). Ecological tax reform in Denmark: History and social acceptability. *Energy Policy*, *34*(8), 905–916.

Kölle, F. (2015). Heterogeneity and cooperation: The role of capability and valuation on public goods provision. *Journal of Economic Behavior and Organization*, *109*, 120-134.

Kölle, F., & Lauer, T. (2020). *Understanding cooperation in an intertemporal context* (No. 046). ECONtribute Discussion Paper.

Lázaro Touza, L., González Enríquez, C. & Escribano, G. (2019). *Los españoles ante el cambio climático*. Real Instituto Elcano. http://www.realinstitutoelcano.org/wps/portal/rielcano_es/contenido?WCM_GLOBAL_CONTEXT=/elcano/elcano_es/zonas_es/cambio-climatico/encuesta-espanoles-ante-cambio-climatico-sep-2019 (last accessed September 2, 2021).

Lusardi, A., Samek, A., Kapteyn, A., Glinert, L., Hung, A., & Heinberg, A. (2017). Visual tools and narratives: New ways to improve financial literacy. *Journal of Pension Economics and Finance*, *16*(3), 297-323.

Manski, C. F. (2000). Economic analysis of social interactions. *Journal of Economic Perspectives*, *14*(3), 115-136.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/#TS (last accessed September 2, 2021)

McEvoy, D. M., & Stranlund, J. K. (2016). *Inequality Aversion and Coalition Formation*. Working Papers 16-09, Department of Economics, Appalachian State University.

Mehling, M. A., Van Asselt, H., Das, K., Droege, S., & Verkuijl, C. (2019). Designing border carbon adjustments for enhanced climate action. *American Journal of International Law*, *113*(3), 433-481.

Milinski, M., Sommerfeld, R. D., Krambeck, H. J., Reed, F. A., & Marotzke, J. (2008). The collective-risk social dilemma and the prevention of simulated dangerous climate change. *Proceedings of the National Academy of Sciences*, *105*(7), 2291-2294.

Muldoon, R., Lisciandra, C., Bicchieri, C., Hartmann, S., & Sprenger, J. (2014). On the emergence of descriptive norms. *Politics, Philosophy and Economics*, *13*(1), 3-22.

Nilsson, A., von Borgstede, C., & Biel, A. (2004). Willingness to accept climate change strategies: The effect of values and norms. *Journal of Environmental Psychology*, *24*(3), 267-277.

Nordhaus, W. (2015). Climate clubs: Overcoming free-riding in international climate policy. *American Economic Review*, *105*(4), 1339-1370.

Nordhaus, W. (2021). Dynamic climate clubs: On the effectiveness of incentives in global climate agreements. *Proceedings of the National Academy of Sciences*, *118*(45), e2109988118.

Nordlund, A. M., & Garvill, J. (2003). Effects of values, problem awareness, and personal norm on willingness to reduce personal car use. *Journal of Environmental Psychology*, *23*(4), 339-347.

Nyborg, K., Anderies, J. M., Dannenberg, A., Lindahl, T., Schill, C., Schlüter, M., Adger, W.N., Arrow, K.J., Barrett, S., Carpenter, S., Stuart Chapin III, F., Crépin, A-S., Gretchen D., Ehrlich P., Folke, C., Jager, W., Kautsky, N., Levin, S.A., Madsen, O.J. ... De Zeeuw, A. (2016). Social norms as solutions. *Science*, *354*(6308), 42-43.

Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups*. Harvard University Press.

Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives*, *14*(3), 137-158.

Pacheco, J. M., Santos, F. C., Souza, M. O., & Skyrms, B. (2009). Evolutionary dynamics of collective action in N-person stag hunt dilemmas. *Proceedings of the Royal Society B: Biological Sciences*, *276*(1655), 315-321.

Paluck, E. L. (2009a). Reducing intergroup prejudice and conflict using the media: a field experiment in Rwanda. *Journal of Personality and Social Psychology*, *96*(3), 574.

Paluck, E. L. (2009b). What's in a norm? Sources and processes of norm change. *Journal of Personality and Social Psychology*, *96*(3), 594–600.

Pollitt, M. G., & Shaorshadze, I. (2013). The role of behavioural economics in energy and climate policy. In R. Fouquet, *Handbook on Energy and Climate Change* (pp. 523-546). Edward Elgar Publishing.

Ramos Muñoz, D., Cabrales, A., & Sanchez, A. (2022). *Central banks and climate change. Fit, opportunity and suitability in the law and beyond*. European Banking Institute Working Paper Series 2022 - No. 119.

Rebonato, R. (2012). *Taking liberties: A critical examination of libertarian paternalism*. Palgrave Macmillan.

Rode, J., & Weber, A. (2016). Does localized imitation drive technology adoption? A case study on rooftop photovoltaic systems in Germany. *Journal of Environmental Economics and Management*, *78*, 38-48.

Rogna, M. (2019). Coalition formation and bargaining protocols: a review of the literature. *Journal of Economic Surveys*, *33*(1), 226-251.

Sandler, T., & Tschirhart, J. T. (1980). The economic theory of clubs: An evaluative survey. *Journal of Economic Literature*, *18*(4), 1481-1521.

Schmidt, K. M., & Ockenfels, A. (2021). Focusing climate negotiations on a uniform common commitment can promote cooperation. *Proceedings of the National Academy of Sciences*, *118*(11), e2013070118.

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, *18*(5), 429-434.

Sedlmeier, P., & Gigerenzer, G. (2001). Teaching Bayesian reasoning in less than two hours. *Journal of Experimental Psychology: General*, *130*(3), 380-400.

Simon, H. A. (1955). A behavioral model of rational choice. *The Quarterly Journal of Economics*, *69*(1), 99-118.

Sparkman, G., Howe, L., & Walton, G. (2021). How social norms are often a barrier to addressing climate change but can be part of the solution. *Behavioural Public Policy*, *5*(4), 528-555.

Spiegelhalter, D., Pearson, M., & Short, I. (2011). Visualizing uncertainty about the future. *Science*, *333*(6048), 1393-1400.

Sturm, B., & Weimann, J. (2006). Experiments in environmental economics and some close relatives. *Journal of Economic Surveys*, *20*(3), 419-457.

Svenningsen, L. S., & Thorsen, B. J. (2020). Preferences for distributional impacts of climate policy. *Environmental and Resource Economics*, *75*(1), 1-24.

Szekely, A., Lipari, F., Antonioni, A., Paolucci, M., Sánchez, A., Tummolini, L., & Andrighetto, G. (2021). Evidence from a long-term experiment that collective risks change social norms and promote cooperation. *Nature Communications*, *12*(1), 1-7.

Tagliapietra, S., & Wolff, G. B. (2021). Form a climate club: United States, European Union and China. Comment. *Nature*, *591*(7851), 526-528.

Tavoni, A., Dannenberg, A., Kallis, G., & Löschel, A. (2011). Inequality, communication, and the avoidance of disastrous climate change in a public goods game. *Proceedings of the National Academy of Sciences*, *108*(29), 11825-11829.

Thaler, R., & Sunstein, C.R. (2008). *Nudge: Improving decisions about health, wealth and happiness*. Penguin.

Todorov, A., & Mandisodza, A. N. (2004). Public opinion on foreign policy: The multilateral public that perceives itself as unilateral. *Public Opinion Quarterly*, *68*(3), 323-348.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124-1131.

Van der Linden, S. L., Leiserowitz, A. A., Feinberg, G. D., & Maibach, E. W. (2015). The scientific consensus on climate change as a gateway belief: Experimental evidence. *PloS ONE*, *10*(2), e0118489.

Van der Werff, E., Steg, L., & Keizer, K. (2014). I am what I am, by looking past the present: The influence of biospheric values and past behavior on environmental self-identity. *Environment and Behavior*, *46*(5), 626-657.

Vogt, C. (2016). Climate coalition formation when players are heterogeneous and inequality averse. *Environmental and Resource Economics*, *65*(1), 33-59.

Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Climatic Change*, *77*(1), 103-120.

Weikard, H.-P., Finus, M., & Altamirano-Cabrera, J. C. (2006). The impact of surplus sharing on the stability of international climate agreements. *Oxford Economic Papers, 58*(2), 209-232.

Weitzman, M. L. (2014). Can negotiating a uniform carbon price help to internalize the global warming externality?. *Journal of the Association of Environmental and Resource Economists*, *1*(1/2), 29-49.

Winchester, N., Paltsev, S., & Reilly, J. M. (2011). Will border carbon adjustments work?. *The BE Journal of Economic Analysis & Policy*, *11*(1).

Yang, Z. (1999). Should the North make unilateral technology transfers to the South?: North–South cooperation and conflicts in responses to global climate change. *Resource and Energy Economics*, *21*(1), 67-87.

Yang, Z. (2008). *Strategic bargaining and cooperation in greenhouse gas mitigations: an integrated assessment modeling approach*. MIT Press.

Young, H. P. (2015). The evolution of social norms. *Annual Review of Economics*, *7*(1), 359-387.

Zhu, X., Li, L., Zhou, K., Zhang, X., & Yang, S. (2018). A meta-analysis on the price elasticity and income elasticity of residential electricity demand. *Journal of Cleaner Production*, *201*, 169-177.

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# Climate action 2.0: can Green Deals help deliver a just Net-Zero Transition?

# *Acción climática 2.0: ¿pueden los Pactos Verdes llevarnos a una transición justa hacia las emisiones netas nulas?*

Lara Lázaro Touza
Centro de Enseñanza Superior Cardenal Cisneros y Real Instituto Elcano

Gonzalo Escribano Francés
Universidad Nacional de Educación a Distancia y Real Instituto Elcano

***Abstract***

*Structural economic reform is needed on an unprecedented scale and at an unprecedented rate to avert the worst impacts of climate change. Drawing on the lessons learned from Roosevelt's New Deal, the paper analyses the extent to which green deal proposals and recovery plans put forth this century can deliver climate-resilient development according to a green growth (ecomodernisation) perspective. The paper concludes that while some greening of laws and post-crisis stimulus packages has been observed, it cannot be unequivocally concluded that pro-growth green deals can deliver a just net-zero and just transition.*

***Keywords:*** *New Deal, green fiscal stimulus, green New Deal, ecomodernisation, degrowth.*

***JEL classification:*** *Q10, H3, Q480, Q5.*

***Resumen***

*Es necesaria una reforma estructural sin precedentes para evitar los peores impactos del cambio climático. Partiendo del New Deal de Roosevelt, se analiza en qué medida los pactos verdes propuestos y los planes de recuperación presentados desde principios de siglo pueden resultar en un desarrollo resiliente al clima según el enfoque del crecimiento verde y la ecomodernización. El artículo concluye que, si bien la legislación y los paquetes de recuperación contienen elementos «verdes», no se puede afirmar de manera inequívoca que los pactos verdes resulten en una transición justa hacia las emisiones netas nulas.*

***Palabras clave:*** *New Deal, estímulo fiscal verde, new deal verde, ecomodernización, decrecimiento.*


DOI: https://doi.org/10.32796/cice.2022.104.7475
Recibido: Abril 2022 · Aceptado: Agosto 2022

## 1. Introduction

Structural economic reform is needed globally at an unprecedented rate to avert the worst impacts of climate change (Köberle et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) quantified the magnitude of the required change: by 2030 greenhouse gas emissions need to be approximately 45 % below 2010 levels and should reach net-zero around 2050 to limit global mean temperature increase to 1.5 °C compared to pre-industrial levels[1] (Rogelj et al., 2018). The above-mentioned temperature increase is the lower bound of those included in the Paris Agreement in 2015, with the higher bound being set at "well below 2 °C"[2]. Current international climate commitments under the Paris Agreement (Nationally Determined Contributions, NDCs) however will lead to further increases in greenhouse gas (GHG) emissions, estimated at +13.7 % in 2030 compared to 2010 (UNFCCC, 2021).

The ubiquitous presence of greenhouse gases that result in anthropogenic climate change represent a market failure of global proportions which has resulted in over three decades of (clearly insufficient) government intervention. Although command and control is by far the most common approach to address market failures in the environmental policy realm (e.g., through setting standards and legally binding requirements for public and private stakeholders) they are inefficient when damage curves are relatively flat. Market Based Instruments (MBIs) (e.g., taxes, tradable permits, etc.) are, at least theoretically, statically and dynamically efficient, and hence superior from a purely economic perspective (Weitzman, 1974). Political feasibility and acceptability by stakeholders[3] limit the extent to which MBIs are used. Said MBIs have nevertheless become increasingly popular since the 80's. The European Emission Trading System (EU-ETS) for instance is one of the flagship climate policy instruments used in the European Union (EU).

Success of climate policy in certain jurisdictions has been significant. The EU has reduced its Greenhouse gas (GHG) emissions by 23 % since 1990 while its Gross Domestic Product (GDP) has grown by over 60 %. A recent analysis of 18 developed countries by Le Queré et al. (2019) finds decoupling of GDP and GHG emissions

---

[1] The above figures are applicable to no overshoot scenarios. To have a 66% probability of limiting temperature increases to 2 °C GHG emissions should be around 25% lower than in 2010 by 2030 and reaching Net-Zero around 2070.

[2] The latest international climate meeting in Glasgow, known as the 26th Conference of the Parties (COP26), de facto enhanced global climate ambition by recognising that a mean temperature increase of 1.5 °C would mean significantly less impacts than limiting global mean temperatures to 'well below' 2 °C.

We are however far from limiting global mean temperature increases to 1.5 °C. The International Energy Agency estimated in 2021 that temperature increases could be limited to 1.8 °C if all net-zero pledges were implemented (IEA, 2021). Said temperature increase would rise to 2.4 °C compared to pre-industrial levels if all countries implemented climate action pledges under the Paris Agreement (known as Nationally Determined Contributions or NDCs) submitted until late 2021. NDCs do not include net-zero pledges that would materialise later and are hence more uncertain. If climate action was limited solely to current policies the global mean temperature increase is estimated at 2.7 °C by the end of the century, compared to pre-industrial temperatures (Climate Action Tracker, 2021).

[3] Command and Control measures (CAC) can be easier to lobby; they do not require companies to pay for every unit emitted and they are better aligned with the moral sense of right and wrong.

due to the displacement of fossil fuels by renewables, among other. However, a recent extensive review of the literature on decoupling by Haberl et al. (2020) shows that absolute decoupling of GHG and growth is not happening globally and that the observed cases of decoupling are insufficient to deliver our collectively agreed climate goals. In fact, globally, greenhouse gas emissions (measured in $GtCO_2e$) have increased approximately 58% between 1990 and 2019 (UNEP, 2020). The extent to which past lack of global decoupling will extend to the future is at this stage uncertain. To achieve global decoupling of GHG emissions and growth, investments in renewables and energy efficiency between 1.5% and 2% of global GDP annually (estimated at $1.5 trillion[4]) would be required according to Pollin (2018). We are however far from this level of clean investment. Mathis (2022) states that in 2021 low carbon investment amounted to $755 billion (with $366 billion in renewables and $273 in transport electrification), a significant increase (27%) from 2020 but lower that what is required for absolute decoupling of emissions and growth. Policy is hence seen as key to align financial flows with climate goals, helping shift to the "trillions" in climate finance.

Acknowledging the limited success in GHG emission reductions some governments have embraced green deal narratives and programmes (within a green growth paradigm) to try and bring about the structural transformation needed to abide by the temperature goals enshrined in the Paris Agreement. Some of these green deal proposals could lead to adopting enhanced climate policies for a deep transformation of the economy, at least on paper. Examples of elements that have been included in recent green deal proposals include: climate laws with ambitious net-zero targets, legally binding requirements for the penetration of renewable energy sources (RES), banning fracking, phasing out fossil fuel subsidies and investing in clean Research and Development (R&D), among others (EC, 2019; Galvin & Healy, 2020; Barbier, 2019a, 2019b).

Additionally, both in the aftermath of the Global Financial Crisis of 2008-2009 and in the wake of COVID-19, large fiscal stimulus packages have been put forward, with at least 10% of the funds globally allocated to green stimulus (Barbier, 2019a, 2019b; Vivid Economics and Finance for Biodiversity Initiative, 2021).

The question remains though as to whether national or regional green deal proposals, plus post crises fiscal stimulus packages inspired by Roosevelt's Keynesian New Deal can help deliver a just net-zero transition by deeply transforming the economic model through green Keynesianism.

In order to explore whether national and regional green deal proposals and recovery programmes can help deliver a just net-zero transition, the authors have surveyed the academic and grey literature, building, among other, on analyses commissioned by the Elcano Royal Institute on post-COVID recovery programmes of the five largest European greenhouse gas emitters (Berghmans, 2021; Bieliszczuk, 2021; Feás & Steinberg, 2021; Kiefer, 2021; Leonardi & Bellisai, 2021; Lázaro Touza et al., 2022).

[4] Please note that trillion = 10 to the power of 12 and billion = 10 to the power of 9.

The article is structured as follows: Section 2 briefly discusses the impacts of climate change that support climate policies and green deal proposals. Section 3 reviews some of the key elements of green deal proposals that are inspired by Roosevelt's New Deal. It also presents some of the defining features of COVID-19 recovery programmes. Section 4 discusses the extent to which green deal policies can be thought to deliver both economic growth and positive climate impacts and whether the New Deal framing is fit to address the climate emergency. Section 5 concludes.

## 2. Climate change and its impacts in brief

The impacts of limited climate action in the past and insufficient commitments at present beg the question of whether we can operate within planetary boundaries (Rockström et al., 2009). The latest analysis of peer-reviewed literature undertaken by the Intergovernmental Panel on Climate Change (IPCC), known as the Sixth Assessment Report (AR6) (IPCC, 2021; IPCC, 2022), states that human induced climate change is unequivocal. Some impacts of climate change are unprecedented in hundreds to thousands of years, especially in the ocean, ice sheets and as regards sea level rise (estimated to range between 0.28m and over 1m by the end of the century compared with 1995-2014 levels, depending on the scenarios analysed).

Extreme weather events and compound extremes (e.g., concurrent heatwaves and droughts) have become more frequent and severe, and have been more readily attributed to humans since the AR5 was published. Extreme weather and climate events can affect supply-chains and markets across national borders. Slow on-set climate change can cause redistribution of natural resource stocks such as fisheries, which will require enhanced cooperation to limit resource management conflicts. The water cycle will continue to intensify. Global precipitations could increase up to 13% depending on the scenarios analysed. However, wet regions will potentially experience significantly higher precipitations whereas dry regions could be subject to significant reductions in precipitations, i.e., exacerbating pre-existing trends.

Between 3.3 and 3.6 billion people are exposed to environments that are highly vulnerable to climate change. Half of the species analysed have shifted to higher lands towards the poles. Significant levels of biodiversity loss are also likely. These could range from 3% to 48% of species in terrestrial ecosystems, depending on the warming scenarios (*Ibid.*). The irreversibility of extinction makes these findings particularly worrying.

Estimates are inherently uncertain regarding the macroeconomic impact of temperature increases expected under current climate pledges. The IPCC's AR6 explains that although economic damages increase in a non-linear fashion as temperatures rise, the varying methodologies, data limitations and lack of comparability across studies prevents the authors from offering robust data on the economic impacts of climate change (IPCC, 2022). Nevertheless, some relatively recent estimates are briefly mentioned for reference purposes, while reiterating the difficulties and inherent uncertainty of future impacts, damages of and of allocating an economic value to these. Nordhaus and Moffat (2017) analysed the economic impacts of climate change using estimates from 36 studies concluding that a 3 ºC warming[5] would lead to a loss of GDP of about 3 %. More recent empirical studies gathering evidence of the impacts of climate over the last 5 decades indicate the economic impact of a 3 ºC increase could range between 5 % and over 20 % of GDP (Dietz, 2019).

Estimates on the cost of mitigation are also wide-ranging. Köberle et al. (2021) provide an up-to-date summary of these estimates and conclude that mitigation costs could range between 1 % and 4 % of GDP throughout the century depending on the socioeconomic pathways analysed, with expected GDP growth ranging from 300 % to 900 % throughout the century. Annualised reductions in the growth rate of consumption arising from mitigation costs would range between 0.04 % and 0.14% (*Ibid.*). Given the above research on the cost of climate change and the cost of mitigation one plausible explanation for limited climate action is that short-term costs of action are borne by a concrete group of (high-income) countries over the short-to-medium term while the benefits of action would occur in the long-run and benefit people across jurisdictions (Hope & Newberry, 2006), benefitting vulnerable people the most.

Adding to the above-discussed time and space burden-sharing asymmetry, as well as the public good nature of a stable climate and the free-rider problem of providing such stable climate, at this stage it is unclear whether limiting temperature increases to 1.5 ºC would pass a cost-benefit test. However, given the potentially catastrophic consequences unfettered human-induced climate change could have, it has been argued that climate action could be considered a matter of insuring socioeconomic and environmental systems against the worst impacts of climate change rather than passing a cost-benefit test. Furthermore, science tells us that if we want to retain the option of limiting temperature increases to 1.5 ºC deep and accelerated mitigation is called for (Dietz, 2019) in the current decade.

Conscious of the above impacts of climate, green deals and (more or less green) fiscal stimulus packages have been proposed as wide-ranging programmes to change the structure of the economy across jurisdictions.

## 3. From the New Deal to Green New Deals

### *3.1. The New Deal*

In the aftermath of the Great Depression Franklin D. Roosevelt embraced a Keynesian response to deliver economic recovery that has been touted as economic experimentation rather than economic planning. This response came to be known as the New Deal. It was based on two pillars 1) reducing unemployment 2) providing economic security, welfare and a safety net when the market was unable to deliver these. Roosevelt deployed a myriad of initiatives to support the unemployed,

[5] A common calibration point in these analyses.

accelerate recovery and engage in "the kind of structural reform that could protect people in future crises" (Winkler, 2009).

Leading figures of Keynesianism such as Gardner Means, Alvin Hansen as well as John Maynard Keynes shared the following insights regarding the Great Depression (Green, 2020):

a) The underlying cause of the Great Depression was underconsumption. It hence followed that the Great Depression would be overcome by increasing consumption. According to Green (2020), Roosevelt's Keynesian-inspired New Deal embraced "productivism" which meant full production, full employment and high consumption.
b) The economy is not static and governed by "immutable laws". Economic policies should therefore be tailored towards the historical context in which they were to be deployed.

Key initiatives within the New Deal were geared towards reducing the perception of uncertainty and risk by consumers, providing assurances to bank depositors and lenders, providing information to investors, ensuring predictable wages for vulnerable workers, providing a social safety net for workers and retirees (Kennedy, 2009). Roosevelt's New Deal sought to reactivate economic growth through investments in many economic sectors including transport and energy infrastructure, forest and water management initiatives. The New Deal additionally trained millions of young unemployed workers (The Living New Deal, 2022).

Kennedy (2009) argues that the New Deal brought about the largest social and institutional change in American history. It also arguably brought "stability and predictability" to the US economy and helped develop the building blocks for sustained economic growth, even if it failed to fully resolve short-term economic woes derived from the Great Depression (including a high unemployment rate) (*Ibid.*). Shiller (2017) further argues that the post-2008 crisis interest in Roosevelt or the New Deal may be explained as an efficient way to communicate a basic economic recovery narrative.

### *3.2. Green Deals in the Global Financial Crisis era*

Thomas Friedman is credited to have coined the idea of a green deal that would address America's ailments in the XXIst century: (lack of) jobs, rising temperatures and terrorism (Friedman, 2007). The green deal amounted to an overarching programme that could allegedly be supported across the aisle to address the key challenges of the United States by investing in renewables, mandating efficiency standards, etc. Also in 2007, and inspired by Roosevelt's New Deal, the Green New Deal Group proposed a set of structural reform measures to address the Global Financial Crisis (GFC), climate change and the energy price spike in the United Kingdom. These measures included both the regulation of financial systems and taxation, as well as an on-going and widespread low-carbon investment programme coupled with demand-side management initiatives (Green New Deal Group, 2008).

Similarly, yet broader in scope, the United Nations Environment Programme commissioned a report in the aftermath of the 2008 Global Financial Crisis (GFC) where it was acknowledged that economic recovery would require the same kind of response as that of Roosevelt's New Deal. However, to ensure a lasting and sustainable recovery it was argued that a larger, and more green-tailored approach, would be needed (Barbier, 2009a, 2009b). To ensure long-lasting growth UNEP's Global Green New Deal called for addressing global environmental and social challenges (reducing emissions, preserving ecosystems, preventing water scarcity and protecting the vulnerable) in addition to recovering from the Global Financial Crisis. The UNEP-commissioned report acknowledged however that few fiscal stimulus packages put forth after the Global Financial Crisis would amount to a Green Deal that ensured lasting, green and just economic recovery.

The UNEP report recommended that developed high- and middle- income countries in the G20 spent 1 % of their GDP in the two years following the publication of the report on reducing emissions, phasing out fossil-fuel subsidies, implementing carbon pricing policies, etc. As of December 2009, only a handful of countries (Australia, China, Japan, Saudi Arabia and South Korea) had allocated 1 % or more of their GDP to green stimulus (GS), and even less had allocated 1 % of their GDP to low carbon power and energy efficiency measures (Australia, China, Japan and South Korea), see Table 1 for further details[6].

Overall, countries around the world eyed energy efficiency and investments in renewables in their countercyclical fiscal stimulus packages in response to the Global Financial Crisis (Mastini et al., 2021). Out of the global fiscal stimulus provided in the aftermath of the 2008 Global Financial Crisis (>US$ 3 trillion up to July 2009), 15.7 % was allocated to green fiscal stimulus (Barbier, 2016; Nahm et al., 2022).

The majority of said green stimulus (US$ 443 billion out of $522.1 billion) was allocated to low carbon investments and energy efficiency. These included renewable energy, nuclear, carbon capture and storage, energy efficiency, public transport, railways and improving power grids. More specifically, under two thirds (64.2 %) of the green fiscal stimulus was allocated to energy efficiency (energy conservation in buildings; fuel-efficient vehicles; public transport and rail; and improving electrical-grid transmission). Low carbon power (classified by Barbier as including renewables, nuclear and Carbon Capture and Storage, CCS) received 20.6 % of the green stimulus. Water conservation, treatment and supply, alongside waste and pollution control received the remaining 15.15 % of the green stimulus funds. A further breakdown of investments shows that rail infrastructure received over a quarter of green investments (26 %), the power grid (18 %) and increasing energy efficiency in buildings (17 %). A lower 8 % of the green stimulus was allocated to nuclear and renewables, see Figure 1.

[6] Note that Barbier published estimates for fiscal stimulus programs that covered investments up to December 2009.

**TABLE 1**

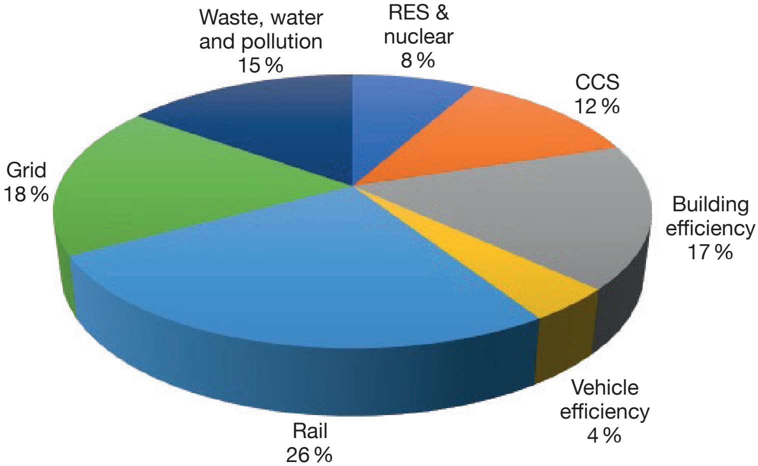
**GLOBAL GREEN STIMULUS, FROM SEPTEMBER 2008 THROUGH DECEMBER 2009**

| | | Green Stimulus (GS), US$ billion (bn) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Fiscal Stimulus (TS) US$ bn | Low Carbon Power[a] | Energy Efficiency[b] | Waste, Water & Pollution[c] | Total green stimulus | GDP (US bn)[d] | GS as % of TS | GS as % of GDP |
| Argentina | 13.2 | | | | | 526.4 | 0.0 | 0.0 |
| Australia | 43.8 | 3.5 | 6.5 | | 9.9 | 773.0 | 22.7 | 1.3 |
| Brazil | 3.6 | | | | | 1,849.0 | 0.0 | 0.0 |
| Canada | 31.8 | 1.1 | 1.4 | 0.3 | 2.8 | 1,271.0 | 8.7 | 0.2 |
| China | 649.1 | 1.6 | 182.4 | 34.0 | 218.8 | 7,099.0 | 33.6 | 3.1 |
| France | 33.7 | 0.9 | 5.1 | 0.2 | 6.2 | 2,075.0 | 18.2 | 0.3 |
| Germany | 104.8 | | 13.8 | | 13.8 | 2,807.0 | 13.2 | 0.5 |
| India | 13.7 | | 1.0 | | 1.0 | 2,966.0 | 7.3 | 0.0 |
| Indonesia | 5.9 | 0.1 | 0.0 | | 0.1 | 843.7 | 1.7 | 0.0 |
| Italy | 103.5 | | 1.3 | | 1.3 | 1,800.0 | 1.3 | 0.1 |
| Japan | 711.9 | 14.0 | 29.1 | 0.2 | 43.3 | 4,272.0 | 6.1 | 1.0 |
| Mexico | 7.7 | | 0.8 | | 0.8 | 1,353.0 | 9.7 | 0.1 |
| Russia | 20.0 | | | | | 2,097.0 | 0.0 | 0.0 |
| Saudi Arabia | 126.8 | | | 9.5 | 9.5 | 546.0 | 7.5 | 1.7 |
| South Africa | 7.5 | | 0.7 | 0.1 | 0.8 | 467.8 | 10.7 | 0.2 |
| South Korea | 76.1 | 30.9 | 15.2 | 13.8 | 59.9 | 1,206.0 | 78.7 | 5.0 |
| Turkey | | | | | | 853.9 | | 0.0 |
| United Kingdom | 35.5 | 0.9 | 4.9 | 0.1 | 5.8 | 2,130.0 | 16.3 | 0.3 |
| United States | 976.9 | 39.3 | 58.3 | 20.0 | 117.7 | 13,780.0 | 12.0 | 0.9 |
| European Union[e] | 38.8 | 13.1 | 9.6 | | 22.8 | 14,430.0 | 58.7 | 0.2 |
| Total G20 | 3,004.3 | 105.3 | 330.1 | 78.1 | 513.5 | 63,145.8 | 17.1 | 0.8 |
| Total Other[f] | 314.1 | 2.3 | 5.3 | 1.0 | 8.6 | 6,902.9 | 2.7 | 0.1 |
| **Global Total** | **3,318.4** | **107.6** | **335.4** | **79.1** | **522.1** | **70,048.7** | **15.7** | **0.7** |

NOTES: [a] Support for renewable energy (geothermal, hydro, wind and solar), nuclear power, and carbon capture and sequestration. [b] Support for energy conservation in buildings; fuel-efficient vehicles; public transport and rail; and improving electrical-grid transmission. [c] Support for water, waste, and pollution control, including water conservation, treatment, and supply. [d] Based on 2007 estimated Gross Domestic Product (GDP) in terms of purchasing power parity. [e] Only the direct contribution by the European Union (EU) is included. [f] Includes the national stimulus packages of non-G20 EU countries: Austria, Belgium, Greece, Hungary, the Netherlands, Poland, Portugal, Spain, and Sweden. The non-EU countries in this group are Chile, Israel, Malaysia, New Zealand, Norway, the Philippines, Switzerland, Thailand, and Vietnam.

**SOURCE:** Barbier (2016)

**FIGURE 1**
**BREAKDOWN OF GLOBAL GREEN STIMULUS INVESTMENTS 2008-2009**
**(In %)**




**SOURCE:** Authors based on Barbier (2016).

### *3.3. Pre-COVID Green Deals*

Before the outbreak of the COVID-19 pandemic a new round of green deal proposals emerged. Arguably, the most influential ones have been the Green New Deal (GND) proposal by US congresswoman Alexandria Ocasio-Cortez and Senator Ed Markey (supported by Senator Bernie Sanders), and the European Green Deal (EGD) proposed by the President of the European Commission Ursula von der Leyen. These green deal proposals build on and go beyond the use of market-based and command and control instruments to address climate change by providing an all-encompassing vision of a net-zero development model that is inclusive and seeks to deliver a just transition.

In the US, the Green New Deal proposal resembles Roosevelt's New Deal insofar as it embraces a pro-growth approach (Green, 2020). Roosevelt's New Deal and the Green New Deal invest significant funds in hard infrastructure (in the power, water and transport sectors) and the environment. However, in the current carbon constrained context, the emphasis of the Green New Deal on clean power is distinct, as is the greater focus on R&D and clean R&D. When compared with the 2008 US fiscal stimulus package, the weight of low carbon power, energy efficiency and clean transport is significantly larger in size (x6) in the 2019 Green New Deal proposal.

President Joe Biden stated that the Green New Deal is critical in facing the climate challenge. It is therefore unsurprising that Biden's Build Back Better (BBB) plan, that amounted to $1.75 trillion, shared elements of the Green New Deal proposal (White House, undated). In the BBB the Biden-Harris administration proposed tax credits and rebates to help families shift to clean energy and increase electrification. More specifically the BBB pledged to reduce the cost of installing solar rooftop by 30% and reducing the cost of purchasing American built EVs by $12,500. It also foresaw handing out grants and loans to rural communities to shift to clean energy.

An additional goal of the BBB was to develop a "made in America" clean energy technology supply chain through grants, loans, tax credits and green procurement. Through a Clean Energy Accelerator public transport would be greened, capacity building reinforced, and a Civilian Climate Corps of 300,000 Americans employed to protect public land, help adapt and build resilience to climate change. Coastal restoration, forest management and soil conservation were also the focus of the BBB, with farmers playing a key role.

The BBB Act didn't pass, among others, due to the opposition by senator Joe Manchin, a democrat from West Virginia (Manchin, 2021). Other proposals by Manchin and colleagues to raise taxes on the rich to reduce debt and address climate change (Washington Post, 2022) emerged. In fact, in August 2022, the House of Representatives passed the Inflation Reduction Act that included a $369 billion climate package. The bill is expected to reduce US GHG by 40% by 2030 vs 2005 levels; insufficient to meet US latest NDC goals but the largest climate spending package to date (Greve, 2022).

The US also passed the Infrastructure Investment and Jobs Act[7], known as the Bipartisan Infrastructure Law in November 2021. This is a $1.2 trillion programme with $500 billion in new funding for infrastructure. Some of the investments in transport infrastructure seek to green the transport sector and address pollution. A summary of some of these investments is provided in Table 2.

Moving on to the EU, the European Green Deal (EGD) seeks to deliver climate neutrality in the EU by 2050. It is set to be Europe's new growth and competitiveness strategy in a climate neutral future. A strategy that strives to decouple resource use from economic growth and where natural capital is maintained or enhanced, akin to the strong sustainability paradigm (Neumayer, 2013), while protecting the health and well-being of Europeans (EC, 2019). Key elements of the European Green Deal include: becoming the "first climate neutral continent" by 2050 and increasing climate ambition by 2030; ensuring energy security; pursuing a clean and circular model for European industry; helping ramp up the transition to smart mobility; greening the food system; reducing pollution; protecting biodiversity; maintaining EU's climate leadership globally; financing the low-carbon transition; ensuring an inclusive and just transition for industries, workers and regions and engaging citizens through a European Climate Pact.

[6] Biden's BBB plan included the American Rescue Plan, the American Jobs Plan and American Families Plan. The Infrastructure Investment and Jobs Act includes some of the investments proposed in the American Jobs Plan.

**TABLE 2**
**INFRASTRUCTURE INVESTMENT AND JOBS ACT: ENERGY, CLIMATE & ENVIRONMENT**

| Area | Description | Amount($ billion) |
|---|---|---|
| Power | Updating power lines and funding clean energy. | 65 |
| Water | Funding is allocated to lead pipe replacement programme and the provision of clean water to communities. | 55 |
| | Funding will include water treatment, storage, and reuse to address droughts in the west | 8 |
| Climate change (& cybersecurity) | Funding would cover both slow on-set and extreme weather events: coastal erosion, droughts, floods and wildfires. | >50 |
| Transport | Funds upgrades to the public transport system. | 39 |
| | Includes funding for reducing truck emissions at ports. | 17 |
| | Funds EV charging stations | 7.5 |
| | Funds EV school buses | 7.5 |
| Environment | Funding would include the clean-up of polluted mining sites as well as oil and gas wells. | 21 |
| **Total** | | **≥270** |

**SOURCE:** Authors based on Probasco (2022).

Some salient legislative and executive measures within the European Green Deal include:

1. *European Climate Law* that enshrines the climate neutrality target by 2050 into law and the reduction of at least 55% of GHG emissions by 2030. It also created the European Scientific Advisory Board on Climate Change, an expert body tasked with providing independent and scientific advice on EU climate action (measures, targets and GHG budgets) and its alignment with the EU Climate Law and the EU's international climate commitments (EEA, 2022).
2. Update of the *Energy Taxation Directive* aligning energy taxation with the EU's climate goals (taxing fuels according to their energy content and environmental performance, not according to their volume), phase out fossil fuel subsidies and encourage the uptake of clean technologies. The update of the Energy Taxation Directive is part of the European Green Deal (EGD's) Fit for 55 package[8].

[8] The Fit for 55 package is a set of legislative and executive proposals (and reviews) aimed at delivering the EU's climate goals. It is structured around different instruments: pricing, targets, rules and support measures.

3. *The Carbon Border Adjustment Mechanism (CBAM). The* CBAM seeks to prevent carbon leakage and provide a level playing field for European companies so that environmental regulation and taxation does not unfairly disadvantage them. Operationally, the CBAM would ensure European and non-European products and imports bare the same carbon price. EU importers would purchase carbon certificates reflecting the carbon price that their imports would have endured should production had occurred in the EU. When an equivalent carbon price has been applied in the country of origin, importers would deduct the cost of CBAM. A gradual phase in of the CBAM is expected (with reporting requirements from 2023 to 2025) and would initially be applied to a handful of sectors: iron and steel, cement, fertilisers, aluminium and power generation. However, proposals to expand its scope to organic chemicals, hydrogen, polymers and indirect emissions were tabled in late 2021. The CBAM is part of the EGD's Fit for 55 package.
4. Updated *Renewable Energy Directive*. The EU's goal of reducing GHG emissions by at least 55 % by 2030 compared to 1990 levels required, according to the European Commission (EC), a higher share of renewables in its final energy consumption of 40 % (*vs.* the previous 32 %). This headline target is divided into sectoral targets including heretofore hard to abate sectors such as buildings and transport[9]. The updated Renewable Energy Directive is part of the EGD's Fit for 55 package.
5. A recast *Energy Efficiency Directive*. The goal would be to reduce primary energy consumption by 39% and final energy consumption by 36% by 2030. These goals would carry indicative energy efficiency targets for Member States and would almost double energy efficiency requirements compared to previous energy efficiency goals. Building renovations, improving efficiency in heating and cooling systems, addressing energy poverty and empowering consumers are seen as key enablers of the above energy efficiency goals. The updated Energy Efficiency Directive is part of the EGD's Fit for 55 package.
6. Review of the *Effort Sharing Regulation* (ESR) (or as civil society is suggesting calling it the Climate Action Regulation for Europe, CARE). The proposed goal is to reduce emissions of non-ETS sectors by 40 % by 2030 compared to 2005 emission levels. The updated *Land Use, Land Use Change and Forestry (LULUCF) regulation* is part of the EGD's Fit for 55 package.
7. Revision of the *EU Emissions Trading System (EU ETS)*. The EU ETS is one of the pillars of EU decarbonisation. The revised ETS will align this market-based instrument with the 2030 climate goals. This will mean a 61 %

[9] The above mentioned renewables (RES) sectoral targets include: 49 % RES of energy use in EU buildings; +1.1 % annual increase in RES use by industry; a binding target of +1.1 % annual increase in the use of RES in heating and cooling; an indicative target of +2.1 % in the use of RES in district heating and cooling; a decrease GHG intensity of transport fuels by 13 %; a minimum 2.2 % share of advanced biofuels in transport; a 2.6 % target for renewable fuels (mainly hydrogen) in transport; a 50 % share of RES in hydrogen consumption in industry.

GHG emission reductions in ETS sectors has been proposed (up from a 43% reduction required at present). A reduction in the cap and an increase in the linear reduction factor (from 2.2% to 4.2% per year) is called for to accelerate emission reductions. The revised ETS would include maritime transport under the current proposal. A revision of the ETS for aviation is also proposed. Additionally, a new ETS for buildings and transport is proposed, while maintaining emission reduction targets under the ESR for these sectors. The revision and expansion in the EU ETS is included in the Fit for 55 EGD implementation package.

8. To reduce the impact of the new ETS for the buildings and transport sector the EC proposed a *Social Climate Fund* that would amount to 25% of the revenues obtained from auctioning emission permits under the new ETS. This would amount to € 72.2 billion that would be complemented by national funds. Funds would be used to improve energy efficiency in buildings, integrating renewables, supporting low carbon mobility and supporting vulnerable households. The Social Climate Fund is part of the EGD's Fit for 55 package.

To implement the EGD the EU developed the European Green Deal Investment Plan, also known as the Sustainable Europe Investment Plan which:

1. Seeks to mobilise at least €1trillion up to 2030 with the following breakdown and funding sources: €503 billion will come from the EU budget; €25 billion from the EU ETS; €143 billion to be allocated for the Just Transition Mechanism to support workers, regions and industries; InvestEU[10] which is expected to leverage €279 billion of public and private investments for climate and environmental projects between 2021 and 2030; and, national co-financing of structural funds amounting to €114 billion.
2. Has developed an enabling framework including the EU Taxonomy, the EU Green Bond Standard and green public procurement requirements.
3. Will strive to develop a sustainable project pipeline by providing advice and technical support to project promoters and public administrators.

The above brief description of some of the key European Green Deal proposals shows the breadth and depth of the EU's net-zero implementation programme. A programme that includes the Fit for 55 implementation package (as indicated above) and which was being negotiated at the time of writing.

[10] InvestEU is a fund that includes 13 EU financial instruments and the European Fund for Strategic Investments. It seeks to finance sustainable infrastructure, research, innovation and digitization, SMEs and social investments and skills.

### *3.4. Post COVID-19 recovery plans*

Academic literature, grey literature and political declarations made it clear that several countries and regions (e.g., the EU, the US, South Korea, Canada) would seek to recover from COVID-19 and transform their economies into low(er) carbon growth engines building on the Green Deal ethos. Given the limited time that has passed since the announcement of COVID-19 recovery packages and the fact that their implementation is on-going at the time of writing, the following analysis is based on government plans rather than on investments executed.

A recent analysis by Vivid Economics and Finance for Biodiversity Initiative (2021) showed that up until July 2021, the global fiscal stimulus planned to recover from the COVID-19 pandemic amounted to US$ 17.2 trillion in G20 plus other selected countries[11]. Even if fiscal stimulus in these G20+ countries is over five times that of the Global Financial Crisis, the authors argue that in percentage terms, the COVID-19 green response is proportionally smaller than that of the 2008-2009 recovery (10,4 %[12] versus 15.7 % in the post Global Financial Crisis green fiscal stimulus). Sectors that were the hardest hit by the pandemic across the countries analysed received the bulk of the funding (industry, transport, energy and, to a lesser extent, agriculture).

The OECD's Green Recovery Database update published in September 2021 indicates that green stimulus in OECD countries and partner countries[13] amounted to 21 % of total COVID-19 recovery spending. Although significant, green spending is argued to be substantially lower than the continued support received by fossil fuels. The OECD study finds, similarly to the Vivid study, that most green fiscal stimulus was planned to support mitigation goals, disregarding broader climate and environmental challenges such as adaptation or biodiversity losses. In terms of the sectoral allocation of funds ground transport, energy, buildings and industry (in that order) receive the bulk of green stimulus across the OECD countries analysed while R&D and agriculture receive limited funds (OECD, 2021), see Figure 2.

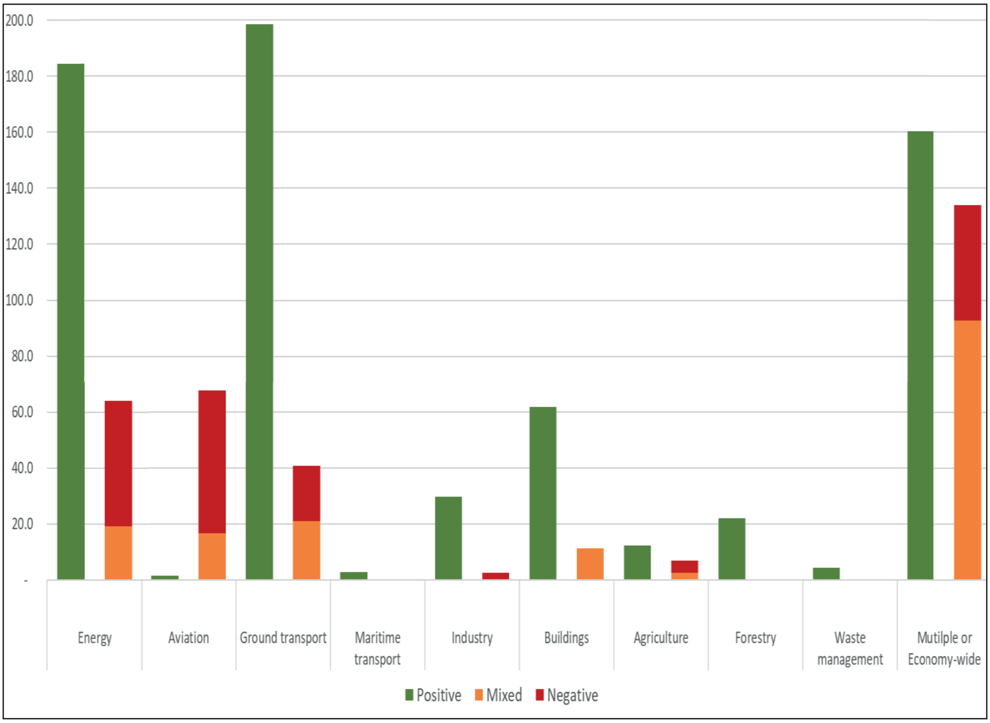
---

[11] The Vivid Economics and Finance for Biodiversity Initiative study included G20 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union), plus the Nordic countries, Colombia, Switzerland, Spain, Singapore and the Philippines.

[12] Note that other authors analysing the $14 trillion in post-COVID fiscal stimulus planned by G20 countries estimate that only 6 % was allocated to reducing GHG emissions while 3 % was allocated to supporting activities that can increase emissions such as subsidising the coal industry (Nahm et al., 2022). Earlier analysis such as Herburn et al. (2020) indicated that only 4% of global post-COVID fiscal stimulus could be considered 'green' (i.e. potentially driving down GHG emissions), with a further 4 % considered 'brown' (i.e. potentially increasing emissions) and 92% being colourless (maintaining the status quo).

[13] OECD countries include: Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak, Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

**FIGURE 2**
**FUNDING TOTALS BY SECTOR AND BY ENVIRONMENTAL IMPACT**

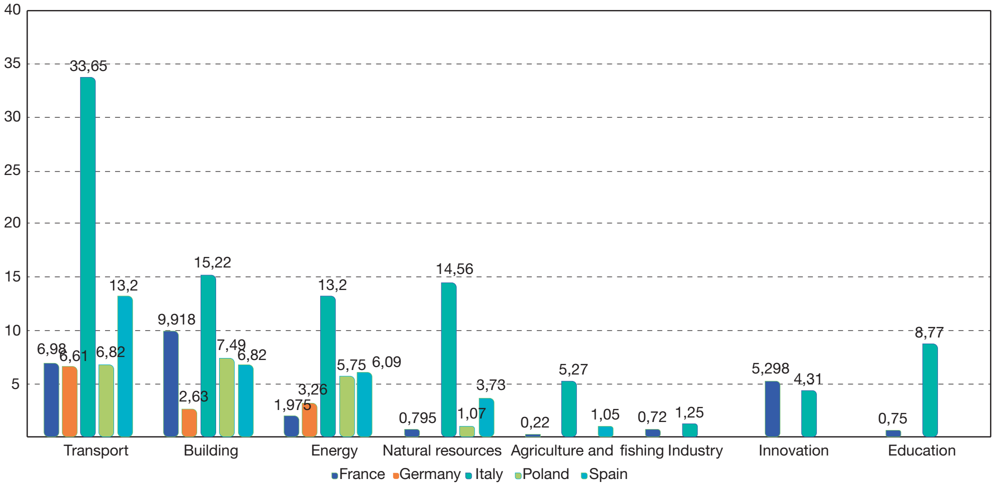



**SOURCE:** OECD (2021).

Focusing on the EU, the five largest GHG emitters (Germany, France, Italy, Poland and Spain) allocate 37% or more of their planned investments to support climate objectives, also allocating 20% or more of the funds to the digital transition as required by the EU (Lázaro Touza et al., 2022). As for the sectoral breakdown of National Recovery and Resilience Plans (NRRPs) across the EU's five largest emitters Figure 3 indicates that transport, building and energy are the key recipients of what we have termed 'high-impact' climate investments (contributing 40% or more to climate objectives). Figures 3 and 4 provide a country and sectoral breakdown of said high climate-impact investments in absolute and relative terms.

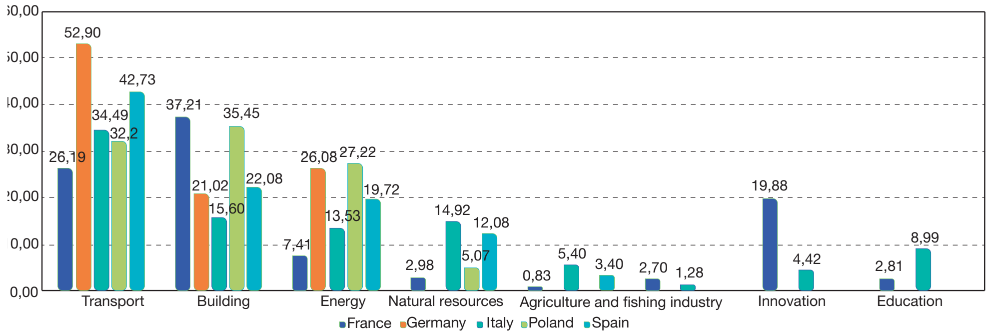
Funds with a high climate impact or "climate tag" (contributing 40% or more to climate objectives) are aligned with the EU's priorities called "flagships": flagship 1 (Power Up) on clean technologies and renewables, flagship 2 (Renovate) on improving energy efficiency of public and private buildings, and flagship 3 (Recharge and Refuel) on sustainable transport, charging stations and extending public transport. The transport (including aviation), building (households, commerce, institutions and others) and energy (energy industries) jointly amounted to 64,1% of emissions in the EU-27 in 2019 (Eurostat, 2021), justifying the greater investment allocated to these sectors.

## FIGURE 3
## ALLOCATION OF FUNDS WITH SIGNIFICANT CLIMATE CONTRIBUTION (IN BILLIONS OF EUROS) IN SELECTED NRRPS




**SOURCE:** Lázaro Touza et al. (2022).

## FIGURE 4
## ALLOCATION OF FUNDS WITH SIGNIFICANT CLIMATE CONTRIBUTION IN SELECTED NRRPS
## (In %)




**SOURCE:** Lázaro Touza et al. (2022)

As argued by Lázaro Touza et al. (2022) the key policy instruments used to implement the NRRPs are: public spending, regulation, subsidies, tax exemptions and deductions. New carbon pricing instruments could have been expected after economic recovery to help restore public finances (OECD, 2020). However, the current energy price spike and Russia's invasion of Ukraine might make carbon pricing initiatives unfeasible at this stage.

The extent to which NRRPs in the EU (and across other jurisdictions) contribute to the achievement of green deal goals will depend on whether several hard to come by challenges are effectively addressed. These have been summarized in Box 1.

**BOX 1**
**KEY CHALLENGES IN THE SUCCESSFUL IMPLEMENTATION OF NRRPS**

- The inclusion of concrete goals in NRRPs that will enable ex-post evaluation.
- The integration of NRRPs and broader climate and energy legislation.
- Updating legislative frameworks to reflect COVID-19 and Net-Zero targets.
- Greater definition of the policy instruments to be used.
- Limited administrative capabilities.
- Weak governance structures.
- The capacity to effectively absorb the influx of Next Generation EU funds ahead of 2026.
- The selection of truly transformative projects.
- The engagement with sub-national governments and non-state actors.
- Preventing social and political backlash by ensuring a Just Transition and explaining and raising awareness of the reforms envisaged in the NRRPs.
- Energy transition goals require long-term investments after NGEU funds are disbursed. Reflecting on long-term investment needs is arguably required.

**SOURCE:** Lázaro Touza et al. (2022)

## 4. Discussion

Green deals and recovery programmes presented in previous sections advocate for reinvigorating economic growth, reducing unemployment, decarbonising the economy and, in the case of the European Green Deal, decoupling resource use from GDP growth.

Based on Hepburn et al. (2020), this section first builds on the analysis of policies implemented after the 2008 Global Financial Crisis to discern whether governments overall selected policies that would yield high long-term economic multipliers and high (and positive) climate impacts. Policies under this approach could be included in the ecomodernism school of thought that is based on three core strategies: green technological innovation, resource efficiency and the sustainable use of land (IPCC, 2022).

The discussion then follows Green (2020) in asking whether the New Deal that inspired green deal proposals and recovery plans after the Global Financial Crisis and the COVID-19 pandemic can lead to a net-zero (emissions) economy given their pro-growth approach. In so doing this final part of the discussion reflects on one of the low carbon transformation pathways included for the first time in the IPCC's latest report (IPCC, 2022): degrowth[14], which considers sharing the remaining and diminishing global carbon budget using legislation to limit GHG overshoot and abandoning growth as a key economic objective. The purpose of the degrowth discussion is not to advocate for it but rather to explore, in a preliminary manner and pending future research, opposing theoretical options in delivering a net-zero development model to which governments around the world agreed to in the Paris Agreement. This debate, as Jackson and Webster (2016) contends, remains essential in understanding future challenges to economic progress.

Early on in 2020 Hepburn et al. (2020) published the results of a survey conducted among 231 economic experts from central banks and finance ministries. Experts evaluated 700 policies that had been implemented since the Global Financial Crisis. The survey plus evidence from academic literature concluded that the following policies summarised in Box 2 can deliver economic growth and foster meeting climate goals:

**BOX 2**

**POLICIES FOR ECONOMIC GROWTH AND A CLIMATE-POSITIVE RECOVERY**

- Clean R&D spending.
- Clean physical infrastructure investment in the form of renewable energy assets, storage (including hydrogen), grid modernisation, and CCS technology.
- Investment in education and training to address unemployment caused by COVID and unemployment caused by decarbonisation.
- General R&D spending.
- Building efficiency spending for renovations and retrofits including improved insulation, heating, and domestic energy storage systems.
- Natural capital investment for ecosystem resilience and regeneration including restoration of carbon-rich habitats and climate-friendly agriculture.
- In many low and middle-income countries, clean R&D spending might be replaced with:
- Rural support scheme spending, particularly that associated with sustainable agriculture, ecosystem regeneration, or accelerating clean energy installations.

**SOURCE:** Hepburn et al. (2020).

Comparing the results from Table 1 (Barbier, 2016) with policies in Box 2 above it can be argued that clean R&D spending –one of the measures with higher long-term economic multiplier and high positive climate impact– was not the primary

[14] In this context degrowth has been defined as a "planned reduction of energy and resource use designed to bring the economy back into balance with the living world in a way that reduces inequality and improves human well-being" (Hickle, 2021).

focus of the 2008 recovery packages after the Global Financial Crisis. Investment in education and training was also largely absent in the analysis of post 2008 recovery programmes. According to the OECD (2021) in the post COVID-19 action to foster R&D and upskilling workers have also been limited.

Post 2008, low carbon power (including investments in renewables, nuclear energy and CCS) received 3.2 % of total fiscal stimulus in those countries analysed by Barbier (2016)[15]. Energy efficiency was awarded 10.1 % of the total fiscal stimulus. Waste, water and pollution received 2.4 % of the total fiscal stimulus. In the post COVID-19 era, stimulus packages analysed by the OECD (2021) saw investments in renewables, ground transport and buildings topped sectoral stimulus as of 2021 reaching $455 billion.

Transport, energy efficiency in buildings and investments in clean energy are the key sectors to which NRRPs across the EU's largest emitters are allocated. Innovation and education are only prominent in French and Spanish post-COVID recovery plans. Agriculture has received limited funding in the EU's largest emitter's NRRP, as has been the case across OECD+ countries analysed by the OECD (2021).

Overall, investments in transport and energy infrastructure are common from the New Deal to the recent green deals and post-COVID-19 recovery pans. Building efficiency and investments in nuclear, CCS and renewables have been significant in post 2008 fiscal stimulus programs as well as in post COVID-19 recovery plans. A common gap in these plans seems to be investment in clean R&D as well as upskilling workers. However, government actions in these areas might have been included in other initiatives that have not been covered by recovery plans.

Finally, some authors (e.g., Green, 2020; Taherzadeh, 2021; Hickle & Kallis, 2020) have argued that New Deal-inspired green deals might not be fit for purpose. They argue that pro-growth New Deal responses are conceptually ill-suited to address economic and environmental/climate crises caused by over-consumption and growth. It has been argued that countries have nevertheless put forth pro-growth green deals to deal with economic and climate crises as steady state and degrowth options would have been socially and politically unfeasible (Haberl et al., 2020).

Other authors however (including Pollin, 2018; Trezi, 2022; Jackson & Webster, 2016) criticise degrowth on a number of grounds. Some of the arguments put forth by degrowth analysts and critics include: 1) that degrowth theory is more a slogan than a coherent transformational proposal that is only supported by a handful of 'radical academics and activists' whose proposals do not yet offer a blueprint for a new society; 2) degrowth theory lacks a complete GHG stabilisation framework; 3) if fossil fuels were replaced by a combination of renewables and energy efficiency this would lead to significant (and climate positive) economic growth; 4) the case of Japan, which has grown little in the past decades and remains a very high emitter,

[15] G20 countries plus non-G20 EU countries and non-EU countries: Austria, Belgium, Greece, Hungary, the Netherlands, Poland, Portugal, Spain, and Sweden, Chile, Israel, Malaysia, New Zealand, Norway, the Philippines, Switzerland, Thailand, and Vietnam.

is seen as a rebuttal of degrowth; 5) dating back to the limits to growth debate back in the 70's (Meadows et al., 1972; Jackson & Webster, 2016) degrowth proponents allegedly paid limited attention to the growth-innovation-substitution potential of economic systems; 6) degrowth would likely bring undesirable economic impacts such as debt defaults and limited fiscal space to respond to crises such as the one caused by COVID-19 or the energy crisis caused by Russia's invasion of Ukraine, all of which are known to disproportionally affect the poor; 7) since growth and employment are highly correlated, embracing degrowth would require managing higher unemployment levels; 8) degrowth will dismantle current incentives for innovation, including green innovation that is crucial for a net-zero society. This would call for a new innovation system to be devised within a degrowth paradigm.

The debate on the relationship between economic growth and the environment is decades old and far from being resolved. An environmental Kuznets Curve for greenhouse gas emissions remains elusive on a global level as turning points would be well above current incomes (Neumayer, 2013). More broadly, Hickle and Kallis (2020) also highlight the lack of evidence on a global scale regarding absolute decoupling between economic growth and resource use. The key issue though, in the authors opinion, is not so much with resource use but with the environment's limited pollution absorption capacity. Hickle and Kallis (2020) also highlight the unlikely 1.5ºC-compatible decoupling of growth and greenhouse gas emissions. These authors hence question the green growth paradigm and suggest policymakers should seek other alternatives to future development.

Green (2020) encourages learning from the New Deal regarding government planning, significant investment efforts and a socioeconomic transformation that had a broad and speedy reach. He furthermore suggests embracing the idea of economic policy being tailored (flexible) to the specific context in which it must be applied. Such a context is now that of a carbon-constrained world with multiple socioeconomic and environmental crises occurring simultaneously and interacting with each other. Green argues for the abandonment of a so-called "productivist" model and suggests the uptake of "new statistical imaginaries" that would help transcend the New Deal era of GDP growth in favour of other development measures that would include the environment.

These "imaginaries" have been developed since the 1990's (Atkinson et al., 1997) and include indicators such as Genuine Savings (GS), now called Adjusted Net Savings (ANS), that measures weak sustainability assuming perfect substitution of different forms of capital. Indicators of strong sustainability have also been developed (and criticised) including the use of ecological footprints, sustainability gap analysis, etc (Dietz & Neumayer, 2007). Although green national accounting has gained ground, GDP is still the measure of choice, even if its limits as a measure of welfare and disregard for natural capital and environmental bads (Pollin, 2018) are well known.

Based on the above discussion we argue that given the limited progress in reducing greenhouse gas emissions (despite past climate policy efforts, green deal proposals and green recovery plans), further academic enquiry into alternative modes of development is still warranted and will be increasingly demanded by civil society and, ultimately, politicians that will have to deal with the impacts, adaptation costs, losses and damages resulting from climate change.

Abandoning growth is unlikely to be the solution, given innovation for a low-carbon transition requires significant amounts of capital and growth. Properly including sources and sinks in our GDP estimates and subjecting growth optimisation goals to 1.5 ºC carbon budgets that result in absolute decoupling of said growth, fossil fuel (Pollin, 2018) and land–use emissions could arguably be the (extremely hard) way forward if we are hoping to avoid having to fight future wars over food and water (EC, 2021).

## 7. Conclusions

Scientific evidence on the causes and the impacts of climate change indicates that if we want to avoid catastrophic climate change, we must engage this decade in a rapid, orderly and profound restructuring of the global economy, with developed countries taking the lead. Conscious of the limited decarbonisation progress so far and seeking to reap the benefits of first mover advantages in the low-carbon world countries have proposed economy-wide transformation roadmaps.

New Deal-inspired green deal proposals put forth since the turn of the century have sought to design a grand strategy for a new development model that yields economic growth, green competitiveness, a fair transition and climate neutrality. Fiscal stimulus programmes enacted in the aftermath of the Global Financial Crisis and amid the COVID-19 pandemic have, to a greater or lesser extent, been guided by green deal proposals. Both green deal proposals and economic recovery plans are grounded on a pro-consumption and pro-growth paradigm.

However, whether greenhouse gas emissions can be decoupled from economic growth globally is unclear. Empirical evidence indicates absolute decoupling of economic growth and greenhouse gas emissions has not occurred so far on a global scale, although a handful of high-income countries have shown past growth and emissions decoupling (Jackson, 2017; Pollin, 2018). But, even if $CO_2$ emissions followed an Environmental Kuznets Curve, turning points would arguably be unattainable at present in many countries. Hence, it has been argued that pro-growth New Deal-inspired green deals could be ill-suited to respond to an overconsumption-related problem whose emissions are leading to an unsafe operating space for humanity (Rockström et al., 2009).

Discussions of degrowth as an alternative development model are once again re-emerging and have been included in the latest analysis of peer-reviewed literature undertaken by the IPCC. Even if degrowth models have low social and political appeal at present and could potentially hinder low carbon innovation, further academic enquiry into alternative modes of development that include developing within planetary boundaries (*Ibid.*) is warranted and will be increasingly demanded as the impacts of climate change become more severe.

## References

Atkinson, G., Hett, T., & Newcombe, J. (1997). *Measuring "corporate sustainability"*. CSERGE Working Paper GEC 99-01.

Barbier, E.B. (2009). *Rethinking the Economic Recovery: A Global Green New Deal*. UNEP.

Barbier, E. B. (2010). Global governance: The G20 and a global green new deal. *Economics*, *4*(1), 1-29.

Barbier, E.B. (2016). Building the green economy. *Canadian Public Policy*, *42*(s1), S1–S9.

Barbier, E. B. (2019a). How to make the next Green New Deal work. *Nature*, *565*(7737), 6-7.

Barbier, E.B. (2019b). *The Fall and Rise of the Green New Deal. Public Administration Review Bully Pulpit Symposium on "The Green New Deal: Pathways to a Low Carbon Economy*", July 16, 2019. https://www.publicadministrationreview.com/2019/07/16/gndbarbier/

Berghmans, N. (2021, September 10). Is the French recovery and resilience plan climate-compatible? A preliminary analysis. ARI nº 75/2021. *Elcano Royal Institute*.

Bieliszczuk, B. (2021, October 10). The Polish Recovery Plan: a careful step toward energy transition. ARI nº 87/2021. *Elcano Royal Institute*.

Bureau of reclamation. (2022). *About us*. Last access the 20th of March 2022. https://www.usbr.gov/main/about/fact.html

Climate Action Tracker (2021). *Glasgow's 2030 credibility gap: net-zero's lip service to climate action Wave of net-zero emission goals not matched by action on the ground*. Warming Projections Global Update, November 2021. Last accessed the 14th of March 2022. https://climateactiontracker.org/documents/997/CAT_2021-11-09_Briefing_Global-Update_Glasgow2030CredibilityGap.pdf

Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: concepts and measurement. *Ecological Economics*, *61*(4), 617-626.

Dietz, S. (2019, February 14). *The economics of 1.5°C climate change*. [video]. Youtube. Last accessed the 8th of March, 2022. https://www.youtube.com/watch?v=t_8S2qX5ONs

EC, European Commission. (2020a). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. *The European Green Deal*. Last accessed the 18th of March 2022. https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

EC, European Commission. (2020b). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. *Sustainable Europe Investment Plan European Green Deal Investment Plan.* Last accessed the 18th of March 2022. https://ec.europa.eu/commission/presscorner/detail/en/fs_20_48

EC, European Commission. (2020c). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. *Sustainable Europe Investment Plan European Green Deal Investment Plan*. Last accessed the 28th of March 2022. https://eurlex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52020DC0021&from=EN

EC, European Commission. (2021). *Statement by Executive Vice-President Timmermans on delivering the European Green Deal*. Last accessed the 11th of August 2022). https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_21_3722

EC, European Commission. (2022). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. *REPowerEU: Joint European Action for more affordable, secure and sustainable energy.* Last accessed the 12th of March 2022. https://eur-lex.europa.eu/resource.html?uri=cellar:71767319-9f0a-11ec-83e1-01aa75ed71a1.0001.02/DOC_1&format=PDF.

EEA, European Environment Agency. (2022). *European Scientific Advisory Board on Climate Change*. Last access the 24th of August 2022. https://www.eea.europa.eu/about-us/climate-advisory-board/members-of-the-advisory-board

Feás, E., & Steinberg, F. (2021, July 6). The climate and energy transition component of the Spanish National Recovery and Resilience Plan. *ARI* nº 64/2021. *Elcano Royal Institute*.

Foxon, J. T., Köhler, J., Michie, J., Oughton, C. (2012). Towards a new complexity economics for sustainability. *Cambridge Journal of Economics, 37*(1), 187-208. https://doi.org/10.1093/cje/bes057

Friedman, T. L. (2007, April 15). The power of Green. *The New York Times*. Last accessed the 27th of March, 2022. https://www.nytimes.com/2007/04/15/opinion/15iht-web-0415edgreen-full.5291830.html

Galvin, R., & Healy, N. (2020). The Green New Deal in the United States: What is it and how to pay for it. *Energy Research and Social Science*, *67*. https://doi.org/10.1016/j.erss.2020.101529

Green New Deal Group. (2008). *A Green New Deal. Joined-up policies to solve the triple crunch of the credit crisis, climate change and high oil prices*. Green New Economics Foundation. Last accessed the 14th of August 2022. https://neweconomics.org/uploads/files/8f737ea195fe56db2f_xbm6ihwb1.pdf

Green, J. (2020). The Green New Deal in the Shadow of Keynes – old ideas for new challenges?. *Cambridge Open Engage*. https://doi.org/10.33774/coe-2020-dz5q5

Greve, J. (2022, August 12). US House passes Democrats' landmark healthcare and climate Bill. *The Guardian*. Last accessed the 13th of August 2022. https://www.theguardian.com/us-news/2022/aug/12/us-house-passes-climate-bill-inflation-reduction-act

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Fishman, T., Hausknost, D., Krausmann, F., Leon-Gruchalski, B., Mayer, A., Pichler, M., Schaffartzik, A., Sousa, T., Streeck, J., & Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. *Environmental Research Letters*, *15*(6). https://doi.org/10.1088/1748-9326/ab842a

Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J., & Zenghelis, D. (2020). Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?. *Oxford Review of Economic Policy*, *36*(Supplement_1), S359-S381.

Hickle, J., & Kallis, G. (2020). Is green growth possible?. *New Political Economy, 25*(4), 469-486. https://doi.org/10.1080/13563467.2019.1598964

Hickel, J. (2021). What does degrowth mean? A few points of clarification. *Globalizations, 18*(7), 1105-1111. https://doi.org/10.1080/14747731.2020.1812222

Hope, C., & Newbery, D. (2006). *Calculating the social cost of carbon*. Working Papers EPRG 0720, Energy Policy Research Group, Cambridge Judge Business School, University of Cambridge. Last accessed the 13th of August 2022. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.320.6580&rep=rep1&type=pdf

IEA, International Energy Agency. (2021). *COP26 climate pledges could help limit global warming to 1.8 °C, but implementing them will be the key.* Last accessed the 8th of March, 2022.https://www.iea.org/commentaries/cop26-climate-pledges-could-help-limit-global-warming-to-1-8-c-but-implementing-them-will-be-the-key

IMF, International Monetary Fund. (2021). *Building Back Better: How Big Are Green Spending Multipliers?*. IMF Working paper, Working Paper No 2021/087.

IPCC, Intergovernmental Panel of Climate Change. (2021). Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32. https://doi.org/10.1017/9781009157896.001

IPCC, Intergovernmental Panel of Climate Change. (2022). Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33.

Jackson, T., & Webster, R. (2016). *LIMITS REVISITED. A review of the limits to growth debate*. All Party Parliamentary Group (APPG) on Limits to Growth. Last accessed the 12th of August 2022. https://limits2growth.org.uk/wp-content/uploads/Jackson-and-Webster-2016-Limits-Revisited.pdf

Jackson, T. (2017). *Prosperity without Growth: Economics for a Finite Planet.* Oxon: Routledge.

Kennedy, D. M. (2009). What the New Deal Did. *Political Science Quarterly*, *124*(2), 251-268. https://www.jstor.org/stable/25655654

Kiefer, C. (2021, July 19). Next Generation EU: Germany focuses its climate policy on hydrogen and sustainable mobility. ARI nº 69/2021. *Elcano Royal Institute*.

Köberle, A. C., Vandyck, T., Guivarch, C., Macaluso, N., Bosetti, V., Gambhir, A., Tavoni, M., & Rogelj, J. (2021). The cost of mitigation revisited. *Nature Climate Change,* 11, 1035–1045. https://doi.org/10.1038/s41558-021-01203-6

Lázaro Touza, L., Averchenkova, A., & Escribano Francés, G. (2022). High-impact green recovery in the EU's 'big five' (emitters): key elements and caveats. Elcano Policy Paper. *Elcano Royal Institute.*

Leiter, T. (2021). Do governments track the implementation of national climate change adaptation plans? An evidence-based global stocktake of monitoring and evaluation systems. *Environmental Science and Policy, 125*, 179–188. https://doi.org/10.1016/j.envsci.2021.08.017

Le Quéré, C., Korsbakken, J. I., Wilson, C., Tosun, J., Andrew, R., Andres, R. J., Canadell, J. G., Jordan, A., Peters, G. P., & van Vuuren, D. P. (2019). Drivers of declining $CO_2$ emissions in 18 developed economies *Nature Climate Change, 9*(3), 213–217. https://doi.org/10.1038/s41558-019-0419-7

Manchin, J. (2021). *Manchin Statement on Build Back Better Act*. Last accessed the 24th of March, 2022. https://www.manchin.senate.gov/newsroom/press-releases/manchin-statement-on-build-back-better-act

Mastini, R., Kallis, G., & Hickel, J. (2021). A Green Deal without growth?. *Ecological Economics*, *179*. https://doi.org/10.1016/j.ecolecon.2020.106832

Mathis, W. (2022, January 27). *Energy Transition Drew Record $755 Billion of Investment in 2021*. Bloomberg.

Mattei, L., & Bellisai, F. (2021, December 16). Italy's National Recovery and Resiliency Plan's climate impact. ARI nº 107/2021. *Elcano Royal Institute*.

Meadows, D., Meadows, D., Randers, J., & Behrens III, W.W. (1972). *The Limits to Growth*. Universe Books. Last accessed the 12th of August 2022. https://www.donellameadows.org/wp-content/userfiles/Limits-to-Growth-digital-scan-version.pdf

Nahm, J., Miller, S., & Urpelainen, J. (2022). G20's US$14-trillion economic stimulus reneges on emissions pledges. *Nature*, *603*(7899), 28-31. https://doi.org/10.1038/d41586-022-00540-6

National Archive. (2022). *National Industrial Recovery Act (1933)*. Last accessed the 20th of March 2022. https://www.archives.gov/milestone-documents/national-industrial-recovery-act#:~:text=On%20June%2016%2C%201933%2C%20this,by%20which%20President%20Franklin%20D.

Neumayer, E. (2013). *Weak versus Strong Sustainability. Exploring the Limits of Two Opposing Paradigms*, Fourth Edition. Edward Elgar.

OECD, Organisation for Economic Co-operation and Development. (2021). *Key findings from the update of the OECD Green Recovery Database*. Last accessed the 25th of March 2022. https://read.oecd-ilibrary.org/view/?ref=1109_1109272-nuk0ptos4l&title=Key-findings-from-the-update-of-the-OECD-Green-Recovery-Database

Pollin, R. (2018). De-growth vs a green new deal. *New Left Review,* 112, 5-25.

Probasco, J. (2022, February 23). Understanding Infrastructure Legislation. Investopedia. Last accessed the 26th of March 2022. https://www.investopedia.com/here-s-what-s-in-the-usd1-trillion-infrastructure-bill-passed-by-the-senate-5196817#citation-48

Real Instituto Elcano. (2022). *Barómetro del Real Instituto Elcano Resultados octubre-noviembre de 2021 y febrero de 2022, 42ª oleada Madrid, febrero de 2022*. Last accessed the 25th of March, 2022. https://media.realinstitutoelcano.org/wp-content/uploads/2022/02/42brie-informe-febrero2022.pdf

Roberts, J. (2011). *Environmental Policy*. 2nd Edition. Oxon: Routledge.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., … Foley, J. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society, 14*(2). http://www.ecologyandsociety.org/vol14/iss2/art32/

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, S., Kriegler, E., Mundaca, L., Séférian, R., & Vilariño, M.V. (2018). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: *Global*

*Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. [Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (eds.)]. In Press.

Shiller, R. J. (2017). Narrative Economics. *American Economic Review*, *107*(4), 967-1004.

Stern, N. (2006). *The Economics of Climate Change. The Stern Review*. Cambridge University Press. https://doi.org/10.1017/CBO9780511817434

Taherzadeh, O. (2021). Promise of a green economic recovery post- Covid: trojan horse or turning point? *Global Sustainability, 4* E2, 1–6. https://doi.org/10.1017/sus.2020.33

Trezi, A. (2022). *Growth for Good. Reshaping Capitalism to Save Humanity from Climate Catastrophe*. Harvard University Press.

UN, United Nations. (2015). *Paris Agreement*. Last accessed 15th of March 2022. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

UNEP, United Nations Environment Programme. (2009). *Global Green New Deal*. Green Economy Initiative, Nairobi, Kenya.

UNEP, United Nations Environment Programme. (2020). *Emissions Gap Report*. Last accessed the 27th of March 2022. https://www.unep.org/interactive/emissions-gap-report/2020/

UNFCCC, United Nations Framework Convention on Climate Change. (2021, November 4). Nationally determined contribution synthesis report. Last accessed the 20th of March 2022. https://unfccc.int/sites/default/files/resource/message_to_parties_and_observers_on_ndc_numbers.pdf

UN Habitat. (2020). *World Cities Report 2020. The value of Sustainable Urbanization.* Last accessed the 14th of March 2022. https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf

Vivid Economics and Finance for Biodiversity Initiative. (2021). *Greenness of Stimulus Index.* Last accessed the 14th of August 2022. https://www.vivideconomics.com/wp-content/uploads/2021/01/201214-GSI-report_December-release.pdf

Von der Leyen, U., & Hoyer, W. (2021, March 22). *A Global Green Deal*. Last accessed the 14th of August 2022. https://ec.europa.eu/commission/presscorner/detail/fr/ac_21_1322

Washington Post. (2022, March 6). *Opinion: Make a deal with Manchin on Build Back Better*. Editorial Board Opinion. Last accessed the 24th of March 2022. https://www.washingtonpost.com/opinions/2022/03/06/make-deal-with-manchin-build-back-better/

Weitzman, M. L. (1974). Prices *vs.* Quantities. *The Review of Economic Studies*, *41*(4), 477–491. https://doi.org/10.2307/2296698

Winkler, A. (2009, March 31). *The New Deal: Accomplishments and Failures*. Testimony before the U.S. Senate Committee on Banking, Housing, and Urban Affairs. Last accessed the 7th of March 2022. https://www.banking.senate.gov/imo/media/doc/WinklerTestimony33109TheNewDealSenateTestimony.pdf

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# El efecto del mercado de emisiones europeo en las emisiones de la aviación en España*

# *Effects of the EU ETS on the Spanish aviation market*

Xavier Fageda
Jordi Teixidó
Universitat de Barcelona

***Resumen***

*Desde 2012, todas las rutas aéreas dentro del Espacio Económico Europeo (EEE) están incluidas en el mercado de emisiones de la Unión Europea (ETS, por sus siglas en inglés). La evidencia empírica ha demostrado que esta política redujo las emisiones en un 5 % en comparación con el contrafactual para el conjunto de países del EEE (Fageda y Teixidó, 2022). Sin embargo, este efecto es potencialmente heterogéneo según el país que se examina. Aplicando una estrategia de diferencias en diferencias, aquí nos centramos en España, un país con un alto despliegue ferroviario de alta velocidad y, sobre todo, con una gran industria turística. Encontramos que el ETS redujo las emisiones de la aviación española hasta un 10 %, por lo que el impacto del ETS es potencialmente mayor en España que en otros países europeos. El mayor impacto relativo en España parece venir explicado por la competencia intermodal y el gran peso del turismo, pues las emisiones fueron un 13 % menores en rutas afectadas por la competencia del tren de alta velocidad y un 11 % menores en rutas turísticas. La reducción de las emisiones se explica principalmente por la reducción de la oferta de vuelos.*

***Palabras clave:*** *mercado de emisiones, cambio climático, precio del carbono, aviación.*
***Clasificación JEL:*** *D22, L93, Q54.*

***Abstract***

*Since 2012, all air routes starting or finishing in the European Economic Area are included in the EU Emissions Trading System (ETS). Empirical evidence has shown that this policy instrument reduced emissions by 5 % as compared to the counterfactual at the EU level (Fageda & Teixidó, 2022). However, this effect is potentially heterogeneous across countries. Applying a difference-in-difference strategy, here we focus on Spain, a country with high speed rail deployment and with a significant tourism industry. We find that Spanish aviation emissions were up to 10 % lower because of the EU ETS, 13 % lower if there was a HSR connection and 11 % less when focusing only on tourist destinations. All these reductions in emissions were driven by a reduction in flights.*

***Keywords:*** *emissions trading, climate change, carbon price, aviation.*

* Agradecemos la financiación recibida de proyectos del Ministerio de Ciencia, Innovación y Universidades: J. Teixidó (PID2019-104319RB-I00) y X. Fageda (RTI2018-096155-B-I00).


DOI: https://doi.org/10.32796/cice.2022.104.7474
Recibido: Abril 2022 · Aceptado: Julio 2022

## 1. Introducción

España es uno de los diez países del mundo con mayores emisiones derivadas de vuelos internacionales, registrando uno de los mayores incrementos de emisiones de efecto invernadero en los últimos años (Graver *et al*., 2020). Entre 2013 y 2019, las emisiones contabilizadas en salidas de aeropuertos españoles aumentaron un 45 %, comparado con el incremento medio del 30 % de la Unión Europea (UE) en el mismo periodo; este aumento supuso el mayor incremento de emisiones en términos absolutos de toda la UE (Graver *et al*., 2019; European Environment Agency [EEA], 2020). Buena parte de estas cifras vienen justificadas por la industria del turismo del país, la cual llegó a representar hasta un 12 % del PIB en 2018, comparado con un 4,4 % en los países de la OCDE (OECD, 2020).

A nivel global, el transporte es el único sector que desde 1990 no ha conseguido reducir sus emisiones de dióxido de carbono. La aviación, aunque supone un porcentaje menor del total de emisiones del transporte, se caracteriza por tener un crecimiento muy elevado del tráfico (con permiso de la pandemia). También se caracteriza por un avance tecnológico sostenido, en la medida que las nuevas generaciones de aviones son más eficientes en términos de consumo de combustible, pero de difícil y lenta aplicación. Por ello, se prevé que sus emisiones se tripliquen en 2050, cuando se estima que llegarán a suponer un 22 % del impacto global del cambio climático (Cames *et al*., 2015). Además, las emisiones de volar se distinguen también por tener un impacto climático entre 1,3 y 2,9 mayor que las emisiones generadas en la superficie (Azar y Johansson, 2012; Lee *et al*., 2021). Así, aproximadamente un 5 % del impacto climático antropogénico se puede atribuir a la aviación, el cual se concentra en una capa muy reducida de la población mundial: solo el 1 % de la población es responsable de la mitad de las emisiones globales de la aviación (Gössling y Humpe, 2020).

Así, la Comisión Europea incluyó la aviación en el Mercado Europeo de Emisiones (*EU Emissions Trading System*, o ETS), obligando a las aerolíneas a comprar permisos por cada tonelada de $CO_2$ emitida. Este artículo tiene como objetivo analizar e identificar el efecto que esta política climática tiene sobre las emisiones de la aviación comercial en España, con especial atención a dos rasgos que caracterizan a este país: el peso de su industria turística y su extensa red de tren de alta velocidad (TAV), solo superada por China en kilómetros operativos de vía.

Para identificar el efecto causal del ETS explotamos un cambio de rumbo exógeno en la puesta en marcha de la política sucedido en 2013: en su versión inicial, el ETS debía de afectar a cualquier vuelo que aterrizara o despegara de cualquier aeropuerto europeo. Sin embargo, esto creó un gran malestar entre las aerolíneas no europeas, principalmente estadounidenses y chinas, que consideraban que la política vulneraba la soberanía de los países no europeos. Ante diversas presiones internacionales, la Comisión Europea acabó por limitar el ETS solo a los vuelos con salida y llegada a aeropuertos del Espacio Económico Europeo (EEE), dejando fuera los aterrizajes/despegues de fuera del EEE. La decisión fue formalizada en abril de 2013, justo antes de que las aerolíneas tuvieran que entregar los derechos de emisión correspondientes a su actividad de 2012. Este cambio de rumbo, por desafortunado que sea desde el punto de vista ambiental, nos permite a los investigadores disponer de un grupo control, comparativo, para poder analizar el efecto del tratamiento, aquí consistente en el ETS.

Para poder analizar el impacto del ETS en las emisiones de $CO_2$, hemos recogido datos para el periodo 2010-2016, incluyendo todas las rutas aéreas en Europa y países cercanos (norte de África y Oriente Medio). Nuestra estrategia empírica consiste así en un estimador de diferencias en diferencias (DD) donde el grupo tratado consiste en los vuelos con al menos un aeropuerto situado en España y que tengan como origen o destino aeropuertos del EEE. El grupo de tratamiento, por tanto, identifica los vuelos afectados por la regulación del mercado de emisiones. El grupo de control consiste en todas las demás rutas comparables (vuelos en los que un aeropuerto está en territorio español y el otro fuera del EEE). Por ejemplo, el Barcelona-París pertenece al grupo de tratamiento, mientras que el Barcelona-Zúrich es del grupo control (ambas rutas tienen la misma distancia y conectan Barcelona con ciudades europeas de renta alta)[1]. El grupo de control nos permite estimar el escenario contrafactual, lo que hubiera sucedido si la política no se hubiera implementado (después de comprobar que el Barcelona-París y el Barcelona-Zúrich comparten ciertas características en común y, sobre todo, que han seguido tendencias paralelas antes de la puesta en marcha del ETS).

Nuestros resultados muestran que, a pesar de un precio relativamente bajo durante el periodo analizado (7 euros de media por tonelada de $CO_2$), el ETS tiene efectos significativos en la mitigación del impacto climático causado por la aviación. En concreto vemos que las emisiones del sector en España se redujeron entre un 4 % y un 10 % de media entre 2013 y 2016 comparado con lo que hubiera sucedido de no existir el mercado de emisiones. Es de suponer que, con los precios más elevados que se observan desde el 2018, este efecto ha ido aumentando con el paso del tiempo. En segundo lugar, encontramos que el efecto es mayor si la ruta dispone de alternativa con TAV: gracias al ETS, estas rutas aéreas emiten un 13 % menos en la media comparado con el contrafactual. Esto invita a pensar que, en tanto que los costes están justificados, el TAV puede ser un buen complemento al ETS. Finalmente, el ETS es también más efectivo en reducir emisiones cuando nos centramos en las rutas turísticas: en este tipo de rutas, las emisiones son un 11 % menores de lo que hubieran sido sin la medida. Esto puede venir explicado por la mayor elasticidad, tanto de la oferta como de la demanda, de las rutas turísticas en comparación con rutas que conectan grandes ciudades.

Estos resultados contribuyen, de manera general, a establecer la efectividad ambiental de los mecanismos de precio del carbono y, en concreto, del mercado de emisiones europeo (EU ETS). Asimismo, estudios previos han demostrado efectos

[1] El archipiélago canario es considerado territorio remoto, por lo que los vuelos con origen o destino a cualquiera de sus aeropuertos no están sujetos al ETS y como tal pertenece al grupo control en este análisis. Los vuelos que tienen como origen y como destino aeropuertos canarios, sin embargo, sí están sujetos al ETS.

significativos del ETS europeo en la industria manufacturera alemana (Petrick y Wagner, 2014), francesa (Wagner *et al*., 2014) o Noruega (Klemetsen *et al*., 2016), con efectos de reducción de emisiones del 25 %, 13 % y 33 %, respectivamente. Nuestro análisis se centra en un sector diferente, el de la aviación, que además tiene la particularidad de que más que el efecto en empresas, capturamos el efecto en el conjunto de los mercados (pues medimos emisiones a nivel de ruta aérea, y cada ruta es un mercado).

En segundo lugar, estos resultados ayudan a estudiar la heterogeneidad que el ETS tiene a nivel de país: Fageda y Teixidó (2022) estudian el efecto del ETS en la aviación a nivel europeo y encuentran un efecto del 5 %, el cual viene sobre todo explicado por el mayor efecto en las rutas de menos de 1.000 kilómetros (–10 %) y de las aerolíneas de bajo coste (–11 %). El análisis para España ofrece un contexto ideal para estudiar el efecto del ETS cuando las rutas aéreas son turísticas o existe tren de alta velocidad. En este sentido, el mayor impacto relativo del ETS en España respecto a otros países europeos podría explicarse por la relevancia del mercado doméstico con varias rutas sujetas a competencia intermodal, y por el mayor peso relativo del turismo y las aerolíneas de bajo coste.

El artículo se estructura de la forma siguiente. En el segundo apartado, explicamos el funcionamiento del mercado europeo de emisiones y su aplicación en el mercado de la aviación. En el apartado tercero, detallamos los datos con los que contamos para hacer el análisis y la estrategia de identificación empírica. En el apartado cuarto, presentamos y discutimos los resultados del análisis econométrico. El último apartado se centra en las implicaciones de política que pueden derivarse del estudio.

## 2. El mercado de emisiones y la aviación

El mercado de emisiones europeo, iniciado en 2005, es aún hoy la política climática más ambiciosa a nivel internacional por el número de países y sectores implicados. Cubre hasta alrededor del 45 % de las emisiones de gases de efecto invernadero de la UE y abarca más de 11.000 unidades entre instalaciones y aerolíneas. El sistema consiste en la fijación de una cantidad máxima de emisiones que se va reduciendo con el tiempo y la distribución entre las empresas reguladas de la misma cantidad de permisos que pueden comerciar entre ellas. La posibilidad de comerciar con los permisos asegura que el instrumento sea coste-efectivo a la vez que determina un precio del carbono que incentiva de manera dinámica la reducción de emisiones, ya sea mediante la adopción de tecnologías más limpias o mediante el ajuste de la propia producción.

Así, a partir de la Directiva 2008/101/EC del Parlamento Europeo, desde enero de 2012, todas las aerolíneas aterrizando o despegando desde algún aeropuerto del EEE estarían sujetas al mercado de emisiones y, en consecuencia, obligadas a monitorear y reportar sus emisiones a la vez que a disponer de los permisos correspondientes al final de cada periodo. Sin embargo, esta decisión estuvo sujeta a intensas presiones internacionales de la propia industria que, entre otras concesiones, como el límite sectorial del sector o el número de permisos distribuidos de forma gratuita, consiguieron limitar el alcance a solo vuelos dentro del EEE (Transport and Environment, 2016).

Ya en 2009 (un año después de la directiva europea), varias aerolíneas estadounidenses presentaron una demanda contra la Directiva por considerarla contra el derecho internacional. A la presión desde los Estados Unidos se le sumaron aerolíneas de la misma UE, China, Rusia, India, entre muchas otras, conformando una coalición que denunciaría la normativa por violar el derecho internacional. Así, a pesar de que el Tribunal de Justicia de la UE dictaminó que la norma era totalmente respetuosa con la legalidad internacional, en abril de 2013, justo antes de que las aerolíneas tuvieran que entregar los permisos correspondientes al año 2012, un acuerdo entre el Consejo y el Parlamento Europeo redujo, de manera retroactiva, el alcance del mercado de emisiones a los vuelos con despegue y aterrizaje en aeropuertos del EEE, quedando fuera los demás. La decisión se justificó en el marco de la Asamblea de la Organización de Aviación Civil Internacional (ICAO, por sus siglas en inglés), donde existía (y existe aún) la propuesta del CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), consistente en un mecanismo de compensación de emisiones para la aviación internacional. Así, el mercado de emisiones se introdujo de manera efectiva a partir de enero 2013, momento a partir del cual las aerolíneas estarán obligadas a entregar permisos del ETS por sus emisiones provenientes de vuelos entre aeropuertos del EEE.

Este cambio inesperado de la política es importante para nuestra estrategia de identificación empírica: de haberse aprobado la introducción del ETS con el alcance previsto, no se dispondría de un grupo control contra el cual comparar el efecto de la política. Asimismo, con la ayuda de la econometría, las rutas aéreas afectadas por el ETS (entre aeropuertos EEE) serán comparadas con rutas aéreas control (con al menos un aeropuerto no EEE), que sean comparables en todas las características observables. En esta línea, adoptamos la estrategia empírica ejecutada en Fageda y Teixidó (2022).

## 3. Análisis empírico

### *3.1. Muestra y estrategia de identificación*

Para evaluar el efecto del mercado europeo de emisiones en las emisiones de la aviación, aplicamos la lógica de diferencias en diferencias (DD), una metodología común adoptada dentro del marco de la evaluación de políticas (Angrist y Pischke, 2008).

La estimación por DD exige contar con datos anteriores y posteriores a la aplicación de la política, y datos que incluyen un subconjunto de observaciones afectadas por la política (grupo de tratamiento) y un subconjunto de observaciones no afectadas por la política (grupo de control). La implementación del DD nos permite identificar la relación causal entre la variable de interés (en nuestro caso las emisiones) y la política (ETS) comparando los cambios en el grupo de tratamiento respecto a los cambios en el grupo de control tras la aplicación de la política. Es necesario comprobar que el grupo de control es un buen contrafactual del grupo de tratamiento. En tal caso, la evolución del grupo de control nos permite predecir qué le hubiera pasado al grupo de tratamiento de no aplicarse la política.

Contamos con datos trimestrales de 2010 a 2016 de todos los vuelos dentro de Europa –incluyendo a Turquía y Rusia– y países cercanos (norte de África y Oriente Medio) al nivel de aerolínea y ruta aérea. Dado que el ETS entra en la práctica en funcionamiento en 2013, tenemos datos para antes (2010-2012) y después (2013-2016) de aplicación de la política.

El análisis se centra en los efectos de la política a corto plazo, dado que únicamente consideramos los años inmediatamente anteriores y posteriores a la introducción de la política. En este sentido, podría haber efectos temporales no observables que pueden alterar las estrategias de adaptación de las aerolíneas a dicha política. La ventaja de centrarse en el corto plazo es que podemos esperar que tales efectos temporales no observables tengan un efecto limitado en un periodo de tiempo que abarca unos pocos años. En cualquier caso, esta es una posible limitación que debe tenerse en cuenta en la interpretación de los resultados de nuestro análisis.

Las rutas de tratamiento son vuelos entre países que forman parte del EEE (Unión Europea, Noruega, Islandia y Liechtenstein)[2]. En nuestro caso, restringimos el grupo de tratamiento a vuelos que conectan España con otros países del EEE dado que nuestro interés está en examinar el impacto del ETS en las emisiones de la aviación en España.

Las rutas tratadas (rutas entre España y EEE) son rutas de corta o media distancia. Para tener rutas tratadas y de control comparables en términos de distancia, centramos el análisis en rutas que conectan aeropuertos de Europa, norte de África y Oriente Medio. Es decir, excluimos del análisis rutas de larga distancia como podrían ser, por ejemplo, vuelos entre Europa y Estados Unidos[3]. Por tanto, las rutas de control incluyen vuelos entre España y países cercanos fuera del EEE.

La muestra cuenta con más de 125.000 observaciones. La base de datos tiene la estructura típica de datos de panel en la medida que se cuenta con información de rutas aéreas repetidas en el tiempo. Se trata de un panel no balanceado, ya que algunos pares ruta/aerolínea no tienen vuelos o tienen menos de un vuelo por semana en al menos un trimestre del periodo considerado[4].

---

[2] Los países europeos que no forman parte del EEE incluye a Albania, Armenia, Azerbaiyán, Bielorrusia, Bosnia y Herzegovina, Georgia, Macedonia, Montenegro, Moldavia, Rusia, Serbia, Suiza, Turquía y Ucrania. Por otro lado, el Reino Unido es parte de la Unión Europea en el periodo considerado y Croacia lo es desde julio de 2013 (entra en el ETS en el 2014).

[3] Las rutas de larga distancia utilizan aviones más grandes y (con muy pocas excepciones) operan con muchos menos vuelos que las rutas de corta y media distancia.

[4] Para minimizar las distorsiones de los vuelos que no se ofrecen en la mayoría de los trimestres del periodo considerado, restringimos nuestra muestra a pares rutas/aerolíneas con al menos un vuelo por semana.

En este contexto, nuestro estimador del DD es una variable binaria que toma el valor 1 para rutas que conectan España con países del EEE para el periodo 2013-2016. El estimador del DD nos permite identificar los cambios en emisiones desde 2013 en rutas que conectan España con el EEE respecto a los cambios en rutas entre países de la muestra en los que al menos uno de ellos no está en el EEE. Por ejemplo, podemos ver los cambios en vuelos de Barcelona a París (afectados por el ETS desde 2013) con vuelos de Barcelona a Zúrich (no afectados por el ETS).

Nuestra hipótesis es que el ETS puede conllevar una reducción de emisiones vía reducción de la oferta de vuelos, ya sea en términos de asientos o de frecuencias. El ETS impone un coste a las aerolíneas en términos de la compra de derechos de emisiones (o en términos del coste de oportunidad de no venderlos). Dado que las aerolíneas operan en un contexto de competencia imperfecta, un aumento de costes debería implicar una reducción de la oferta. Por otro lado, este aumento de costes puede trasladarse, total o parcialmente, al consumidor vía aumento de precios. Y el aumento de precios implicará una reducción de la demanda.

El traslado de costes a precios dependerá del tipo de competencia que prevalece en el mercado y de la elasticidad de la demanda. La literatura generalmente asume que el traslado de aumento de costes a precios por parte de las aerolíneas será elevado, dado que el sector aéreo es un mercado competitivo en el que los márgenes de beneficios en muchas rutas son modestos, o incluso negativos en periodos de baja demanda (Vivid Economics, 2007; Koopmans y Lieshout, 2016; Zimmerman y Carlson, 2010).

En cualquier caso, sea cual sea el traslado de costes a precios, el efecto esperado es una reducción de la oferta y emisiones. Es decir, las aerolíneas reducirán oferta porque asumen más costes o reducirán oferta porque el mayor precio conlleva menos demanda. El porcentaje del coste que se traslada al precio determinará los efectos distributivos de la medida entre aerolíneas y consumidores, pero no afecta a nuestra hipótesis de que el ETS debería reducir la oferta y las emisiones.

Cabe señalar aquí que esperamos que el efecto de reducción de emisiones venga principalmente vía reducción de la oferta. Otra vía por la que el ETS también podría afectar a la reducción de emisiones es mediante la creación de incentivos para el cambio tecnológico en la línea de utilizar aviones menos contaminantes. Las nuevas generaciones de aviones son más eficientes en el consumo de combustible y, por tanto, más limpios. Sin embargo, dicho cambio tecnológico esperamos que pueda ser relevante en un análisis a largo plazo, dado que en el corto la flota de aviones, para la gran mayoría de aerolíneas, no cambia de forma relevante. Como comentábamos anteriormente, nuestra estimación del impacto del ETS se centra en los efectos a corto plazo. Por otro lado, más allá del cambio a aviones más eficientes, las posibilidades de una auténtica revolución tecnológica en el sector son limitadas. Por ejemplo, la tecnología basada en aviones propulsados por hidrógeno está lejos de ser viable tanto desde el punto de vista técnico (poca autonomía en términos de horas de vuelo) como económico (coste elevadísimo respecto a aviones propulsados por queroseno).

### *3.2. Modelo y variables*

La ejecución del modelo de DD se lleva a cabo mediante la estimación econométrica de la siguiente Ecuación [1] para el par ruta/aerolínea *i* en el trimestre *q* y año *t*[5]:

$$\log(emisiones)_{iqt} = \alpha + \beta ETS_{it} + \lambda X_{it} + \gamma_i + \eta_t + \nu_q + \varepsilon_{iqt} \quad [1]$$

En donde la principal variable dependiente es el logaritmo natural de las emisiones de $CO_2$ de la aerolínea *i* en el trimestre *q* del año *t*. Los datos de emisiones han sido calculados a partir de la información de oferta con la que contamos. Disponemos de datos a nivel de ruta y aerolínea que incluyen el número total de asientos, las frecuencias, el tamaño y tipo de avión, y la distancia de la ruta. Los datos han sido obtenidos de RDC Aviación. Para estimar las emisiones a nivel de ruta aérea, utilizamos la herramienta de pequeños emisores (SET) de Eurocontrol, diseñada para ayudar a los operadores de aeronaves en sus obligaciones de seguimiento y notificación para el ETS. El SET se basa en muestras de consumo de combustible de operaciones de vuelos reales y proporciona estimaciones precisas de las emisiones para cualquier distancia y tipo de aeronave. Con el tipo de aeronave, la distancia de la ruta y la cantidad de vuelos, podemos estimar las emisiones a nivel de ruta de la aerolínea por trimestre.

La principal variable explicativa es el ETS, que es una variable ficticia que toma el valor 1 para el par ruta/aerolínea que se ve afectado por el ETS en el periodo *t*. En nuestro caso, la variable ETS toma el valor 1 en rutas que conectan España con países del EEE desde 2013. Y toma el valor 0 cuando el origen o destino de la ruta es un país que no forma parte del EEE.

$X_{it}$ denota el conjunto de variables de control. Dado que las emisiones están determinadas principalmente por las decisiones de oferta de las aerolíneas, nuestras estimaciones se basan en una ecuación de oferta. En los estudios de aviación, comúnmente se asume que las aerolíneas primero toman decisiones de oferta y luego ajustan precios según la evolución de la demanda. Por tanto, los precios no se incluyen habitualmente como variable explicativa en las ecuaciones de oferta.

Dada la fuerte correlación entre la demanda y la oferta, variables que afectan a la demanda (población, renta) suelen incluirse como controles. La distancia (que en nuestro contexto se captura mediante los efectos fijos de la ruta y la línea aérea) y la intensidad de la competencia también suelen considerarse como determinantes relevantes de la oferta de las aerolíneas. Teniendo esto en cuenta, incluimos como variables de control la población y el PIB per cápita.

Así, consideramos la población de las áreas urbanas en los puntos de origen y destino de las rutas. Para áreas urbanas con más de 300.000 habitantes, los datos se han obtenido de la base de datos World Urbanization Prospects de la ONU. Para

[5] Todas las variables continuas se transforman mediante logaritmos, de modo que se reduce la influencia de los valores atípicos y las estimaciones de los parámetros se pueden interpretar como elasticidades.

áreas urbanas con menos de 300.000 habitantes en el EEE, Suiza y Turquía, hemos recopilado datos de Eurostat (NUTS 3). Para las áreas urbanas del resto de países con menos de 300.000 habitantes, hemos recopilado datos de las agencias nacionales de estadística.

También consideramos el PIB per cápita en el origen y destino de la ruta. Los datos de esta variable no están tan desagregados como los datos de población, pues fuera de la Unión Europea solo están disponibles a nivel de país. Los datos a nivel de país se han obtenido de la base de datos de Indicadores de Desarrollo del Banco Mundial.

La otra variable de control es el índice de Herfindahl-Hirschman, que informa sobre la concentración del mercado. Consiste en la suma de los cuadrados de las cuotas de mercado de cada aerolínea a nivel de ruta, de modo que un valor elevado implica alta concentración. Las cuotas se calculan a partir de los datos de oferta (vuelos) que proporciona RDC Aviación. Utilizamos esta variable como *proxy* de poder de mercado.

Los datos utilizados presentan una estructura de panel, por lo que empleamos las técnicas típicamente aplicadas en el marco de los modelos de datos de panel. Por lo tanto, la especificación incluye efectos fijos de ruta/aerolínea, así como efectos fijos de año y trimestre. Una clara ventaja del modelo de efectos fijos de ruta/aerolínea es que nos permite controlar por variables omitidas que están correlacionadas con las variables de interés y que no cambian con el tiempo (Verbeek, 2000).

El modelo de efectos fijos ruta/aerolínea explota la llamada variabilidad *within*; cambios en el valor de las observaciones respecto a su media. Es, por tanto, el modelo de datos de panel más adecuado para evaluar políticas, dado que pone la atención en el efecto de cambios de las variables, y no tanto en el efecto medio estimado. Además, nos permite controlar por variables constantes en el tiempo –observables y no observables– como la distancia recorrida, los vínculos históricos entre países y la heterogeneidad de costes y estrategias de negocios de las aerolíneas. Además, añadimos variables binarias de año para controlar por *shocks* temporales que pueden ser comunes a todos los pares ruta/aerolínea (por ejemplo, la crisis financiera global con efectos especialmente al inicio del periodo considerado) y variables binarias de trimestre para controlar los efectos estacionales (por ejemplo, hay más tráfico en verano que en invierno). Además, en atención al reciente trabajo de Sant'Anna y Zhao (2020), donde alertan de potenciales sesgos en el estimador de efectos fijos cuando se utilizan variables control con variación temporal, como es nuestro caso, complementamos nuestras estimaciones con el estimador de DD doblemente robusto (DRDD, por sus siglas en inglés). Finalmente, los errores estándar de la estimación son robustos a la heterocedasticidad y se aplican *clusters* a nivel de ruta para tener en cuenta la posible correlación entre observaciones de una misma ruta y por estar el tratamiento definido a nivel de ruta.

Dos aspectos que son imprescindibles a tener en cuenta en nuestro análisis son la comparabilidad entre el grupo de tratamiento y de control, y que se cumpla el supuesto de tendencias paralelas. Podría ser que diferencias prepolítica entre el grupo de control y de tratamiento condicionen el resultado esperado de la política. Por ejemplo, el grupo de control incluye a países de menor renta que España como Turquía, Rusia o Marruecos, o países de mayor renta como Suiza. Para abordar esta cuestión utilizamos el método de balanceo entrópico (Hainmueller, 2012) que permite contar con un grupo de control y de tratamiento similar en términos de las características observables.

El Cuadro 1 muestra la estadística descriptiva referente al grupo tratado y grupo control, antes y después de ponderar el grupo control con el método del balanceo entrópico. La Figura 1 muestra cómo las diferencias entre tratados y controles se han reducido significativamente, siendo estas menores al 10 % del sesgo estandarizado comúnmente usado como referencia. Es particularmente relevante, dadas las grandes diferencias en la muestra sin ponderar, que la aplicación del método del balanceo entrópico permita contar con una muestra de rutas de tratamiento y de control comparables en términos de PIB per cápita.

Por otro lado, para comprobar que se cumple el supuesto de tendencias paralelas, interaccionamos nuestra variable de tratamiento (una variable binaria que toma el valor 1 para rutas que conectan España con países del EEE) con cada uno de los años

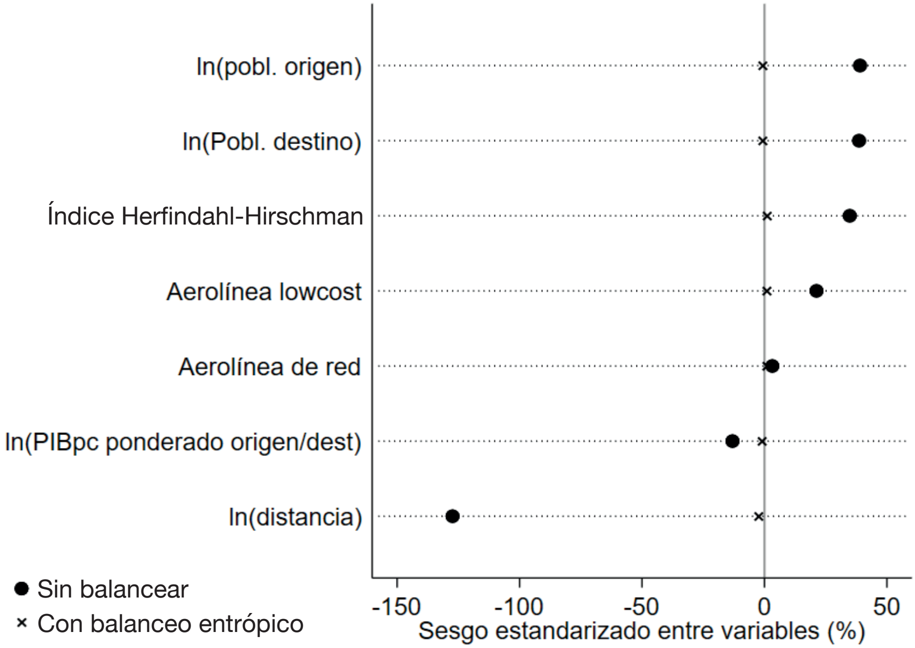
**CUADRO 1**

**ESTADÍSTICAS DESCRIPTIVAS ENTRE GRUPO TRATADO Y GRUPO CONTROL ANTES DE 2013**

| Sin balancear | | | | |
|---|---|---|---|---|
| | Grupo tratado | | Grupo control | |
| | Media | Desviación estándar | Media | Desviación estándar |
| ln(PIBpc Pond. Origen/Destino) | 10,45 | 0,15 | 10,47 | 0,31 |
| ln(Pobl. Pond. Origen/Destino) | 14,55 | 0,90 | 14,20 | 1,01 |
| Índice Herfindahl-Hirschman | 0,72 | 0,28 | 0,65 | 0,28 |
| ln(Pobl. Origen) | 14,02 | 1,16 | 13,61 | 1,26 |
| ln(Pobl. Destino) | 14,02 | 1,16 | 13,61 | 1,26 |
| **Con balanceo entrópico** | | | | |
| | Grupo tratado | | Grupo control | |
| | Media | Desviación estándar | Media | Desviación estándar |
| ln(PIBpc Pond. Origen/Destino) | 10,45 | 0,14 | 10,45 | 0,14 |
| ln(Pobl. Pond. Origen/Destino) | 14,67 | 0,87 | 14,95 | 0,74 |
| Índice Herfindahl-Hirschman | 0,70 | 0,28 | 0,70 | 0,29 |
| ln(Pobl. Origen) | 14,15 | 1,14 | 14,16 | 1,16 |
| ln(Pobl. Destino) | 14,14 | 1,14 | 14,15 | 1,16 |

**FUENTE:** Elaboración propia.

**FIGURA 1**
**SESGO ESTANDARIZADO ENTRE TRATADOS Y CONTROLES DE MUESTRAS SIN Y CON BALANCEO ENTRÓPICO**




**FUENTE:** Elaboración propia.

del periodo considerado. Ello nos permite examinar si, antes de la aplicación de la política, los grupos de control y tratamiento siguieron una evolución parecida, y nos permite también evaluar el impacto de la política a lo largo del tiempo. En este sentido, solo podremos afirmar que encontramos un efecto causal, y no una correlación en la relación entre las emisiones y la política, si se cumple el supuesto de tendencias paralelas.

Finalmente, como mencionábamos anteriormente, hay dos submercados de la aviación en España que es de interés tener en cuenta. En primer lugar, un hecho diferencial del caso español respecto a muchos otros países europeos es el gran peso que tiene el turismo en el mercado aéreo. Así, por ejemplo, en torno a un 25 %-30 % del mercado incluye rutas que tienen como origen y/o destino a islas, submercado que se caracteriza por una fuerte predominancia del tráfico turístico operado por aerolíneas de bajo coste y vuelos chárter.

Podemos esperar un mayor impacto del ETS en rutas que incluyen a grandes destinos turísticos, dado que tanto la elasticidad de la oferta de las aerolíneas a costes como la demanda de pasajeros a precios pueden ser más altas que en otros submercados, como por ejemplo el tráfico canalizado en Madrid por aerolíneas de red.

Para examinar si realmente es el caso, realizamos una estimación que utiliza una submuestra de rutas con aeropuertos de importantes destinos turísticos. Así pues, generamos una variable que identifica a tales destinos turísticos, considerando únicamente aquellos aeropuertos con más de un millón de pasajeros al año. Se incluyen aquí: islas en España (Gran Canaria, Tenerife, Lanzarote, Fuerteventura, Palma de Mallorca, Ibiza, Menorca), Italia (Catania, Palermo, Cagliari, Olbia/Costa Esmeralda, Alguero), Francia (Ajaccio), Grecia (Heraklion, Rodas, Corfú, Zákinthos, Creta, Mikonos, Santorini) y Portugal (Madeira, Ponta Delgada). Además, se incluyen Málaga, Alicante, Faro, Bari, Reus, Niza y grandes destinos turísticos del norte de África y Turquía (Bodrum, Kayseri, Marrakech, Monastir, Enfidha-Hammamet, Djerba, Sharm el-Sheikh, Hurghada, Marsa Alam y Luxor). Cabe señalar aquí que grandes ciudades europeas como Londres, París, Roma, Ámsterdam o Barcelona reciben muchos turistas al año, pero también reciben (o generan) mucho tráfico aéreo que está relacionado con viajes de negocios u otros motivos. El sentido de esta variable, sin embargo, es centrarse en rutas aéreas que sabemos que cuentan con una elevada proporción de viajeros por turismo.

Por otro lado, la aviación en varias rutas del mercado aéreo español está afectada por la fuerte competencia del tren de alta velocidad. En particular, las rutas que unen Madrid con Alicante, Barcelona, Málaga, Sevilla, Valencia y Zaragoza, y la ruta Barcelona-París. En estas rutas, el impacto del ETS puede ser también elevado, dado que tanto la oferta como la demanda pueden ser muy elásticas.

## 4. Resultados

El Cuadro 2 recoge el coeficiente del estimador de diferencias en diferencias para distintas especificaciones y modelos. Mostramos los resultados de regresiones que incluyen como variable dependiente las emisiones de $CO_2$ y la oferta total de vuelos. Esto nos permitirá confirmar si el impacto del ETS sobre las emisiones viene explicado principalmente por la reducción de la oferta de vuelos.

La columna (1) recoge el efecto del ETS usando el grupo control sin ponderar. Según este, el ETS reduce las emisiones en casi un 9% y el coeficiente es estadísticamente diferente a cero. Sin embargo, este resultado podría estar distorsionado por sesgos relevantes al no considerarse aquí las diferencias entre el grupo tratado y de control: las rutas aéreas entre estos dos grupos no son comparables en características observables y no observables, por lo que el efecto del ETS se confunde con otros factores distintos a la política climática. Así, si incluimos las variables de control mencionadas anteriormente en la especificación, el efecto del ETS se reduce a un 4% y es estadísticamente significativo. Sin embargo, esto implica asumir que las variables que cambian en el tiempo siguen también tendencias paralelas (Sant'Anna y Zhao, 2020). Para relajar este supuesto, la columna (3) estima de nuevo el modelo sin variables de control y en su lugar pondera las rutas del grupo de control según esas mismas variables observables mediante el método de balance entrópico mencionado previamente

(Hainmueller, 2012). El balance entrópico asegura que la media y la varianza de las variables explicativas para el grupo de control sean idénticas a las del grupo tratado (ver Cuadro 1). Con esto, de nuevo, el efecto se mantiene cercano y vemos que la reducción de emisiones es de 4,5 % (y es estadísticamente significativo) en comparación a lo que hubiera sucedido sin la política. Finalmente, la columna (4) evita el uso del estimador de efectos fijos, y en su lugar se usa el estimador doblemente robusto de diferencias en diferencias (DRDD), que permite controlar por errores de especificación en las variables de control dos veces, mediante un procedimiento de *matching* y de regresión (Sant'Anna y Zhao, 2020): según este, el ETS reduce las emisiones en un 10 %.

En resumen, podemos decir a la luz de estos resultados que el mercado de emisiones ha tenido un impacto estadísticamente significativo en la reducción de emisiones, de entre el 4 % y el 10 %. Este impacto es superior al encontrado por Fageda y Teixidó (2022) utilizando una metodología similar para el conjunto de países del EEE. Por otro lado, el impacto es muy similar en todas las regresiones cuando consideramos el número de vuelos en vez del total de emisiones como variable dependiente. De ahí, como podría esperarse al menos en un análisis de corto plazo, el impacto del ETS viene explicado por la reducción de la oferta.

**CUADRO 2**

**EFECTO DEL EU ETS EN LAS EMISIONES DE LA AVIACIÓN EN ESPAÑA**

| | **(1)** | **(2)** | **(3)** | **(4)** |
|---|---|---|---|---|
| **Panel A: ln(emisiones)** | | | | |
| Mercado de emisiones ETS | –0,087***<br>(0,015) | –0,040***<br>(0,015) | –0,045*<br>(0,025) | –0,104***<br>(0,028) |
| Observaciones | 125,235 | 125,168 | 72,965 | 88,609 |
| **Panel B: ln(vuelos)** | | | | |
| Mercado de emisiones ETS | –0,096***<br>(0,015) | –0,042***<br>(0,015) | –0,051**<br>(0,023) | –0,139***<br>(0,020) |
| Observaciones | 125,243 | 125,168 | 72,965 | 88,609 |
| Estimador | TWFE | TWFE | TWFE | DRDD |
| Control vars. | NO | SÍ | Entropía B. | SÍ |
| Aerol.-ruta FE | SÍ | SÍ | SÍ | SÍ |
| Año FE | SÍ | SÍ | SÍ | SÍ |
| Trimestre FE | SÍ | SÍ | SÍ | SÍ |

NOTAS: Este cuadro recoge el coeficiente del estimador de diferencias en diferencias para distintas especificaciones y modelos. La columna (1) recoge el efecto del ETS usando el grupo control sin ponderar. La columna (2) incluye variables control en la especificación. La columna (3) estima de nuevo el modelo sin variables control, y en su lugar pondera las rutas del grupo control según esas mismas variables observables mediante el método de balance entrópico (Hainmueller, 2012). La columna (4) usa el estimador doblemente robusto DRDD de diferencias en diferencias (Sant'Anna y Zhao, 2020). Errores estándar robustos entre paréntesis.

*** $p<0,01$; ** $p<0,05$; * $p<0,1$.

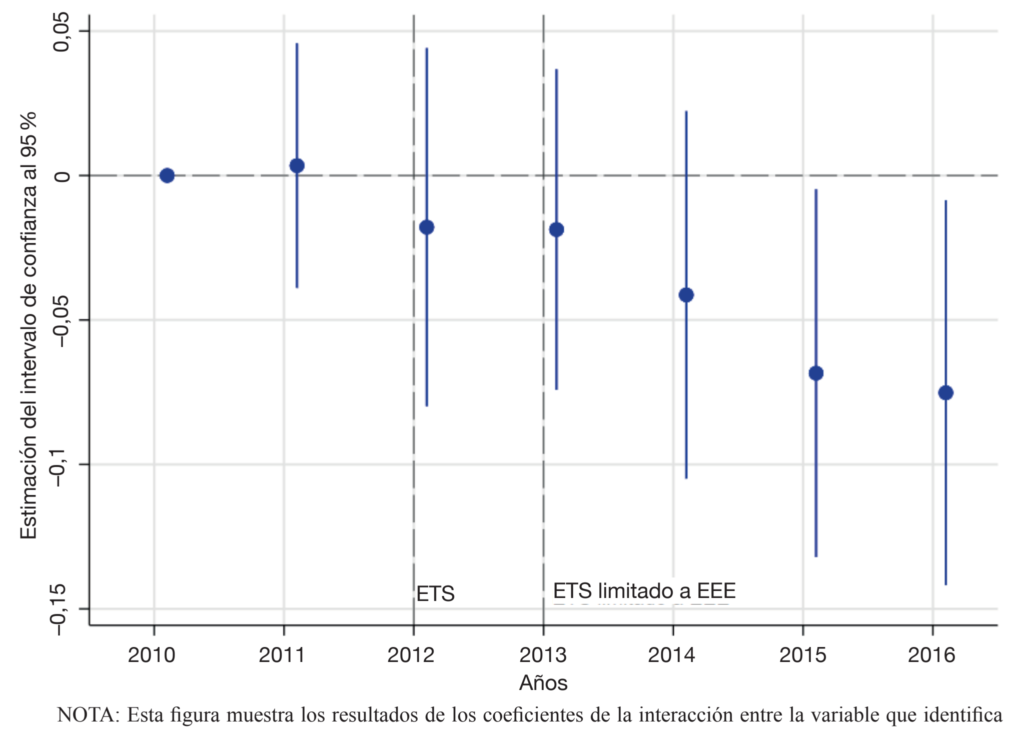
**FUENTE:** Elaboración propia.

Sin embargo, la identificación del efecto causal depende de que se cumpla la hipótesis de tendencias paralelas. Es decir, no debería haber diferencias significativas en las tendencias en emisiones seguidas por los grupos de control y tratamiento antes de la aplicación de la política. Cabe tener en cuenta aquí que el año 2012 es un año de incertidumbre regulatoria, dado que no estaba claro qué rutas estarían finalmente afectadas por el ETS. Así pues, el año 2013 es el momento en el que se aclara que solo las rutas entre aeropuertos del EEE estarían realmente afectadas por la política, pero eso no excluye la posibilidad de que esta ya produjera algunos efectos en el año 2012.

La Figura 2 muestra que el supuesto de tendencias paralelas es factible en tanto que no hay diferencias estadísticamente significativas entre el grupo de control y tratamiento antes de la aplicación de la política, aunque un cierto impacto (no significativo) se observa ya en el 2012. Por otro lado, el impacto de la política es gradual, ya que sus efectos en términos de reducción de emisiones van creciendo en los años posteriores a la introducción de la política.

**FIGURA 2**

**DIFERENCIAS EN DIFERENCIAS DEL ETS SOBRE LAS EMISIONES COMO ESTUDIO DE EVENTOS**




NOTA: Esta figura muestra los resultados de los coeficientes de la interacción entre la variable que identifica vuelos entre países del EEE y cada uno de los años considerados. El año de referencia es el 2010 y los intervalos de confianza son al 95 %. Ver Borusyak y Jaravel (2020) para más detalles sobre esta técnica de estimación.

**FUENTE:** Elaboración propia.

El mayor impacto del mercado de emisiones en España respecto al conjunto de países del EEE podría explicarse por dos motivos. En primer lugar, el mercado doméstico tiene mayor peso en España que en otros países europeos (España tiene, de hecho, el mayor mercado doméstico europeo de aviación). Asimismo, varias rutas domésticas están afectadas por la competencia de otros modos de transporte en la medida que cubren distancias menores a los 600 kilómetros. Además, la competencia que pueda ejercer el tren de alta velocidad o el transporte por carretera es más importante en España que en otros países europeos (con la excepción de Francia).

En segundo lugar, España cuenta con varios destinos turísticos conocidos a nivel internacional, de manera que una parte substancial del tráfico aéreo en aeropuertos españoles se relaciona con el turismo. De hecho, solo Estados Unidos y Francia reciben más turistas al año en todo el mundo. Aproximadamente el 70 % de los turistas internacionales llegan a España por avión. Cabe señalar aquí que, dado el número de rutas implicadas, podemos esperar que tenga mayor relevancia el peso del tráfico turístico que la competencia ejercida por el tren de alta velocidad a la hora de explicar el mayor impacto del ETS en España que en el conjunto de países europeos.

Como comentábamos anteriormente, el mercado de emisiones implica un coste adicional para las aerolíneas que, en mayor o menor medida, trasladan al consumidor en forma de aumento de precios. Puede esperarse que el impacto de dicho aumento de costes y/o precios sobre la oferta y las emisiones sea mayor en rutas afectadas por la competencia intermodal y en rutas con elevada proporción de viajeros por turismo. En ambos casos, las elasticidades de la oferta a costes y de la demanda a precios pueden ser particularmente elevadas.

El Cuadro 3 y la Figura 3 muestran el efecto del ETS tanto en emisiones como en vuelos añadiendo la interacción entre la variable de ETS y una variable binaria que toma el valor 1 en rutas afectadas por la competencia del tren de alta velocidad. Los resultados de esta estimación adicional aportan evidencia clara de que el impacto de la política es mayor en aquellas rutas afectadas por la competencia del tren de alta velocidad. Es de esperar que la elasticidad de la demanda sea mayor en rutas afectadas por la competencia intermodal (en particular por la competencia intensa que ejerce el tren de alta velocidad) que en rutas donde las aerolíneas monopolizan el tráfico (Brons *et al.*, 2002). Por otro lado, el impacto es más relevante en términos de menor oferta de vuelos que en términos de menos emisiones. Por tanto, parece que en estas rutas las aerolíneas reaccionan reduciendo frecuencias, pero utilizando aviones más grandes que pueden ser más eficientes en términos de consumo de combustible por kilómetro.

El Cuadro 4 muestra el efecto del ETS utilizando la submuestra que solo considera rutas con aeropuertos de grandes destinos turísticos. El impacto es mayor del 11 %, tanto en términos de emisiones como de vuelos. El supuesto de tendencias paralelas (Figura 4) no muestra diferencias estadísticamente significativas entre el grupo de control y tratamiento antes de la implementación de la política.

Por tanto, encontramos evidencia clara de que el impacto del ETS es mayor en rutas aéreas con gran proporción de viajeros por turismo. Dado el gran peso del

**CUADRO 3**

**EFECTO DEL ETS EN LAS EMISIONES DE LA AVIACIÓN DE ESPAÑA CON INTERACCIÓN CON EL TREN DE ALTA VELOCIDAD**

| | **(1)** |
|---|---|
| **Panel A: ln(emisiones)** | |
| ETS | –0,043*<br>(0,025) |
| ETS x TAV | –0,132*<br>(0,069) |
| Observaciones | 72,965 |
| **Panel B: ln(vuelos)** | |
| Mercado de emisiones ETS | –0,047**<br>(0,023) |
| ETS × TAV | –0,212***<br>(0,043) |
| Observaciones | 72,965 |
| Estimador | TWFE |
| Control vars. | Entropía B. |
| Aerol.-ruta FE | SÍ |
| Año FE | SÍ |
| Trimestre FE | SÍ |

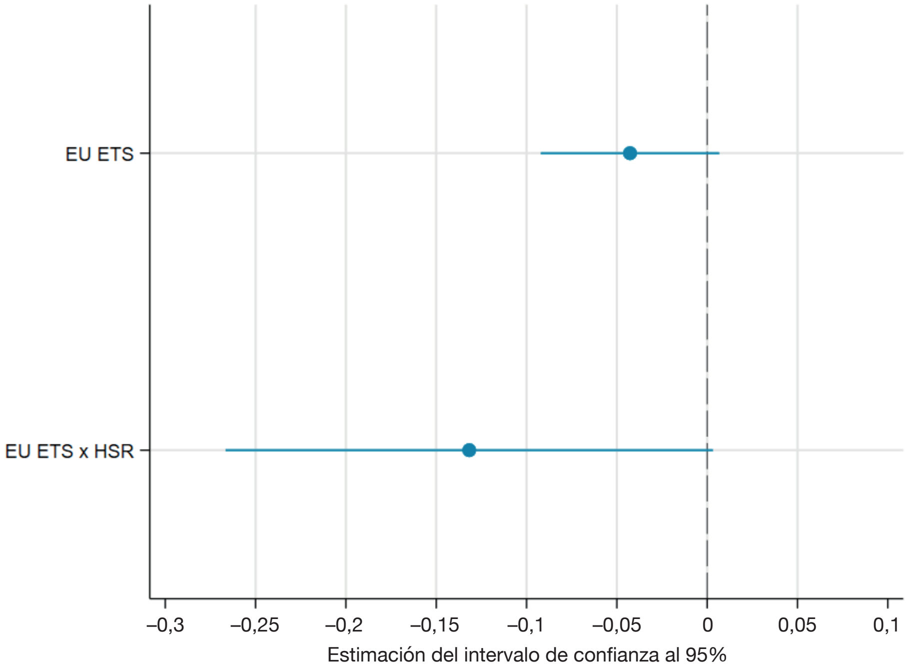
NOTA: Errores estándar robustos a heterocedasticidad. *** p<0,01; ** p<0,05; * p<0,1.
**FUENTE:** Elaboración propia.

turismo en el mercado de la aviación en España, esto explicaría que tal impacto sea mayor aquí que para el conjunto de países del EEE.

Como en la estimación anterior, una elevada elasticidad de la demanda implicará un mayor efecto del ETS. Asimismo, podemos esperar que la elasticidad de la demanda al precio sea mayor para viajeros por turismo que para viajeros por otros motivos como trabajo o visitas a familiares y amigos que tienen mayor peso en, por ejemplo, rutas entre grandes ciudades (Brons *et al.*, 2002). Por otro lado, la elasticidad de la oferta a mayores costes también puede ser elevada en este caso.

Las aerolíneas de red como Iberia operan desde aeropuertos *hub,* desde donde articulan complejas redes de rutas basadas en el tráfico de conexión (las llamadas redes *hub-and-spoke*). Este tipo de aerolíneas están muy ligadas a sus aeropuertos *hub* y a su país de origen, de manera que difícilmente trasladarán su negocio a otros aeropuertos y países a no ser que el aumento de costes sea realmente muy elevado. En cambio, las aerolíneas de bajo coste y, más aún, las aerolíneas de vuelos chárter

**FIGURA 3**
**EFECTO EN EMISIONES DE LA INTERACCIÓN ETS Y TREN DE ALTA VELOCIDAD**




**FUENTE:** Elaboración propia.

no tienen un vínculo tan estrecho con ningún aeropuerto o país (a no ser que sean subsidiarias de las aerolíneas de red como es el caso de Vueling).

Teniendo esto en cuenta, casi todo el tráfico turístico es canalizado por aerolíneas de bajo coste o aerolíneas chárter y estas pueden fácilmente trasladar sus aviones y empleados a otros aeropuertos o países en respuesta a un aumento de costes. De hecho, un efecto colateral del ETS podría ser el desplazamiento del tráfico de este tipo de aerolíneas a otros mercados turísticos (Turquía, Marruecos, Egipto, Túnez, etc.) que compiten directamente con el mercado europeo. Esto conllevaría el llamado fenómeno del *carbon leakage*, que implica que la reducción de emisiones en la zona regulada es en realidad un aumento de emisiones en las zonas no reguladas, poniendo en cuestión el objetivo de reducción global de las emisiones de $CO_2$. Por este motivo, las políticas climáticas son más efectivas en la lucha contra el cambio climático en la medida que la regulación ambiental se extiende a más países, en nuestro caso más allá del mercado europeo. Aun así, Fageda y Teixidó (2022) no encuentran evidencia a nivel europeo de *carbon leakage* en el sector.

**CUADRO 4**

**EFECTO DEL ETS EN LAS EMISIONES DE LA AVIACIÓN DE ESPAÑA EN RUTAS TURÍSTICAS**

| | **(1)** |
|---|---|
| **Panel A: ln(emisiones)** | |
| ETS | –0,116***<br>(0,020) |
| Observaciones | 41,312 |
| **Panel B: ln(vuelos)** | |
| ETS | –0,111***<br>(0,020) |
| Observaciones | 41,312 |
| Estimador | TWFE |
| Control vars. | Entropía B. |
| Aerol.-ruta FE | SÍ |
| Año FE | SÍ |
| Trimestre FE | SÍ |

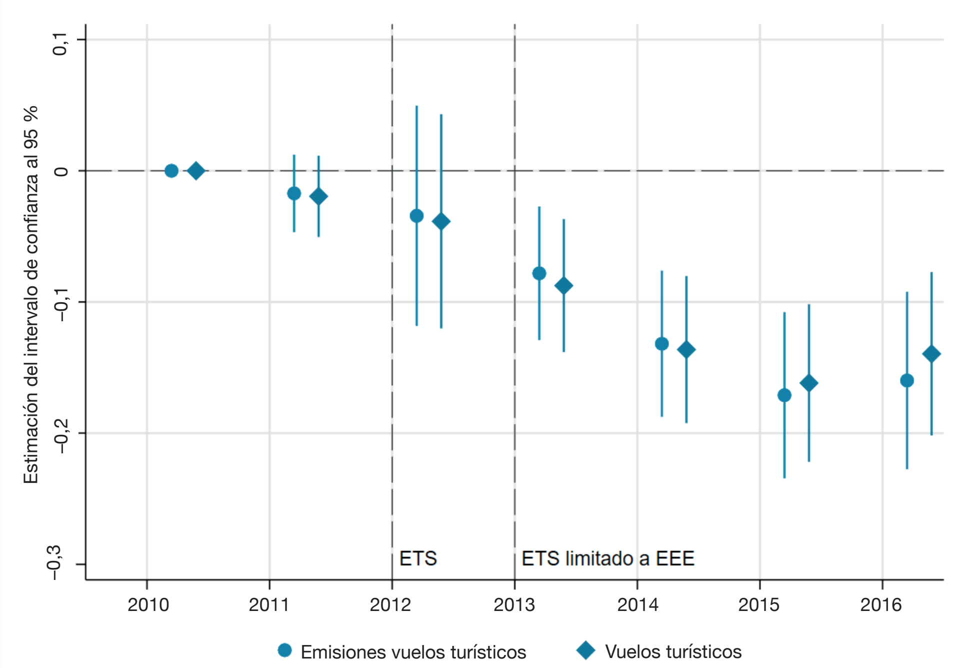
NOTA: Errores estándar entre paréntesis.
*** $p<0,01$; ** $p<0,05$; * $p<0,1$.
**FUENTE:** Elaboración propia.

## 5. Conclusiones

En este estudio, hemos examinado el impacto del mercado europeo de emisiones sobre la oferta y las emisiones de las aerolíneas que operan en aeropuertos españoles. Encontramos evidencia robusta de un fuerte impacto de esta política en España, de mayor magnitud del encontrado previamente para el conjunto de países del Espacio Económico Europeo. El mayor impacto relativo en el mercado español podría explicarse por la mayor influencia de la competencia intermodal, particularmente del tren de alta velocidad, pero sobre todo por el gran peso que el turismo tiene en la aviación y la economía españolas en comparación al resto de Europa.

Las rutas turísticas son principalmente operadas por aerolíneas de bajo coste y aerolíneas chárter que pueden fácilmente desplazar su actividad a otros aeropuertos y países en caso de un aumento de costes como el que conlleva el ETS. En este sentido, los márgenes de beneficios que obtienen estas aerolíneas en muchas rutas son estrechos y de hecho suelen ser negativos en la temporada de invierno. Es habitual que las aerolíneas trabajen con factores de ocupación y precios que les permitan, por

**FIGURA 4**
**EFECTO DEL ETS EN LAS EMISIONES DE LOS VUELOS TURÍSTICOS**




NOTA: Esta figura muestra los resultados de los coeficientes de la interacción entre la variable que identifica vuelos entre países del EEE y cada uno de los años considerados. El año de referencia es el 2010 y los intervalos de confianza son al 95 %. Ver Borusyak y Jaravel (2020) para más detalles sobre esta técnica de estimación.
**FUENTE:** Elaboración propia.

lo menos, no tener pérdidas. Es decir, su operativa está ya muy ajustada en términos de ingresos y costes. Por tanto, no es de extrañar que puedan reaccionar de forma significativa a aumentos de costes incluso si tales aumentos son modestos, como es el caso del aumento de costes, que implica el ETS en el periodo considerado. Por otro lado, la demanda basada en el turismo es elástica, así que aumentos de precios conllevan significativas reducciones de demanda, con la consiguiente reacción de las aerolíneas en forma de menos oferta y, con ello, menos emisiones. Por todo ello, no puede descartarse que el tráfico turístico podría estar particularmente afectado por la problemática asociada al *carbon leakage,* que implica un desplazamiento del lugar donde se originan las emisiones, pero no de una reducción global de emisiones.

El hecho de que el impacto del ETS sea elevado en rutas afectadas por la competencia intermodal aporta evidencia de que la inversión en modos de transporte más «limpios» que el avión, singularmente el tren, puede ser una estrategia complementaria para lidiar con el cambio climático. Sin embargo, es necesario hacer dos apuntes aquí que ponen en cuestión la relevancia práctica de esta estrategia. El transporte aéreo es el modo de transporte con mayores emisiones de $CO_2$ por pasajero-kilómetro, más aún que las emisiones de los coches (European Commission, 2019). El servicio de tren, y particularmente el tren de alta velocidad, contamina muy poco, pero el impacto ambiental de la construcción de las vías férreas puede ser considerable. Y el coste económico del tren de alta velocidad es muy elevado, demasiado elevado como para esperar que afecte a un gran número de rutas, al menos el número que sería necesario para realmente combatir el cambio climático.

Así las cosas, encontramos evidencia de que el ETS es un instrumento relativamente eficaz, aunque su efectividad sería aún mayor si su cobertura geográfica fuera mayor que la que abarca actualmente. Esto evitaría distorsiones en potencia en la competitividad relativa entre los mercados turísticos afectados y no afectados por el mercado de emisiones.

Finalmente, indicar que los esfuerzos a realizar son todavía ingentes en atención a que, como se mencionaba al principio de este artículo, las emisiones provenientes de la aviación no han dejado de aumentar, y en España menos: simplemente el crecimiento de las emisiones en rutas de tratamiento es menor que el crecimiento de emisiones en rutas de control, pero esto no implica que no haya habido un incremento en valor absoluto de las emisiones en España (y en los demás países afectados por la política).

## Referencias bibliográficas

Angrist, J. D., & Pischke, J.-S. (2008). *Mostly harmless econometrics*. Princeton University Press.

Azar, C., & Johansson, D. J. A. (2012). Valuing the non-$CO_2$ climate impacts of aviation. *Climatic Change*, *111*, 559-579. https://doi.org/10.1007/s10584-011-0168-8

Borusyak, K., & Jaravel, X. (2020). *Revisiting Event Study Designs*. (Working Paper, Harvard University).

Brons, M., Pels, E., Nijkamp, P., & Rietveld, P. (2002). Price elasticities of demand for passenger air travel: a meta-analysis. *Journal of Air Transport Management*, *8*(3), 165-175.

Cames, M., Graichen, J., Siemons, A., & Cook, V. (2015). *Emission Reduction Targets for International Aviation and Shipping.* Directorate General For Internal Policies Policy Department A: Economic and Scientific Policy. http://www.europarl.europa.eu/RegData/etudes/STUD/2015/569964/IPOL_STU(2015)569964_EN.pdf

European Commission. (2019). *Handbook on the external costs of transport*. Directorate General for Mobility and Transport, European Commission. https://cedelft.eu/publications/handbook-on-the-external-costs-of-transport-version-2019/

European Environment Agency. (2020). *EEA greenhouse gases - data viewer*. https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

Fageda, X., & Teixidó, J. J. (2022). Pricing carbon in the aviation sector: Evidence from the European emissions trading system. *Journal of Environmental Economics and Management*, *111*, 102591. https://doi.org/https://doi.org/10.1016/j.jeem.2021.102591

Gössling, S., & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change*, *65*, 102194. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2020.102194

Graver, B., Zhang, K., & Rutherford, D. (2019). *CO2 emissions from commercial aviation* (ICCT Working Paper No. 2019-16). The International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/ICCT_CO2-commercl-aviation-2018_20190918.pdf

Graver, B., Rutherford, D., & Zengh, S. (2020). *CO2 emissions from commercial aviation. 2013, 2018 and 2019*. ICCT, The International Council on Clean Transportation. https://theicct.org/wp-content/uploads/2021/06/CO2-commercial-aviation-oct2020.pdf

Hainmueller, J. (2012). Entropy Balancing for Causal Effects: A Multivariate Reweighting Method to Produce Balanced Samples in Observational Studies. *Political Analysis*, *20*(1), 25-46. https://doi.org/DOI: 10.1093/pan/mpr025

Klemetsen, M. E., Rosendahl, K. E., & Jakobsen, A. L. (2016). *The impacts of the EU ETS on Norwegian plants' environmental and economic performance*. Statistics Norway, Research Department Discussion Papers No. 833. http://hdl.handle.net/10419/192815

Koopmans, C., & Lieshout, R. (2016). Airline cost changes: To what extent are they passed through to the passenger? *Journal of Air Transport Management*, *53*(3), 1-11.

Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., & Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, *244*, 117834. https://doi.org/https://doi.org/10.1016/j.atmosenv.2020.117834

OECD. (2020). OECD Data - Tourism GDP. https://data.oecd.org/industry/tourism-gdp.htm

Petrick, S., & Wagner, U. J. (2014). *The Impact of Carbon Trading on Industry: Evidence from German Manufacturing Firms* (Kiel Working Papers No. 1912). Kiel Institute.

Sant'Anna, P. H. C., & Zhao, J. (2020). Doubly robust difference-in-differences estimators. *Journal of Econometrics*, *219*(1), 101-122. https://doi.org/https://doi.org/10.1016/j.jeconom.2020.06.003

Transport and Environment. (2016). *Aviation ETS - gaining altitude* (J. Dings, ed.).

Verbeek, M. (2000). *A guide to modern econometrics*. John Wiley & Sons, Ltd.

Vivid Economics. (2007). *A Study to Estimate Ticket Price Changes for Aviation in the EU ETS.* Defra, Climate Change Economics Division.

Wagner, U. J., Muûls, M., Martin, R., & Colmer, J. (2014). The causal effect of the European Union Emissions Trading Scheme: Evidence from French Manufacturing Plants. In *Unpublished.*

Zimmerman, P. R., & Carlson, J. A. (2010). Competition and Cost Pass-through in Differentiated Oligopolies. US Federal Trade Commission.

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# Análisis de impacto de alternativas para la financiación de las energías renovables en España*

# *Impact evaluation of financing mechanisms for renewable energy in Spain*

Mikel González-Eguino
Basque Centre for Climate Change (BC3)
Universidad del País Vasco (UPV/EHU)

Xaquin García-Muros
Basque Centre for Climate Change (BC3)
MIT Joint Program on the Science and Policy of Global Change

Iñaki Arto
Basque Centre for Climate Change (BC3)

Cristina Pizarro-Irizar
Universidad del País Vasco (UPV/EHU)
Basque Centre for Climate Change (BC3)

***Resumen***

*Este artículo analiza el impacto económico, social y ambiental de varios mecanismos de financiación de los costes regulados de las energías renovables en el sector eléctrico (RECORE) en España. Los escenarios analizados, alternativos al sistema actual, en el que los costes se trasladan de forma íntegra a la factura eléctrica de los consumidores finales, son los siguientes: financiación a través de los Presupuestos Generales del Estado (escenario PGE), financiación mediante un impuesto proporcional al consumo final de energía (escenario Energía) y financiación mediante un impuesto al $CO_2$ en los sectores difusos (escenario $CO_2$). El estudio utiliza un modelo de equilibrio general computable (CGE) y un modelo de microsimulación que incluye información detallada de los 22.000 hogares incluidos en la Encuesta de Presupuestos Familiares. Los resultados muestran que el impacto a nivel macroeconómico es positivo pero muy reducido para todos los escenarios analizados y que los cambios a nivel sectorial o en las emisiones dependen notablemente del escenario elegido. Todos los escenarios favorecen a los hogares de renta baja ya que su gasto en electricidad supone un porcentaje relativamente mayor sobre su renta. Aunque ninguna alternativa es mejor en todas las dimensiones analizadas, los impuestos sobre la energía o $CO_2$ favorecen la transición energética, mientras que la alternativa PGE genera efectos distributivos* más progresivo*s.*

***Palabras clave:*** *evaluación de políticas públicas, energía, cambio climático.*

***Clasificación JEL:*** *C6, Q4, Q53, Q54.*

---

* Este trabajo ha sido cofinanciado por Iberdrola, el programa BERC 2018-2021, el Ministerio de Economía y Competitividad a través de la distinción María de Maeztu excelencia acreditación MDM-2017-0714 y el Ministerio de Ciencia, Innovación y Universidades de España (RTI2018-093352-B-I00).


DOI: https://doi.org/10.32796/cice.2022.104.7476
Recibido: Abril 2022 · Aceptado: Mayo 2022

***Abstract***

*This article analyzes the economic, social and environmental impact of various financing mechanisms for the regulated costs of renewable energies in the electricity sector (RECORE) in Spain. The scenarios analysed, alternative to the current system, in which the costs are transferred in full to the electricity bill of final consumers, are the following: financing through the General State Budgets (PGE scenario), financing through a tax proportional to final energy consumption (Energy scenario) and financed through a $CO_2$ tax in diffuse sectors ($CO_2$ scenario). The study uses a computable general equilibrium (CGE) model and a micro-simulation model that includes detailed information on the 22,000 households included in the Household Budget Survey. The results show that the impact at the macroeconomic level is positive but very small for all the scenarios analyzed and that the changes at the sectoral level or in emissions depend notably on the scenario. All the scenarios favor low-income households since their spending on electricity represents a relatively higher percentage of their income. Although no alternative is better in all the dimensions analyzed, taxes on energy or $CO_2$ favor the energy transition, while the PGE alternative generates more progressive distributional effects.*

***Keywords:*** *public policy evaluation, energy, climate change.*

## 1. Introducción

La promoción de las energías renovables ocupa un lugar destacado en la agenda energética y climática de la mayoría de países del mundo, siendo este uno de los instrumentos centrales junto con la eficiencia energética para avanzar en la senda a la neutralidad climática. En este sentido, los planes enviados por los Gobiernos a Naciones Unidas para reducir las emisiones de gases de efecto invernadero (GEI) en el marco del cumplimiento del Acuerdo de París recogen, en su mayoría, objetivos específicos en materia de promoción de las energías renovables. Estos objetivos son cada vez más ambiciosos, habida cuenta de la enorme reducción de costes que han experimentado estas tecnologías en los últimos años (International Renewable Energy Agency [IRENA], 2021). Además, son ampliamente conocidos sus efectos positivos en otras áreas muy destacadas, como son la seguridad de suministro (IRENA, 2016) o la calidad del aire (Markandya *et al.,* 2018).

La Unión Europea (UE) ha propuesto recientemente el Pacto Verde Europeo, que avanza en esta dirección y ha aumentado recientemente los objetivos de reducción de emisiones de GEI de un 40 % a un 55 % con respecto a 1990 para 2030 y, para ello, necesita aumentar los objetivos en materia de energías renovables. Asimismo, el paquete de medidas «Fit-for-55», incluye medidas como la revisión de la Directiva de Fiscalidad Energética, que pretende aumentar la fiscalidad sobre los combustibles fósiles y reducir la asociada a la electricidad.

Sin embargo, también existe una preocupación sobre el impacto que puede tener la promoción de las energías renovables, especialmente la asociada a las inversiones realizadas durante la última década en la que los costes de las renovables aún eran elevados. En el pasado, los costes de las renovables eran superiores a los de otras tecnologías, por lo que se introdujeron instrumentos para su promoción. El instrumento más habitual para promocionar las energías renovables ha sido la inclusión de primas específicas para cada tecnología, lo que garantizaba un precio estable a largo plazo, junto con la obligación de comprar toda la producción proveniente de estas tecnologías. La diferencia entre las primas y el precio mayorista de la electricidad se contabiliza como subsidios a las energías renovables y se paga, generalmente, como un coste regulado (RECORE) incluido en el precio de la electricidad. Entre 2005 y 2019, el coste del RECORE en términos nominales pasó de 2.900 millones de euros a 7.200 millones de euros (Comisión Nacional de los Mercados y la Competencia [CNMC], 2020).

La promoción de las renovables en la última década ha contribuido en términos generales[1] a aumentar los precios finales de la electricidad (Trujillo *et al.,* 2018), lo que ha generado un debate sobre cuál es la forma más adecuada de financiarlas. Aunque actualmente son la forma más barata de producir electricidad, las instaladas en el periodo 2000-2015 tenían unos costes superiores que hay que pagar en los próximos años hasta el final de su vida útil. Este hecho también ha comenzado a recibir la atención de la comunidad científica en los últimos años (Schmalensee, 2012; Neuhoff *et al*., 2013; Ciarreta *et al*., 2014; Mir-Artigues *et al*., 2015; Böhringer *et al*., 2017).

En este sentido, se ha planteado en España la posibilidad de que otros sectores además del sector eléctrico contribuyan a financiar los costes de las renovables. Empresas (Confederación Española de Organizaciones Empresariales [CEOE], 2014), agentes sociales (Fundación Renovables [FR], 2018; Defensor del Pueblo, 2017) y varios comités de expertos (Comisión de Expertos sobre Escenarios de Transición Energética, 2018) han recomendado explorar vías alternativas para hacer más viable la transición energética. También el Gobierno ha planteado recientemente la creación del Fondo Nacional para la Sostenibilidad del Sector Eléctrico (FNSSE) con dicho objetivo. Todo ello ha coincidido en un momento en el que existe una creciente preocupación sobre el aumento del coste de la energía y su impacto en los hogares más vulnerables.

La literatura sobre impactos distributivos muestra (Fullerton, 2008) que las políticas climáticas y energéticas tienden a ser regresivas, ya que aumentan el precio de los productos intensivos en combustibles fósiles, que suelen representar una fracción de gasto más alta en los grupos de bajos ingresos. Además, como las opciones de combustibles no fósiles suelen ser más intensivas en capital que las de combustibles fósiles, inducen a las empresas a demandar más capital en relación con la mano de obra, lo que reduce los salarios relativos y afecta negativamente a los grupos de bajos ingresos. Esta conclusión general también puede aplicarse al fomento y apoyo de las energías renovables. Neuhoff *et al*. (2013) muestran, utilizando microdatos de los hogares de Alemania, que la carga fiscal del apoyo a las renovables a través

[1] Aunque la promoción de las renovables no ha sido el único factor causante del aumento del precio de la electricidad ocurrido en los últimos años, su efecto en el precio sí ha sido positivo según Trujillo *et al*. (2018). El efecto neto de las subvenciones a las renovables sobre el precio final de la electricidad necesita, no obstante, considerar no solo el aumento de costes que generan dichas subvenciones, sino también el efecto depresor en los precios que se produce en el mercado mayorista, ya que estas tecnologías se caracterizan por tener un coste variable o marginal muy bajo (Sáenz de Miera *et al*., 2008).

de impuestos en el sistema eléctrico es significativamente mayor en los grupos de bajos ingresos y, por lo tanto, de manera similar al ejercicio llevado a cabo en este documento, proponen tres medidas para disminuir este efecto: reducir el impuesto sobre la electricidad, aumentar el apoyo a las medidas de eficiencia energética y aumentar las transferencias sociales a los grupos de bajos ingresos. Por otro lado, Böhringer *et al.* (2017), utilizando un modelo de microsimulación integrado en un modelo de equilibro general, metodología también aplicada en este estudio, muestran las pérdidas de eficiencia y la regresividad de las políticas de «Feed in Tarifs» en Alemania, pero también muestran que estos efectos podrían ser distintos si se introducen exenciones en el recargo a la electricidad o, alternativamente, si el coste de las renovables se financia a través de otras fuentes de impuestos como el impuesto sobre el valor añadido (IVA). Estos resultados están alineados con otros estudios para España, como Robinson *et al*. (2019), donde también muestran los beneficios de costear el apoyo a las renovables a través de otras vías de financiación.

Así, dada la problemática planteada y partiendo de un enfoque similar a otros trabajos anteriores (Neuhoff *et al*., 2013; Böhringer *et al.,* 2017; o Robinson *et al*., 2019), este estudio tiene como objetivo analizar los impactos económicos, sociales y ambientales de formas alternativas de financiación de las energías renovables en el sector eléctrico (RECORE) distintas al actual sistema que traslada este coste de forma íntegra a la factura eléctrica que pagan los consumidores, ya sean hogares o empresas. En este estudio, se analizan tres mecanismos de financiación alternativos: *i*) traspaso de los costes a los Presupuestos Generales del Estado (PGE); *ii*) financiación mediante un impuesto al $CO_2$ para los sectores difusos, es decir, no sujetos al Sistema Europeo de Comercio de Emisiones (EU-ETS); y *iii*) reparto de dichos costes proporcionalmente al consumo final de energía por fuente mediante un impuesto a la energía.

Para analizar estas alternativas se ha utilizado un modelo de equilibrio general computable y un modelo de microsimulación de forma integrada (Böhringer *et al*., 2019), lo que permite estimar los impactos económicos y sectoriales, su incidencia en los diferentes grupos sociales y sus implicaciones ambientales.

El trabajo se organiza como sigue. En el apartado 2 se explican brevemente el método y los datos utilizados. En el apartado 3 se presentan los escenarios de financiación alternativos. En el apartado 4 se analizan los resultados, estudiando el impacto macroeconómico y la incidencia en diferentes sectores y grupos socioeconómicos, y se realiza un análisis de sensibilidad. Finalmente, en el apartado 5 se recogen las principales conclusiones del estudio.

## 2. Metodología

### *2.1. Modelo*

El estudio se ha realizado mediante la integración de un modelo macroeconómico y un modelo microeconómico. Más concretamente, se ha integrado un modelo multisectorial de equilibrio general computable (CGE, por sus siglas en inglés) y un modelo de microsimulación (MS). La integración de ambas metodologías permite estimar los impactos económicos y su incidencia en los diferentes grupos económicos y sociales, además de capturar las posibilidades tecnológicas de sustitución entre *inputs* productivos y los cambios de comportamiento en el consumo ante el cambio en los precios. Una formulación detallada de este tipo de modelos y su integración puede encontrase en García-Muros (2017). A continuación, se explican de forma breve ambos modelos.

El modelo CGE captura las relaciones de toda la economía en conjunto (ver Anexo A.1). La producción se basa en funciones de coste con elasticidades de sustitución constantes (CES, por sus siglas en inglés), las cuales describen el efecto de los precios en la sustitución entre los *inputs*: capital, trabajo, energía y materiales de producción. Por otro lado, el consumo privado está determinado por un hogar representativo, el cual maximiza su utilidad sujeta a un presupuesto limitado. El agente representativo recibe ingresos de tres fuentes distintas: trabajo, capital y transferencias. El comercio internacional sigue un enfoque Armington, donde los bienes domésticos y extranjeros son productos heterogéneos. Por último, el modelo incorpora las emisiones de $CO_2$, NOx, $PM_{2.5}$ y $SO_2$ mediante coeficientes asociados al uso de combustibles fósiles. De este modo, las emisiones de un sector pueden reducirse mediante la sustitución de *inputs*.

El modelo MS captura el comportamiento de los consumidores y provee una imagen detallada de los efectos de sustitución entre consumos ante cambios en los precios (elasticidades-precio y elasticidades-renta). Más concretamente, para estimar la demanda de los consumidores, se ha utilizado un modelo Sistema de Demanda Casi Ideal (AIDS, por sus siglas en inglés) (Deaton y Muellbauer, 1980), cuya principal ventaja es que permite realizar una aproximación lineal a un sistema de demanda. Además, este modelo satisface los axiomas de la teoría del consumidor y no impone restricciones sobre la función de utilidad (ver Anexo A.2).

### *2.2. Datos*

El modelo CGE ha sido calibrado a través de la tabla Input-Output (IO) (Instituto Nacional de Estadística [INE], 2017a). La tabla IO es una representación de los usos y recursos de los sectores productivos del sistema de producción español. La producción por sector se relaciona con el consumo de los hogares en términos de categorías de gastos de consumo utilizando una matriz de conversión. En cuanto a las emisiones de $CO_2$, NOx, $PM_{2.5}$ y $SO_2$ por sector y combustible fósil, se han utilizado los datos de las cuentas ambientales de Eurostat.

Para estimar el modelo MS, la base de datos utilizada ha sido la Encuesta de Presupuestos Familiares (EPF) (INE, 2017b). La EPF es una encuesta representativa de la población española que recolecta anualmente información referente a los patrones de consumo de los hogares, así como distintas características socioeconómicas de estos. La encuesta recopila información de más de 20.000 hogares por año. En la fase de estimación del modelo de demanda se han utilizado datos de 2006 a 2013. Finalmente, las fuentes de los ingresos han sido completadas utilizando información de la Encuesta de condiciones de vida (ECV) (INE, 2017c).

Para poder integrar los datos de ambas fuentes se han ajustado los datos de gasto y demanda de la EPF para asegurar que coinciden con los datos agregados de la tabla IO. De manera similar, se han escalado las fuentes de ingreso de los hogares (trabajo y capital) de modo que coincidan ambas fuentes de datos. Finalmente, debido a la falta de información sobre el ahorro en la EPF, se ha distribuido el ahorro agregado de la tabla IO entre los hogares según el peso de las rentas del capital en sus ingresos.

## 3. Escenarios

El actual mecanismo de financiación de las energías renovables en el sector eléctrico se realiza mediante la traslación íntegra de los costes regulados (RECORE) a la factura eléctrica. En este estudio se analizan tres alternativas al sistema actual de financiación:

- *Escenario PGE*: financiación a través de los Presupuestos Generales del Estado mediante una subida proporcional de los impuestos, pero sin alterar la actual composición de los mismos.
- *Escenario Energía*: financiación mediante un aumento de los impuestos energéticos proporcional a la estructura de la demanda final de energía. Esto supone que al sector del gas y del petróleo y, en menor medida al del carbón, les correspondería contribuir con su parte proporcional, mientras que el sector eléctrico reduciría notablemente su contribución, ya que contribuiría con un porcentaje acorde a su *mix* (20 %). Este escenario está relacionado con la actual propuesta del Gobierno de financiar el pasado apoyo a las renovables mediante la creación de un Fondo Nacional para la Sostenibilidad del Sistema Eléctrico (FNSSE). Así, algunos de los resultados y conclusiones asociadas a este escenario pueden trasladarse a la propuesta del Gobierno de España. Sin embargo, las diferencias en el periodo analizado, así como las diferencias en el diseño del escenario (pues está estilizado) hace que ambas no sean comparables al 100 %.
- *Escenario $CO_2$*: el RECORE se financia mediante un impuesto sobre las emisiones de $CO_2$ en los sectores económicos no cubiertos por el ETS y teniendo en cuenta la reducción del consumo energético y de las emisiones después del impuesto.

Todos los escenarios están planteados de tal manera que consiguen cubrir 6.400 M€ del RECORE.

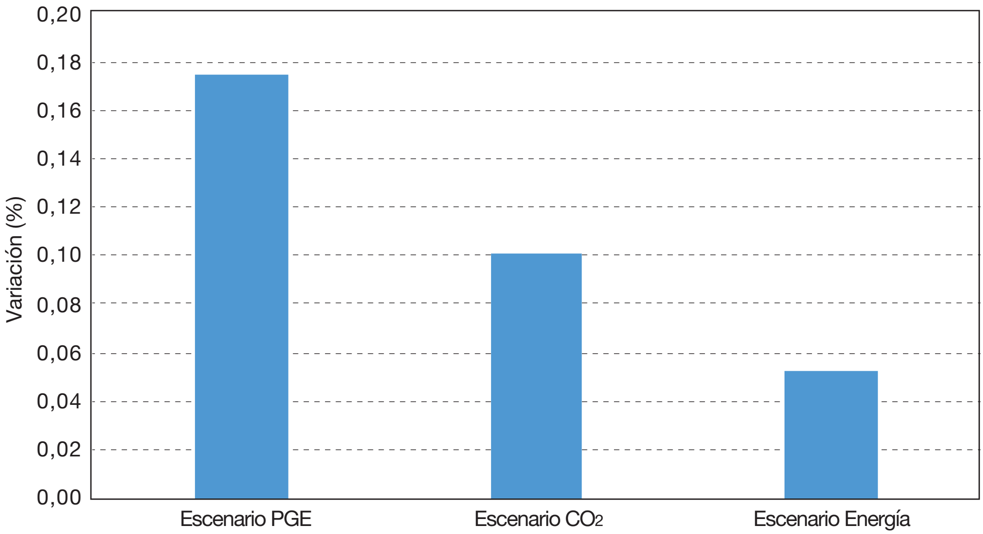
## 4. Resultados

En esta sección se presentan y discuten los resultados obtenidos en los distintos escenarios planteados. Los resultados se exponen divididos de la siguiente forma: *i*) impacto macroeconómico y ambiental; *ii*) impacto sectorial; *iii*) impacto social y distributivo por tipos de hogar; *iv*) impactos en el bienestar social; *v*) análisis comparativo por escenarios, donde se comparan las tres vías de financiación a través de los impactos expuestos con anterioridad.

### *4.1. Impacto macroeconómico y ambiental*

La Figura 1 muestra la variación del PIB en términos porcentuales como consecuencia de la implementación de los distintos mecanismos de financiación. En general, se observa que la introducción de estas nuevas figuras de financiación tiene un impacto macroeconómico positivo pero muy reducido. El RECORE, aunque relevante en el sector eléctrico, es una magnitud pequeña si se compara con el PIB y, si además consideramos que las tres alternativas de financiación son neutrales fiscalmente, lo que sucede realmente es una redistribución del coste del RECORE entre sectores a través de un cambio relativo en los precios de la energía.

**FIGURA 1**
**IMPACTO EN EL PIB**



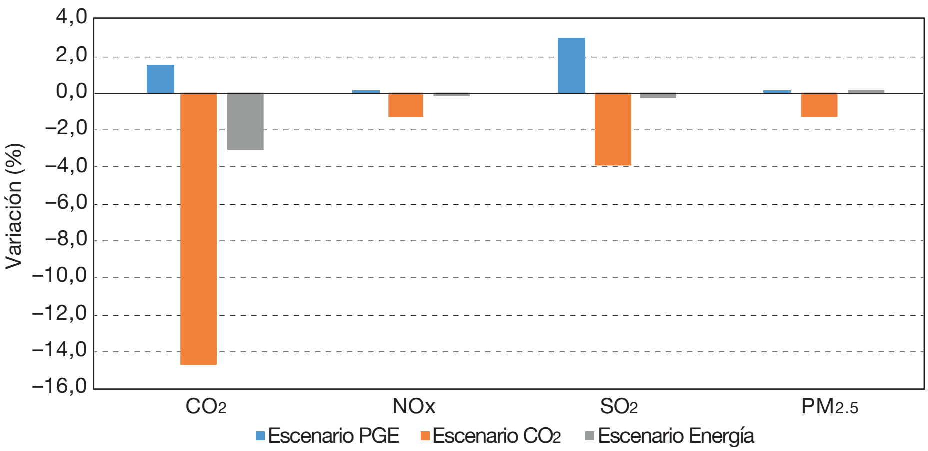

**FUENTE:** Elaboración propia.

El impacto positivo en el PIB se explica principalmente por el hecho de que los tres métodos suponen una ampliación de la base impositiva, además de reducir la carga impositiva de los consumidores (ya que ahora tienen que pagar menos impuestos en su factura eléctrica), lo que favorece la eficiencia del sistema. En general, aquellas vías impositivas que afectan a un mayor número de bienes o de sectores económicos tienen una menor incidencia macroeconómica y, por lo tanto, generan mayores mejoras en el PIB, frente a aquellas medidas que son más restringidas y que tienen, por lo tanto, menores alternativas. Esto explica que el *escenario PGE* sea el sistema con un impacto económico más positivo, pues la base imponible se amplía a todos los impuestos del sector público. Seguido del *escenario $CO_2$*, cuya base imponible son todos los sectores no incluidos en el ETS, y, finalmente, del *escenario Energía*, donde el coste del RECORE recae sobre todos los productos y servicios energéticos y no únicamente sobre el sector eléctrico como en la actualidad.

La Figura 2 muestra la variación de emisiones de $CO_2$, NOx, $SO_2$ y $PM_{2.5}$ para cada uno de los sistemas de financiación alternativos. El *escenario $CO_2$* y el *escenario Energía* son los que logran reducir más las emisiones. El *escenario $CO_2$* reduce principalmente las emisiones de $CO_2$, pero también otras emisiones que generan contaminación atmosférica, ya que ambos están relacionados con la quema de combustibles fósiles. Aunque las reducciones son menores en el *escenario Energía,* también se reducen las emisiones de $CO_2$. Sin embargo, en el *escenario PGE* no se alcanza una reducción de las emisiones, sino que se observa, por el contrario, un leve incremento en las emisiones de $CO_2$ y $SO_2$. La mayor actividad económica va acompañada de un aumento de la demanda energética y, por tanto, de las emisiones. Este incremento en la demanda energética se debe principalmente al abaratamiento de la electricidad, lo cual se traduce en una mayor demanda eléctrica y mayores emisiones en este sector.

**FIGURA 2**

**IMPACTO EN LAS EMISIONES DE $CO_2$ Y OTROS GASES CONTAMINANTES**

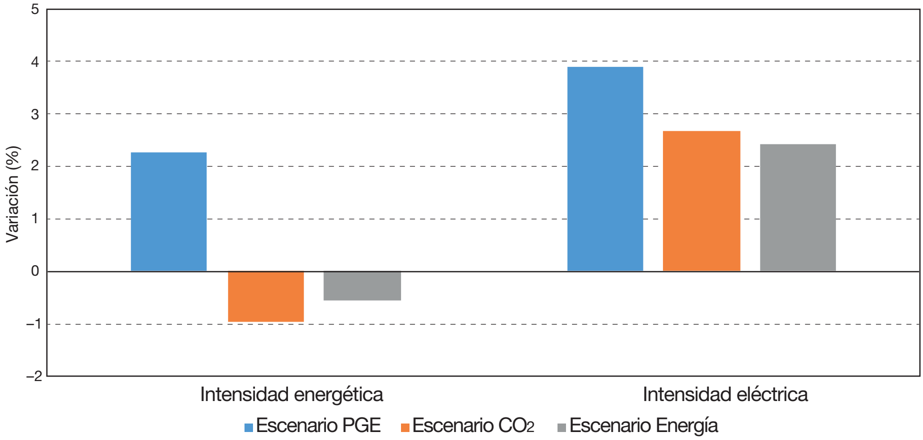



**FUENTE:** Elaboración propia.

La Figura 3 muestra la variación en la intensidad energética y la intensidad eléctrica de la economía española, es decir, la energía consumida (total o eléctrica) por unidad de PIB[2]. Se observa que en el *escenario* $CO_2$ se produce una importante reducción de la intensidad energética. Este efecto se explica por la reducción en el consumo energético de aquellos sectores más dependientes de los combustibles fósiles, como el transporte y los sectores intensivos en energía. Por otro lado, en el *escenario Energía*, aunque se gravan indirectamente a los sectores relacionados con los combustibles fósiles, que suponen un porcentaje muy elevado del *mix* energético, el mantenimiento de parte de la carga fiscal en el sector eléctrico limita el efecto de reducción de la intensidad energética. El *escenario PGE* conlleva incrementos en la demanda energética y, por tanto, en la intensidad energética. Sin embargo, en todos los escenarios observamos que se incrementa la intensidad eléctrica como consecuencia directa de la reducción de precios de la electricidad y el aumento del consumo.

**FIGURA 3**

**IMPACTO SOBRE LA INTENSIDAD ENERGÉTICA Y ELÉCTRICA DE LA ECONOMÍA**




**FUENTE:** Elaboración propia.

## *4.2. Impacto sectorial*

La Figura 4 muestra la distribución de los impactos macroeconómicos por sectores en términos de aumento/disminución de la demanda de cada uno de ellos. En general, los escenarios alternativos no suponen pérdidas importantes de producción para la mayoría de los sectores productivos, ya que la reducción de la demanda no supera el 3 % en ninguno de los escenarios analizados (salvo en el caso de los sectores asociados a los combustibles fósiles). Especialmente, en el sector de bienes y servicios, el cual supone una gran parte de la producción y la demanda final, observamos que el efecto es muy reducido.

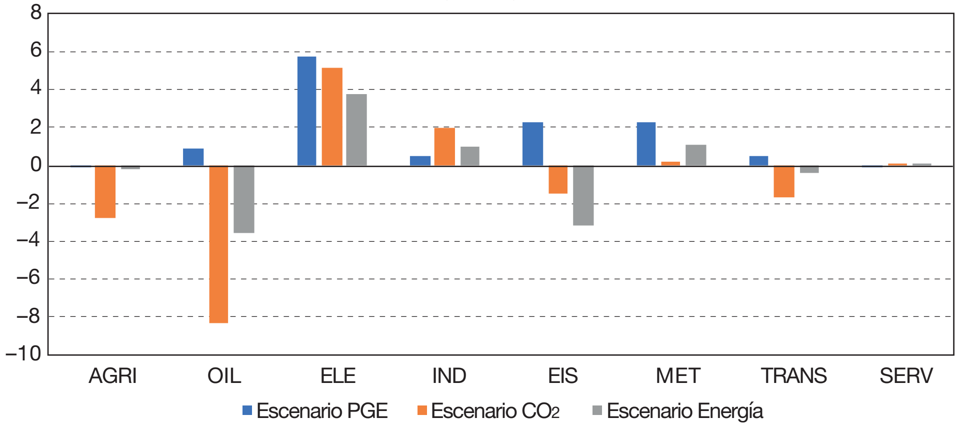
---

[2] La intensidad energética muestra la eficiencia energética de la economía, es decir, el consumo de energía eléctrica o de consumo energético total respecto al *output* total de los todos los sectores de la economía.

Como se ha mencionado, la excepción son los sectores asociados a los combustibles fósiles. El sector del refino de petróleo, por ejemplo, reduce su producción por las políticas introducidas (–5% de media en los tres escenarios), especialmente en el *escenario $CO_2$*. En este mismo sentido, el sector de producción y distribución de gas es el siguiente sector más afectado (–1,3 % de media). Un resultado destacable a nivel sectorial es que los sectores industriales y los electrointensivos como la siderurgia y metalurgia se verían ligeramente favorecidos por estos escenarios alternativos, mientras que los sectores intensivos en energía se verían ligeramente perjudicados.

El análisis sectorial muestra que las ganancias o pérdidas de competitividad que a raíz de estos cambios puedan darse serán pequeñas y podrían además quedar compensadas entre sectores. No obstante, y aunque no se analiza en este trabajo, es posible que algunos subsectores muy específicos intensivos en consumo de gas y muy expuestos al comercio tengan más dificultades que el resto, ya que no podrán fácilmente traspasar los nuevos costes a los precios finales de sus productos. En este sentido, y si así se desea, se podrían diseñar mecanismos de compensación específicos para algunos subsectores, como ya se hace para los sectores en riesgo de fuga de carbono incluidos en el mercado europeo de derechos de emisión de $CO_2$.

**FIGURA 4**
**IMPACTO SOBRE LA PRODUCCIÓN POR SECTORES**
**(En %)**



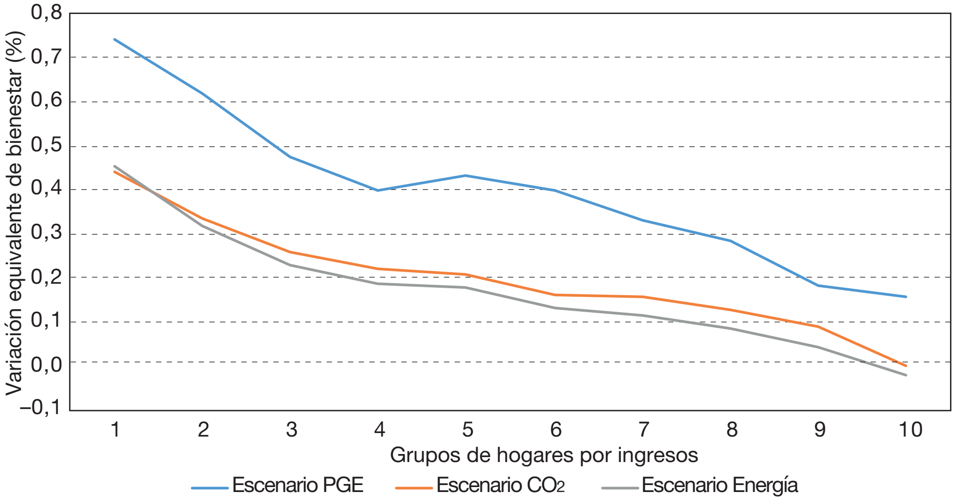

NOTA: AGR (Agricultura y Ganadería); OIL (Crudo, Carbón, Gas, Refino); ELE (Electricidad); IND (Resto de Industria); EIS (Industria Intensiva en Energía); MET (Siderurgia y Metalurgia); TRANS (Servicios de Transporte); SERV (Resto de Servicios).

**FUENTE:** Elaboración propia.

## *4.3. Efectos distributivos sobre distintos grupos de hogares*

Este subapartado analiza los impactos de los escenarios planteados sobre los distintos grupos de hogares. La Figura 5 presenta los impactos en el bienestar (medido como variación equivalente del bienestar[3]) por grupos de renta (deciles), donde el grupo 1 representa los hogares con renta más baja y el grupo 10 a los hogares con renta más elevada, lo que nos permite analizar la regresividad o progresividad de los distintos sistemas propuestos.

**FIGURA 5**
**IMPACTO POR DECILES DE GASTO**




**FUENTE:** Elaboración propia.

Los resultados muestran un efecto progresivo en todos los escenarios planteados, esto es, el impacto positivo es mayor en los tramos de renta más bajos que en los más altos. La escala del efecto y el nivel de progresividad varían en función del escenario elegido, pero el efecto general de los nuevos escenarios es claro.

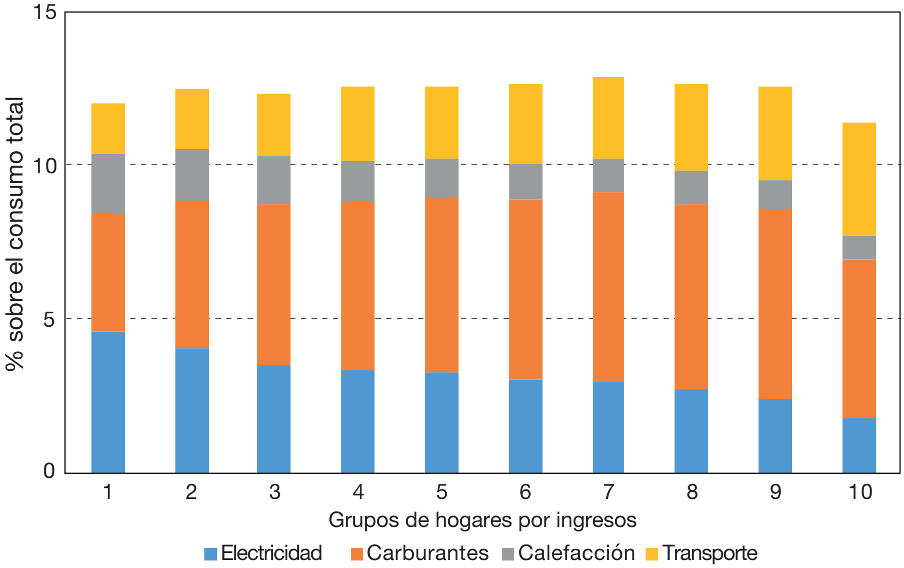
La explicación de este efecto hay que buscarla en los patrones de consumo de los hogares españoles recogidos en la Figura 6 (ver García-Muros *et al.,* 2016). El consumo eléctrico representa una mayor proporción del gasto en los hogares de menor renta. Sin embargo, el gasto en carburantes está más concentrado en hogares de renta media y alta. La reducción de los precios[4] de la electricidad y la elevación de los precios de los carburantes tiene como resultado, por lo tanto, un efecto combinado redistributivo positivo para los hogares de renta baja.

---

[3] La variación equivalente mide la cantidad de dinero que un consumidor pagaría para evitar un cambio de precios, antes de que ocurriese.

[4] En el *escenario* $CO_2$, por ejemplo, el precio de los carburantes aumenta un 0,8 % y el transporte un 1,5 %, mientras que el precio de la electricidad se reduce de media en un 13,5 %.

**FIGURA 6**
**CONSUMO ENERGÉTICO POR HOGAR**

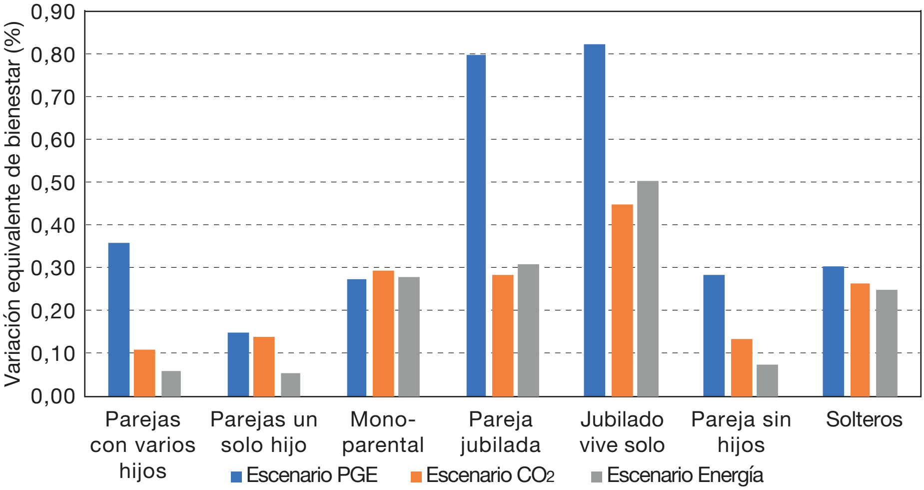



**FUENTE:** Elaboración propia.

Cuando se trata de mejorar la aceptabilidad pública de una política, la progresividad no es la única característica relevante, sino que también es necesario que sea inclusiva con grupos vulnerables. La Figura 7 muestra los impactos en el bienestar según tipos de hogares: parejas sin hijos, parejas con un solo hijo, parejas con más de un hijo, familia monoparental, solteros sin hijos, pareja de jubilados y jubilados que viven solos. Se observa cómo el impacto de las políticas difiere notablemente dependiendo del tipo de familia, siendo las parejas con un solo hijo las menos beneficiadas por los distintos tipos de sistemas de financiación, mientras que los más beneficiados por la reforma son los hogares conformados por jubilados. Existe una fuerte correlación entre el impacto por tipo de familia y los ingresos de esta. Así, podemos explicar que las parejas con o sin hijos son las familias menos favorecidas por el paquete de medidas, ya que, por lo general, se encuentran en tramos de renta más elevados. Por otro lado, las familias conformadas por jubilados se encuentran en tramos de renta más bajos y un elevado consumo en electricidad, por lo que el abaratamiento de la factura eléctrica supone también un incremento en su bienestar.

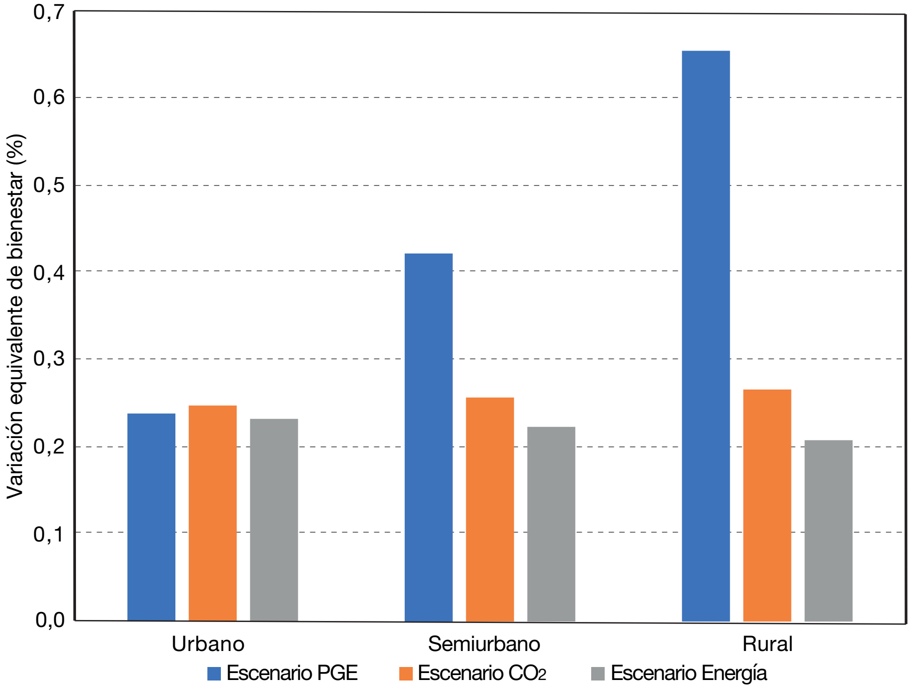
Finalmente, la Figura 8 muestra los impactos en el bienestar según la zona de residencia del hogar: hogares en zonas urbanas, semiurbanas o intermedias y hogares en zonas rurales. Al igual que sucedía según el tipo de hogar, el impacto de las políticas difiere notablemente dependiendo de la zona de residencia del hogar. Así, los hogares rurales se ven ampliamente beneficiados cuando el coste del RECORE recae sobre los Presupuestos Generales del Estado. Estos hogares se encuentran algo más relacionados con tramos bajos de renta y tienen una mayor demanda energética, tanto eléctrica

**FIGURA 7**
**IMPACTOS POR TIPO DE HOGAR**




**FUENTE:** Elaboración propia.

**FIGURA 8**
**IMPACTOS SEGÚN LA ZONA DE RESIDENCIA DEL HOGAR**




**FUENTE:** Elaboración propia.

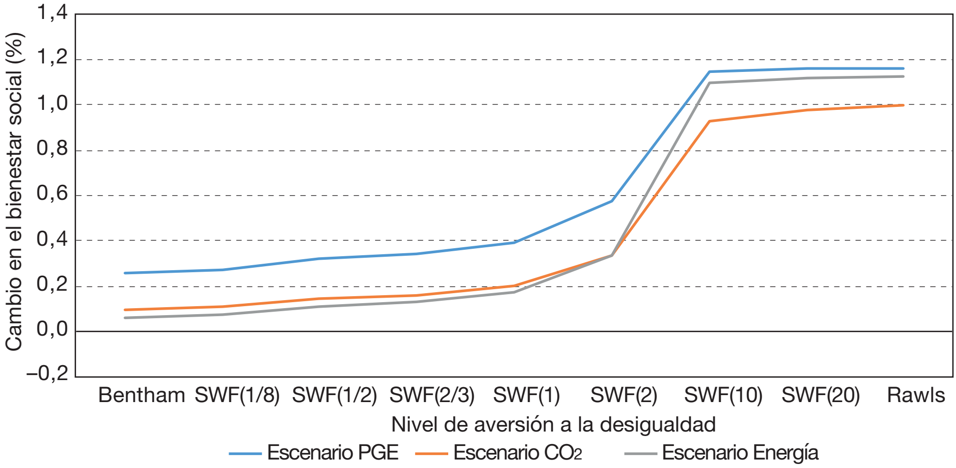
como de otras fuentes de energía, especialmente de combustibles para transporte. Este segundo efecto explica que el posible beneficio derivado de la bajada de la luz se vea compensado por mayores costes de los combustibles fósiles y reduzca el posible beneficio en el bienestar en los *escenarios* $CO_2$ *y Energía*. Por otro lado, los hogares de zonas urbanas tienen una menor dependencia energética y se encuentran en tramos de renta media y media-alta, lo que explica que el beneficio de la eliminación del recargo a la electricidad sea más parejo en todos los escenarios. Este impacto desigual entre hogares que residen en diferentes zonas se debe a las distintas necesidades energéticas de los hogares de zonas diseminadas. Así, los hogares que residen en zonas rurales y semiurbanas dedican una mayor parte de su renta a gasto energético que los hogares de zonas urbanas. Existen dos factores determinantes detrás de las diferencias en los patrones de consumo de los hogares según el nivel de ruralidad: *i*) mayor gasto en energía debido a determinadas características de las viviendas situadas en zonas rurales, semiurbanas o municipios pequeños (como la superficie de la vivienda o la certificación energética); y *ii*) la tendencia a utilizar más el transporte privado en las actividades cotidianas a consecuencia de la falta de alternativas para realizar dichos desplazamientos en las zonas con baja densidad poblacional (Flues y Thomas, 2015; Gago *et al*., 2019; Tomás *et al*., 2020; Tomás *et al.*, 2021).

### *4.4. Análisis de bienestar social*

Las políticas energéticas son habitualmente analizadas desde el punto de vista de la eficiencia, olvidando de manera habitual los impactos distributivos o de equidad que pueden tener y la existencia de *trade-offs* entre ambos. Una forma de capturar ambos elementos en conjunto es mediante el uso de funciones de bienestar social. Estas agregan el bienestar de cada individuo teniendo en cuenta la aversión y tolerancia hacia la desigualdad de la sociedad. Ponderando así, en mayor o menor medida, aquellos hogares más vulnerables (ver Anexo B).

Este apartado recoge los impactos de las medidas alternativas en términos de bienestar social ante distintos grados de aversión a la desigualdad que puede tener una sociedad. Cuando la aversión es muy elevada o máxima, el bienestar de la sociedad solo puede aumentar si la política introducida aumenta el bienestar del individuo o colectivo más pobre (aproximación tipo Rawls). Por el contrario, cuando la aversión a la desigualdad es mínima, el bienestar es simplemente la suma aritmética del bienestar individual, es decir, se pondera igualmente a todos los hogares independientemente de su nivel de renta (aproximación Bentham). La Figura 9 muestra la variación en el bienestar social de los tres escenarios analizados y entre ambos extremos de aversión a la desigualdad. Según un estudio de Bargain *et al*. (2014), la aversión a la desigualdad social es mayor en los países nórdicos y en algunos de Europa continental, apuntando así a unas preferencias rawlsianas, mientras que el sur de Europa (incluido España) y Estados Unidos reflejan una aversión a la desigualdad muy baja, cercana a las opiniones utilitaristas.

**FIGURA 9**
**IMPACTOS EN EL BIENESTAR SOCIAL**




**FUENTE:** Elaboración propia.

Los resultados muestran el reducido impacto de los distintos sistemas de financiación cuando la aversión a la desigualdad es muy baja. Este impacto no es sorprendente, ya que va en la misma línea que los resultados que hemos observado cuando hemos analizado el impacto en el PIB de los distintos escenarios. Por lo tanto, aunque la tendencia es positiva en distintos aspectos, no hay grandes beneficios de trasladar el coste de la financiación de la factura eléctrica a otras vías de financiación.

Sin embargo, cuando la aversión a la desigualdad se hace más relevante, los escenarios analizados incrementan notablemente el bienestar social respecto al sistema de financiación actual. Dado que los hogares con elevados porcentajes de gasto en electricidad se encuentran en tramos de renta baja, el sistema de financiación actual que encarece la factura de la luz incrementa la desigualdad a través de impactos adversos en este tipo de hogares. Este hecho explica el impacto tan positivo en el bienestar de las medidas de financiación alternativas que se consigue cuando la aversión a la desigualdad es elevada. Dado que el *escenario PGE* consigue un mayor abaratamiento de la electricidad, es el escenario de financiación que logra unos mayores impactos en el bienestar social cuando existe una alta aversión a la desigualdad.

### *4.5. Análisis comparativo por escenarios*

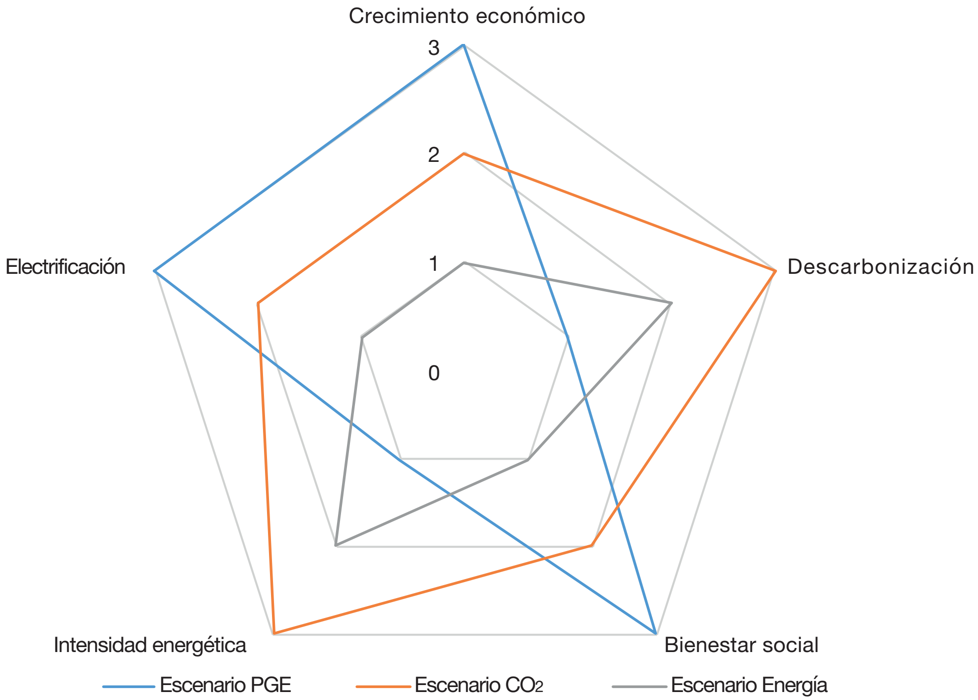
En este apartado se realiza un análisis comparativo de los escenarios en base a cinco dimensiones de relevancia ya analizadas: *i*) impacto ambiental; *ii*) macroeconómico; *iii*) eficiencia energética; *iv*) electrificación; y *v*) distributivo. El objetivo es poner en perspectiva estos impactos y valorar las sinergias existentes entre los distintos escenarios e intentar buscar qué escenario se debería potenciar en función del objetivo deseado. Por otro lado, cabe señalar que, aunque algunas dimensiones, como la eficiencia energética o la electrificación, podrían considerarse simplemente medios para la descarbonización, hemos optado por incluirlas como dimensiones aparte para capturar y comprender mejor los efectos de cada uno de los escenarios.

La Figura 10 muestra la posición de cada escenario respecto a los distintos enfoques analizados, siendo 3 la mejor posicionada y 1 la peor. Es decir, cuanto más próxima está la política a los vértices de la figura, mejores resultados tendrán en dicho aspecto. Esta clasificación tiene un objetivo puramente ilustrativo, no pretende dar pesos exactos a cada dimensión y escenario.

La representación de la Figura 10 evidencia que ninguno de los escenarios es mejor en todos los aspectos analizados. Mientras que el *escenario PGE* es el mejor escenario en términos de PIB o en términos sociales, también es el escenario que menos favorece una transición hacia la descarbonización. En cambio, el *escenario* $CO_2$ destaca por ser el escenario que, siendo también progresivo, logra reducir las emisiones de $CO_2$ y favorecer en mayor medida la electrificación del sistema y la transición energética. Por otro lado, el *escenario Energía* no logra en ninguna de las

**FIGURA 10**

***RANKING* POR DIMENSIONES Y ESCENARIOS**




**FUENTE:** Elaboración propia.

perspectivas comentadas un impacto mayor que el conseguido por el resto de escenarios, y, por ello, está ligeramente dominado por el *escenario* $CO_2$. Sin embargo, sus resultados no están tan alejados del *escenario* $CO_2$, por lo que podría ser una alternativa interesante si la implementación del *escenario* $CO_2$ fuera más compleja por razones de viabilidad política o por razones técnicas. De hecho, esta parece ser la situación que más se aproxime al contexto político actual, como muestra la propuesta para la creación del FNSSE, el cual está alineado con el *escenario Energía*.

Estos resultados y conclusiones están alineados con otros artículos de la literatura, especialmente con aquellos que tienen una metodología similar a la aplicada en este trabajo, como el caso de Böhringer *et al.* (2017), donde para el caso de Alemania muestra cómo, si bien no hay una política netamente mejor que otra, sí que alternativas formas de financiación de las renovables suponen una mejora clara respecto al actual sistema de recargos sobre la factura eléctrica. Del mismo modo, Robinson *et al*. (2019), para el caso de España, aunque con algunos resultados diferentes debido a la distinta metodología y los supuestos en los escenarios analizados, también recomiendan que el coste de las renovables debería financiarse a través del presupuesto del Estado, al tratarse de un bien de interés público.

## 5. Conclusiones

Este informe ha analizado los impactos de mecanismos alternativos de financiación de las energías renovables (RECORE) al actual sistema, en donde estos costes se financian exclusivamente a través de la factura eléctrica. Se han analizado tres escenarios alternativos: financiación a través de los Presupuestos Generales del Estado (*escenario PGE*), impuestos sobre los bienes energéticos proporcionales al consumo final de energía (*escenario Energía*) o financiación mediante un impuesto al $CO_2$ (*escenario* $CO_2$). Para analizar su impacto se han integrado un modelo macroeconómico y un modelo microeconómico.

La metodología aplicada ha permitido evaluar las distintas vías de financiación desde distintos prismas: ambiental, macroeconómico y distributivo. El análisis realizado tiene dos limitaciones principales. En primer lugar, y aunque las herramientas utilizadas son adecuadas para el objetivo planteado, su implementación requería de un mayor grado de detalle en particular en lo relativo a los impuestos incluidos en el modelo (CGE). En segundo lugar, el modelo también es muy estilizado en lo relativo al sector eléctrico y no permite capturar, por ejemplo, cómo un aumento del precio del $CO_2$ puede alterar el orden de mérito de las tecnologías, algo que necesitaría de la integración de un modelo del mercado eléctrico (Rodrigues, 2017).

En base al análisis y las limitaciones encontradas, se pueden destacar las siguientes conclusiones.

Primero, el análisis muestra que es posible buscar alternativas para la financiación de las renovables que no tengan efectos negativos sobre la actividad económica. En todo caso, los efectos positivos que pueden darse también serán muy reducidos.

Segundo, los escenarios analizados no suponen una pérdida de producción relevante a nivel sectorial, a excepción de aquellos sectores asociados a los combustibles fósiles. Los efectos sobre la competitividad que se anticipan serán, por lo tanto, reducidos. No obstante, algunos subsectores intensivos en consumo de gas y abiertos al comercio internacional podrían verse más afectados que la media y, en tal caso, es posible plantear medidas compensatorias que convendrían ser analizadas en futuros trabajos de investigación.

Tercero, todos los escenarios son más progresivos que el sistema actual de financiación del RECORE. Al reducir los precios de la electricidad cuyo peso en el gasto de los deciles bajos es mayor y al aumentar los precios de los carburantes cuyo peso es menor, la reforma beneficia claramente a los hogares de renta baja y a los grupos sociales vulnerables.

Finalmente, se puede concluir que, aunque ninguna de las alternativas es mejor en todas las dimensiones, sí se observa que las financiaciones mediante impuestos a la energía o $CO_2$ son más indicadas para acelerar la transición energética, mientras que la financiación a través de los Presupuestos Generales del Estado sería la más progresiva de las alternativas analizadas. Del mismo modo, parece que una política próxima al *escenario Energía,* como la actual propuesta para la creación del FNSSE, puede tener una mayor viabilidad política, pues mantienen los costes del apoyo a las renovables dentro del sector energético de una manera sencilla, transparente y fácil de aplicar.

## Referencias bibliográficas


Atkinson, A. B. (1970). On the measurement of inequality. *Journal of Economic Theory*, *2*, 244-263.

Bargain, O., Dolls, M., Neumann, D., Peichl, A., & Siegloch, S. (2014). Comparing inequality aversion across countries when labor supply responses differ. *International Tax and Public Finance*, *21*(5), 845-873.

Böhringer, C., Carbone, J. C., & Rutherford, T. F. (2012). Unilateral Climate Policy Design: Efficiency and Equity Implications of Alternative Instruments to Reduce Carbon Leakage. *Energy Economics*, *34*, 208-217.

Böhringer, C., Landis, F., & Tovar Reaños, M. A. (2017). Economic Impacts of Renewable Energy Production in Germany. *The Energy Journal*, *38*(SI1), 189-209.

Böhringer, C., García-Muros, X., & González-Eguino, M. (2019). Greener and Fairer: A Progressive Environmental Tax Reform for Spain. *Economics of Energy & Environmental Policy*, *8*(2), 161-180.

Brooke, A., D. Kendrick, Meeraus, A., & Raman, R. (1998). *GAMS: A User's Guide.* GAMS Development Corporation.

CEOE, Confederación Española de Organizaciones Empresariales. (2014). *Energía y competitividad: propuestas del sector empresarial*. Publicaciones CEOE.

Ciarreta, A., Espinosa, M. P., & Pizarro-Irizar, C. (2014). Is green energy expensive? Empirical evidence from the Spanish electricity market. *Energy Policy*, *69*, 205-215.

CNMC, Comisión Nacional de los Mercados y la Competencia. (2020). *Liquidaciones provisionales de la retribución de las instalaciones de producción de energías renovables cogeneración y residuos*.

Comisión de Expertos sobre Escenarios de Transición Energética. (2018). *Comisión de expertos sobre escenarios de transición energética. Análisis y propuestas para la descarbonización*.

Deaton, A., & Muellbauer, J. (1980). An almost Ideal Demand System. *The American Economic Review*, *70*(3), 312-326.

Defensor del Pueblo. (2018). *Informe anual 2018. Actividades y actuaciones llevadas a cabo a lo largo del 2018*.

Dirkse, S., & Ferris, M. (1995). The PATH Solver: A Non-monotone Stabilization Scheme for Mixed Complementarity Problems. *Optimization Methods & Software*, *5*, 123-56.

Eurostat. (2020). *Renewable energy statistics, 2020*.

Flues, F., & Thomas, A. (2015). *The distributional effects of energy taxes* (OECD Taxation Working Papers No. 23). Organisation for Economic Co-operation and Development. https://doi.org/10.1787/5js1qwkqqrbv-en

FR, Fundación Renovables. (2018). *Hacia una Transición Energética Sostenible: Propuestas para afrontar los retos globales*. Fundación Renovables.

Fullerton, D. (2008). *Distributional Effects of Environmental and Energy Policy: An Introduction* (NBER Working Paper No. 14241). National Bureau of Economic Research. http://www.nber.org/papers/w14241

Gago, A., Labandeira, X., Labeaga, J. M., & Lopez-Otero, X. (2019). Impuestos energético-ambientales en España: situación y propuestas eficientes y equitativas. Fundación Alternativas y Fundación Iberdrola.

García-Muros, X., Burguillo, M., González-Eguino, M., & Romero-Jordán, D. (2016). Local air pollution and global climate change taxes: a distributional analysis for the case of Spain. *Journal of Environmental Planning and Management*, *60*(3), 1-18.

García-Muros, X. (2017). *Distributional implications of environmental policies. Tesis Series ciencias sociales 2016-2017*. Premios Enrique Fuentes Quintana de Tesis Doctorales. FUNCAS.

Defensor del Pueblo. (2017). *Estudio sobre protección de los consumidores vulnerables en materia de energía eléctrica.*

INE, Instituto Nacional de Estadística. (2017a). *Nota metodológica sobre las tablas input-output de la economía española en base 2010. Tabla Input-Output, Año 2015*.

INE, Instituto Nacional de Estadística. (2017b). *Encuesta de presupuestos familiares, base 2006*.

INE, Instituto Nacional de Estadística. (2017c). *Encuesta de condiciones de vida - Base 2013*.

IRENA, International Renewable Energy Agency. (2016). *Renewable Energy Benefits: Measuring the Economics*.

IRENA, International Renewable Energy Agency. (2021). *Renewable Power Generation Costs in 2020.*

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., & González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. *The Lancet Planetary Health*, *2*(3), e126-e133.

Mir-Artigues, P., Cerdá, E., & del Río, P. (2015). Analyzing the Impact of Cost-Containment Mechanisms on the Profitability of Solar PV Plants in Spain. *Renewable and Sustainable Energy Reviews*, *46*, 166-177.

Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M., & El-Laboudy. T. (2013). Distributional Effects of Energy Transition: Impacts of Renewable Electricity Support in Germany. *Economics of Energy & Environmental Policy*, *2*(1).

Robinson, D., Linares, P., López, X., & Rodrigues, R. (2019). Fiscal policy for decarbonization of energy in Europe, with a focus on urban transport: case study and proposal for Spain. In M. Villar-Ezcurra, J. E. Milne, H. Ashiabor, & M. Skou (Eds.), *Environmental fiscal challenges for cities and transport. Critical Issues in environmental taxation series. Volume XXI* (pp. 75-90). Elgar Publishing.

Rodrigues, R. (2017). *Hybrid modeling for electricity policy assessments*. Universidad Pontificia Comillas.

Sáenz de Miera, G., del Río González, P., & Vizcaíno, I. (2008). Analysing the Impact of Renewable Electricity Support Schemes on Power Prices: The Case of Wind Electricity in Spain. *Energy Policy*, *36*(9), 3345-59.

Schmalensee, R. (2012). Evaluating Policies to Increase Electricity Generation from Renewable Energy. *Review of Environmental Economics and Policy*, *6*(1), 45-64.

Tomás, M., García-Muros, X., Alonso-Epelde, E., Arto, I., Rodríguez-Zúñiga, A., Monge, C., & González-Eguino, M. (2021). *Fiscalidad verde y transición justa: Análisis de impacto de medidas compensatorias para el caso del diésel en España*. OTEA.

Tomás, M., López, L. A., & Monsalve, F. (2020). Carbon footprint, municipality size and rurality in Spain: Inequality and carbon taxation. *Journal of Cleaner Production*, *266*, 121798. https://doi.org/10.1016/j.jclepro.2020.121798

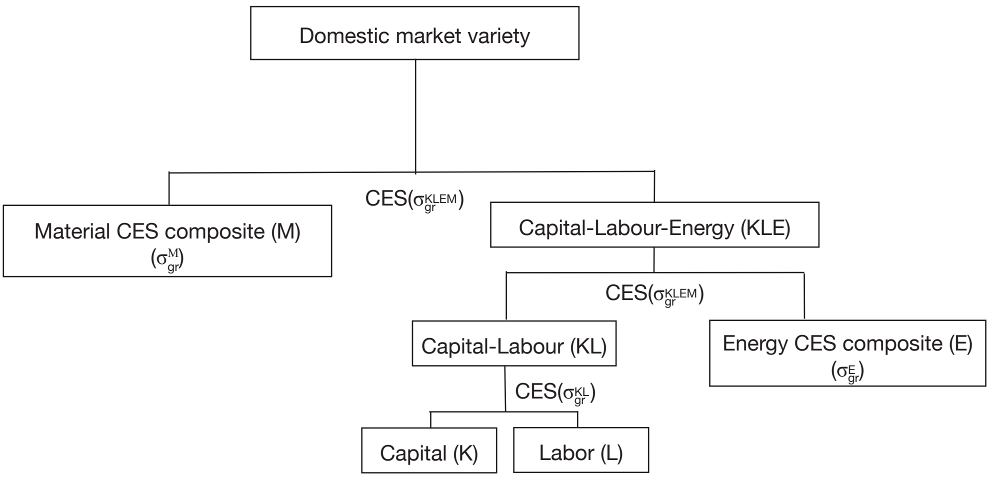
Trujillo-Baute, E., del Río, P., & Mir-Artigues, P. (2018). Analysing the impact of renewable energy regulation on retail electricity prices. *Energy Policy*, *114*, 153-164.

# APÉNDICE
# Metodología

## A.1. Estructura del modelo de equilibrio general

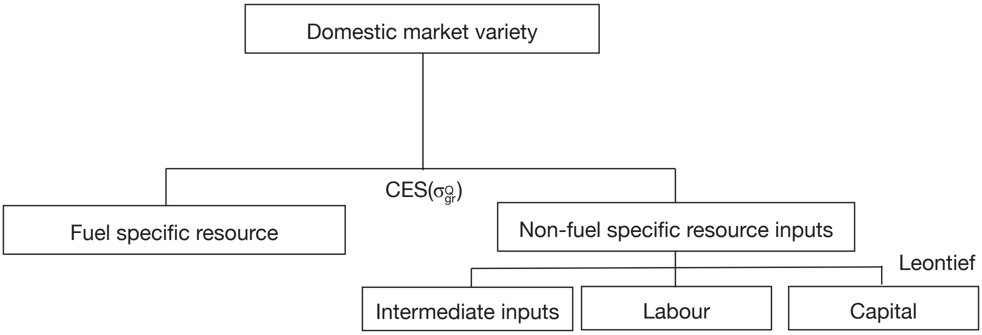
El modelo de equilibrio general está formulado como un sistema de desigualdades no lineales. Las desigualdades corresponden a dos clases de condiciones asociadas con el equilibrio general de una economía: *i*) agotamiento de los mercados (cero beneficios), condiciones para productores con rendimientos constantes a escala; y *ii*) liquidación de mercado para todos los bienes y factores. La primera condición determina los niveles de actividad y la segunda determina el nivel de precios. En equilibrio, cada variable está vinculada a una condición de desigualdad: un nivel de actividad a un agotamiento de la restricción del producto, y un precio de producto a una condición de liquidación de mercado. Las Figuras A1-A3 proporcionan una exposición gráfica de la estructura de producción. Numéricamente, el modelo se implementa en GAMS (Brooke *et al*., 1998) y se resuelve mediante PATH (Dirkse y Ferris, 1995).

**FIGURA A1**
**ANIDACIÓN DE LA PRODUCCIÓN**
**(Excepto combustibles fósiles)**



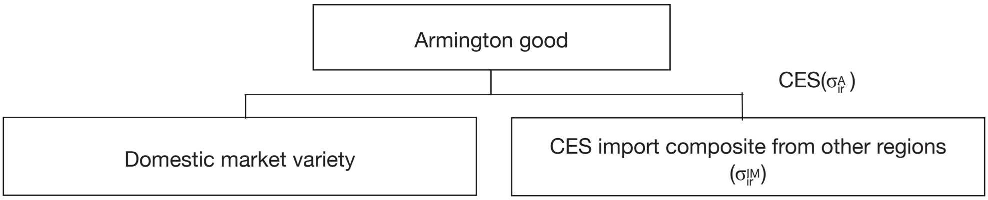

NOTA: Elasticidad de sustitución constante (CES, por sus siglas en inglés).
**FUENTE:** Elaboración propia.

**FIGURA A2**
**ANIDACIÓN DE COMBUSTIBLES FÓSILES**




NOTA: Elasticidad de sustitución constante (CES, por sus siglas en inglés).
**FUENTE:** Elaboración propia.

**FIGURA A3**
**ANIDACIÓN ARMINGTON**




NOTA: Elasticidad de sustitución constante (CES, por sus siglas en inglés).
**FUENTE:** Elaboración propia.

## A.2. Modelo de demanda casi ideal (AIDS, por sus siglas en inglés) y su estimación

El modelo de demanda captura el comportamiento de los hogares. Para este ejercicio se ha estimado un modelo de demanda que permite calcular las elasticidades-precio de sustitución de los bienes analizados. De este modo, se ha utilizado el bien conocido modelo de Sistema de Demanda Casi Ideal (AIDS, por sus siglas en inglés) propuesto por Deaton y Muellbauer (1980). La principal ventaja de este modelo es que permite aproximaciones de primer orden. Además, este tipo de modelos satisfacen los axiomas del consumidor y no imponen restricciones a la función de utilidad. En este caso, se ha seguido una aproximación logarítmica y lineal para estimar esta función (LAIDS):

$$W_i = \alpha_i + \sum_{J=1}^{n} \gamma_{ij} ln\, p_j + \beta_i ln\left(\frac{Y_i}{\tilde{p}}\right) + t + \sum_{i=1}^{3} d_i + e_i \qquad [A.1]$$

Donde $w_i$ representa el porcentaje de gasto del $i$ sobre el gasto total para cada hogar, $p_j$ es el precio del bien $j$, $\tilde{p}$ establece el índice de precios de Stone, $Y$ es el ingreso de cada hogar (así, $Y/\tilde{p}$ representa el ingreso real), $t$ es una variable temporal que captura el rol del ciclo en la economía, $d_i$ es un conjunto de variables de control para cada hogar: la región donde está ubicado cada hogar en términos de NUTS 1; si el hogar es propietario de la vivienda donde vive; el número de habitaciones de cada hogar; la edad del cabeza de familia; si este está desempleado, trabajando o jubilado; el número de personas activas del hogar; si el hogar está equipado con calefacción; y el tipo de familia del hogar. Finalmente, $e_i$ recoge el error de la estimación. Las restricciones de homogeneidad son:

$$\sum_{i=1}^{n} \alpha_i = 1 \qquad [A.2]$$

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \qquad [A.3]$$

$$\sum_{i=1}^{n} \beta_i = 0 \qquad [A.4]$$

Mientras que las de simetría están dadas por:

$$\gamma_{ij} = \gamma_{ji} \qquad [A.5]$$

Finalmente, la suma de $w_i$ debe satisfacer:

$$\sum_{i=1}^{14} w_i = 1 \qquad [A.6]$$

En este estudio se han incluido nueve categorías de consumo: alimentación, vivienda, bienes duraderos, calefacción, electricidad, carburantes, transporte, ocio y educación y otros bienes. El Cuadro A1 representa la estimación llevada a cabo.

**CUADRO A1**
**ESTIMACIÓN DEL AIDS**

| | Alimentación | Vivienda | Carburantes | Electricidad | Calefacción | Transporte | Ocio y educación | Bienes duraderos |
|---|---|---|---|---|---|---|---|---|
| ln (p_alimentación) | 0,030** | –0,007 | –0,018* | –0,001 | 0,001* | 0,014 | –0,057* | –0,011 |
| ln(p_vivienda) | –0,007 | 0,176* | –0,012* | 0,011* | 0,001 | –0,003 | –0,052* | –0,110* |
| ln(p_carburantes) | –0,018* | –0,012* | 0,029* | –0,001* | –0,001* | –0,014* | –0,017* | 0,037* |
| ln(p_electricidad) | –0,001 | 0,011* | –0,001* | 0,015* | –0,001* | –0,004* | –0,008* | –0,007* |
| ln(p_calefacción) | 0,001* | 0,001 | –0,001* | –0,001* | 0,006* | –0,001* | –0,003* | –0,002* |
| ln(p_transporte) | 0,014 | –0,004 | –0,014* | –0,003* | –0,001* | 0,042* | 0,013 | –0,017 |
| ln(p_ocio & educación) | –0,057* | –0,052* | –0,017* | –0,008* | –0,002* | 0,013 | 0,131* | –0,014 |
| ln(p_bienes duraderos) | –0,011 | –0,110* | 0,037* | –0,007* | –0,002* | –0,017 | –0,015 | 0,097* |
| ln(p_otros bienes) | 0,048* | –0,001 | –0,003 | –0,006* | –0,001* | –0,029* | 0,008 | 0,028** |

NOTA: * Estadísticamente significativo al 5%. ** Estadísticamente significativo al 10%.
**FUENTE:** Elaboración propia.

## B. Función de bienestar social

La función de bienestar social planteada por Atkinson (1970) es:

$$SW = \frac{1}{N} \sum_{h} \frac{Y_h^{1-\varepsilon}}{1-\varepsilon} \qquad [B.1]$$

Donde $Y_h$ representa el ingreso real del hogar *h*, $\varepsilon$ es el coeficiente que mide la aversión a la desigualdad de una sociedad y *N* representa el total de hogares analizados. Siguiendo a Böhringer *et al*. (2012), se exploran los cambios en el bienestar a través de los cambios producidos en la renta equivalente distribuida ($Y_{ede}$) definida por Atkinson (1970):

$$Y_{ede} = \left[\frac{1}{N} \sum_{h} Y_h^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}, \qquad if\ \varepsilon \neq 1 \qquad [B.2]$$

$$Y_{ede} = \prod_{h} Y_h^{\frac{1}{N}}, \qquad if\ \varepsilon = 1 \qquad [B.3]$$

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# Distributional impacts of carbon taxation in Mexico*

# *Impactos distributivos de la fiscalidad sobre el carbono en México*

Xavier Labandeira
Universidade de Vigo

José M. Labeaga
Universidad Nacional de Educación a Distancia

Xiral López-Otero
Universidad Nacional de Educación a Distancia

Thomas Sterner
University of Gothenburg

**_Abstract_**

*The main aim of this paper is to analyze the different impacts of carbon taxation in Mexican households at different income levels. First, we estimate a household demand system for non-durable goods with special emphasis on energy-related goods. Then, we use the results to simulate the introduction of a carbon tax. We look at the potential to raise revenue with the aim of implementing different redistributive policies in order to address issues of inequality and poverty. Moreover, we evaluate the effects of carbon taxes on demand and emissions reduction.*
***Keywords****: emissions; carbon taxation; distribution; poverty; Mexico*
***JEL classification****: D12, D31, H23, H31, Q48.*

**_Resumen_**

*El principal objetivo de este artículo es analizar el impacto distributivo de la fiscalidad sobre el carbono en los hogares mexicanos. En primer lugar, estimamos un sistema de demanda de bienes no duraderos de los hogares, prestando una atención especial a los bienes relacionados con la energía. A continuación, utilizamos los resultados para simular la introducción de un impuesto al carbono, analizando su potencial para generar ingresos con la finalidad de llevar a cabo distintas políticas redistributivas, con el objetivo final de reducir la desigualdad y la pobreza. Además, utilizamos los resultados para evaluar los efectos del impuesto sobre la demanda y la reducción de emisiones.*
***Palabras claves:*** *emisiones, imposición al carbono, distribución, pobreza, México.*

* The authors are grateful for the comments and suggestions of two external reviewers. They acknowledge funding from CHIPS as part of AXIS, an ERA-NET initiated by JPI Climate by FORMAS (SE, grant registration number 2018-0271, grant decision number FR-2019/0003), DLR/BMBF (DE), project number PCI2019-103773 of Spanish Research Agency, and ANR (FR). The usual disclaimer applies.


DOI: https://doi.org/10.32796/cice.2022.104.7492
Recibido: Abril 2022 · Aceptado: Agosto 2022

## 1. Introduction

Starting from the Kyoto Protocol in February 2005, and continuing more vigorously in the Paris Agreement (UN, 2015), many signatory countries implemented policies to achieve quantitative reductions in greenhouse gas (GHG) emissions through various instruments, including carbon pricing, either through taxes or emission for emissions allowances. Explicit carbon pricing provides incentives for businesses and households to reduce carbon-intensive energy use and switch to clean fuels, as well as a price signal to mobilise private investments in clean technologies, is more flexible than regulations, provides continuous incentives for mitigation, reduces rebound effects, increases government revenue and generates environmental co-benefits, such as reductions in local pollution (IMF/OECD, 2021). In practice, however, the incentive effects of environmental taxes are often limited for three main reasons: the use of tax rates that are too low to achieve substantial environmental improvement[1], the existence of exemptions or rebates for energy-intensive industries, and the tendency to use taxes on households, where in many cases price elasticity is low and/or product substitution, at least in the short run, is not possible (Fujiwara et al., 2006). So, despite the increasing use of climate policies and legislation, these, overall, have not achieved a substantial reduction in GHG emissions (Somanathan et al., 2014).

Among the environmental taxation actions carried out by many governments, the policies implemented by the European Union countries stand out, whose environmental tax revenues increased by 9.5 % in real terms between 2002-2014 (Speck & Paleari, 2016). Finland was the first country to introduce a carbon tax in the early 1990s and its example was followed by many countries, generally accompanying this measure with other carbon pricing instruments, such as energy taxes, with the aim of reducing energy consumption (Vallés-Giménez & Zárate-Marco, 2020). Thus, there are currently 68 carbon pricing initiatives in 46 national and 36 sub-national jurisdictions, covering 12 Gt of $CO_2$ equivalent emissions, which represents 23 % of global GHG emissions (World Bank, 2022). Still, about 60 % of carbon emissions from energy use in Organisation for Economic Co-operation and Development (OECD) and G20 countries remained untaxed in 2018, with effective carbon tax rates being particularly low in the power and industrial sectors (OECD, 2021b). Although the rate was reduced to 51 % in 2021, existing levels of taxation are not high enough to achieve a successful transition to net zero emissions (OECD, 2021a), as the average global emissions price is only \$2/tonne (Parry, 2019) and only 3.76 % of global emissions are regulated by a carbon price equal to or above \$40/t $CO_2$ (World Bank, 2021).

Among the commitments of the Paris Agreement (UN, 2015), the signatory countries agreed to reduce their greenhouse gas emissions, translating this

[1] To limit global warming to 2 °C or less a high level of taxation is required, such as an immediate global carbon tax that rises rapidly to \$75/t$CO_2$ by 2030 (IMF, 2019).

commitment into Nationally Determined Contributions (NDCs). Mexico committed unconditionally to reduce its GHG emissions by 22 % in 2030 compared to the baseline scenario estimated for 2013 (991Mt$CO_2$e). In addition, conditional commitments would increase emissions mitigation to 36 % in 2030 compared to the baseline scenario (Government of Mexico, 2020)[2]. Within Mexican GHG emissions, energy-related emissions stand out, accounting for 63.5 % of gross GHG emissions and 87.5 % of net emissions (including removals) in 2019 (SEMARNAT, 2022). It is therefore crucial, to achieve significant reductions in the coming years, to design and implement public policies particularly for the energy sector.

Mexico initiated an energy reform in December 2013 (see Álvarez & Valencia, 2015; SENER, 2015; Vargas, 2015), with the aim of substantially transforming the energy sector. This reform was far reaching by Mexican standards and entailed steps that were earlier considered unthinkable in Mexico such as the elimination of PEMEX's monopoly, as well as the modification of the mechanism for determining tax rates on gasoline (which often resulted in the tax actually being a subsidy), replacing it with fixed tax rates (see Muñoz, 2013). A carbon tax on fossil fuels was also introduced (albeit at too low a rate to trigger behavioural change) and the electricity sector was reformed to try to reduce its costs (see IEA, 2016).

These steps were a radical departure with historical precedents in Mexico where politics has been heavily marked by a fierce nationalism that has its origins in the nationalisation of foreign oil companies by President Lázaro Cardenas in 1938. Since at least the 1970s Mexico turned into a major oil producer and exporter with profound effects on the structure of the Mexican economy which showed many of the signs of a Dutch disease (Guevara et al., 2022). During the last thirty years or more, Mexican development has been marked by a dominance of the petroleum sector, low domestic energy prices and the effects this has on (energy intense) technology choice and industrial structure (Sterner, 1985, 1989). However, over time this strategy has led to problems such as the overvaluation of national currency and consequent problems of competitiveness for non-petroleum sectors in the economy. Eventually Mexican exports of oil could not sustain the economy and furthermore the challenge of dealing with climate change and other factors have led to a change in policy.

Starting with the change of government in 2018, several measures were put in place however, with the aim of not increasing real energy prices, which limited the scope of the reforms. In particular, a new mechanism for residential electricity tariffs was established, so that they only adjust based on inflation and do so gradually during the year, as well as the so-called "fiscal stimulus", which is approved weekly and involves a reduction in the tax rate on fuels (see Government of Mexico, 2019). This fiscal stimulus initially involved reductions of between 20-40 % in the tax rate on

---

[2] Fulfilling these commitments involves the international consolidation of technology transfer mechanisms, an international carbon trading price, carbon adjustment tariffs, technical cooperation, access to low-cost financial resources and technology transfer, all on a scale equivalent to the challenge of global climate change.

gasoline, although currently (week of 23-29 April 2022) the fiscal stimulus is 100 % (SEGOB, 2022), which means that the tax on fuels is not applied. Furthermore, residential electricity tariffs are heavily subsidised, so that, on average, households pay only 46 % of the total cost of the service (Hancevic et al., 2019), with electricity subsidies amounting to close to 0.3 % of GDP in 2022 (73 billion pesos), see Government of Mexico (2022).

The 2013 energy reform also provided for the introduction of an emissions trading system (ETS). Mexico initiated a 36-month trial ETS programme in 2020, in which only installations operating in the energy and manufacturing sectors whose annual emissions are at least 100,000 tonnes of direct $CO_2$ emissions participate (SEMARNAT, 2021). While the scheme is expected to be operational from 2023, there is uncertainty both on the timing of its introduction and on the emissions that will be covered by it. In this context of low taxation on energy products and uncertainty about the future emissions trading system, existing public policies are not incentivising energy savings and efficiency, so additional policies are needed to achieve significant reductions in carbon emissions to meet the Paris Agreement commitments. To this end, a carbon tax on energy products can be used at a sufficiently high level to achieve behavioural changes. This policy would also be complementary to the ETS, taxing sectors not covered by the ETS, as well as sectors included in the ETS until it becomes operational.

Therefore, our first objective in this paper is to simulate the environmental, revenue and distributional effects of a $CO_2$ emissions tax on the main Mexican energy products. Energy taxes have the capacity to generate a relevant volume of public revenue, sometimes at the cost of significant distributional impacts (see Gago et al., 2021). So, our second aim is to explore the introduction of compensatory mechanisms aimed to reduce poverty and inequality using the additional revenue generated by the new tax. Countries such as Mexico that show significant problems of poverty and inequality are unlikely to suffer significant distributional problems, but the extent of pre-existing poverty is so significant that the introduction of compensatory mechanisms may still be very important. Table 1 shows the poverty rate in 2018, i.e., the percentage of households living with less than 60 % of median income (the poverty line as defined by Foster et al., 1984 or Heindl, 2015 among others) and using household expenditure as a proxy for income. We find that more than 23 % of Mexican households are in poverty, especially prominent in the south of the country (over 37 % of households in poverty) and in rural areas (almost 43 %). Regarding inequality, the Gini index shows that inequality is also higher in the south and in rural areas.

The academic literature on energy demand in Mexico has mainly focused on studying transport fuel demand (Bernt & Botero, 1985; Gately & Streifel, 1997; Eskeland & Feyzioglu, 1997a, 1997b; Galindo & Salinas, 1997; Haro & Ibarrola, 2000; Bauer et al., 2003; Reyes et al., 2010; Crôtte et al., 2010; Solís & Sheinbaum, 2013; Rodriguez-Oreggia & Yepez-Garcia, 2014; Fullerton et al., 2015; Akimaya & Dahl, 2018). Some papers have analysed electricity demand (Berndt & Samaniego,

**TABLE 1**
**POVERTY RATE AND GINI INDEX, 2018**

| | Total | North | Center | South | Urban | Rural |
|---|---|---|---|---|---|---|
| **Poverty rate** | 23.84 | 21.15 | 19.25 | 37.22 | 17.98 | 43.19 |
| **Gini index** | 0.3711 | 0.3618 | 0.3594 | 0.3881 | 0.3547 | 0.3686 |

NOTE: The poverty rate is a percentage.
**SOURCE:** Own elaboration with data from INEGI (2022b).

1984; Chang & Martinez-Chambo, 2003; Salgado & Bernal, 2007; Hancevic & Lopez-Aguilar, 2019). Finally, we find studies on demand for various energy products (Sterner, 1989; Sheinbaum et al., 1996; Galindo, 2005).

On the other hand, the study of energy demand in the context of a complete demand system to analyse the effects of different policies affecting the energy sector has also received attention. Thus, Moshiri and Martinez (2018) study the effects of increases in the prices of energy products as a result of the 2014 Mexican energy reform; Renner et al. (2018) analyse the effects of the introduction of a carbon tax; Rosas-Flores et al. (2017) and Labeaga et al. (2021) study the impacts of the removal of energy subsidies and the introduction of carbon taxes; Ramírez et al. (2021) assess the impact of the 2014 Mexican energy reform; while Ortega and Medlock (2021) study the elasticity of demand for energy products as a function of household income level.

In addition to the aforementioned objectives, this paper aims to update the previous literature by using more recent data and simulating the impacts of introducing higher carbon prices that allow for a significant reduction in GHG emissions associated with energy consumption. To this end, the article is divided into five sections, including this introduction. Section 2 presents the data used and the methodology employed, while Section 3 reports the estimation results of the econometric model used. Section 4 presents the results of the simulations. The paper ends up with a summary and conclusion.

## 2. Data, variables, and demand system estimation for Mexico

### *2.1. Data and variables*

We use microdata for the period 2006-2018 from the Encuesta Nacional de Ingresos y Gastos del Hogar (ENIGH) published by the Bureau of Statistics of Mexico (INEGI, Instituto Nacional de Estadística y Geografía). It is a biannual survey that uses face-to-face interviews to collect household budget data using stratified random sampling. The survey collects information on the value of household expenditures on different goods and services, providing detailed information on household and housing characteristics (see INEGI, 2022b). The initial sample size is 251,437 observations for all the pooled biannual cross-sections. The characteristics of the data as well as our own objectives make us select the sample as follows. We drop households where several families live, households with no expenditure on food, no expenditure on non-durable goods and households with no income, as well as first top and bottom percentiles of the distributions of total non-durable expenditure and income. This process reduces the sample by 21,142 observations. As we explain latter on, we do further sample selection in specific exercises.

We use the following categories of expenditure:[3] food at home, low octane gasoline (magna), high octane gasoline (premium), liquefied petroleum gases (LPG), electricity, and other non-durable goods:[4] Since our aim is to estimate a flexible Almost Ideal Demand System (either linear or quadratic), we calculate the expenditure shares for each commodity by dividing the expenditure on it by the total expenditure on non-durable goods in the household. As we will see later, in the specification of the demand model we include a wide set of sociodemographic variables whose definitions and descriptive statistics are in Table A1 in Appendix A.[5] Thus, 31.7% of households live in the north of the country, while 44% live in the center and the remaining 24.3% in the south. Furthermore, 67.8% of households live in urban areas, 63.3% own a house without a mortgage, 12.7% rent the house where they live, 27% own a car, and 48% own a vehicle (car, van, pickup and/or motorbike). The household head is, on average 48.8 years old, 25.9% of household heads are women, and 10.2% report higher education level, while 26.6% report having only primary education.

We need price data with as much variation as possible to identify own and cross-price effects. We do have in the ENIGH survey information about the week where the interview took place. From this information, we create the variable month. The INEGI (2022c) considers the price indexes of different goods as well as the Retail Price Index (Índice Nacional de Precios al Consumo, INPC from now on) at monthly

[3] All monetary variables, prices included, have been deflated using the regional Retail Price Index (RPI) to get variables in real terms.

[4] Other non-durable goods include non-alcoholic drinks, alcoholic drinks, tobacco, housing goods for cleaning and caring, goods for personal care, newspapers, stationery not for education, oils, lubricants and additives, candles and candlesticks, other fuels (carboard, paper for burning, etc.), medicines and healing materials, materials for dwelling repairing, photographic material, expenses on gifts to people outside the household (food, drinks and tobacco), diesel and gas for housing, petrol, diesel for transport, wood, fuel for heating and natural gas.

[5] Important variables for the purposes of this paper are geographical location of the household, both Entidad Federativa and municipality. We use the first five digits of variable “ubica_geo”, to get Entidad Federativa (two first digits) and municipality (three following digits). These two different location variables are listed (with assigned numbers) in INEGI (2022a). We check that Entidades Federativas are exactly what is usually named Mexican states.

level in the cities.[6] INEGI provides price data for 46 cities for the whole sample period,[7] which we assign to Entidades Federativas.[8]

We consider the monthly INPC for cities and we assign each household the price corresponding to the month when the survey was conducted. We consider the following nominal price indexes and the Retail Price Index (to construct and use real prices): food, electricity, LPG,[9] magna gasoline, and premium gasoline. To complete a demand system, we add a category of other non-durable goods for which we do not have any information at city level (it implies that we cannot do the previous assignments to Entidades Federativas and municipalities), so the price of other non-durable goods is calculated as a weighted average of prices for alcoholic beverages and tobacco, detergents and similar products, drugs, personal care goods and services, newspapers, and other goods. The weights correspond to the share each household devote to each good.[10] Figure 1 shows some graphical evidence on the evolution of prices.

[6] INEGI also provides information for the INPC for Entidades Federativas, which we introduce, although prices at this level are only available from 2018.

[7] Cities with price data by Entidad Federativa: Aguascalientes (Aguascalientes), Mexicali and Tijuana (Baja California), La Paz (Baja California Sur), Campeche (Campeche), Cd. Acuña, Monclova and Torreón (Coahulia de Zaragoza), Colima (Colima), Tapachula (Chiapas), Cd. Jiménez, Cd. Juárez and Chihuahua (Chihuahua), Ciudad de México (Distrito Federal), Durango (Durango), Cortazar and León (Guanajuato), Acapulco and Iguala (Guerrero), Tulancingo (Hidalgo), Guadalajara and Tepatitlán (Jalisco), Toluca (México), Jacona and Morelia (Michoacán de Ocampo), Cuernavaca (Morelos), Tepic (Nayarit), Monterrey (Nuevo León), Oaxaca and Tehuantepec (Oaxaca), Puebla (Puebla), Querétaro (Querétaro), Chetumal (Quintana Roo), San Luis Potosí (San Luis Potosí), Culiacán (Sinaloa), Hermosillo and Huatabampo (Sonora), Villahermosa (Tabasco), Matamoros and Tampico (Tamaulipas), Tlaxcala (Tlaxcala), Córdoba, San Andrés Tuxtla and Veracruz (Veracruz de Ignacio de la Llave), Mérida (Yucatán), and Fresnillo (Zacatecas).

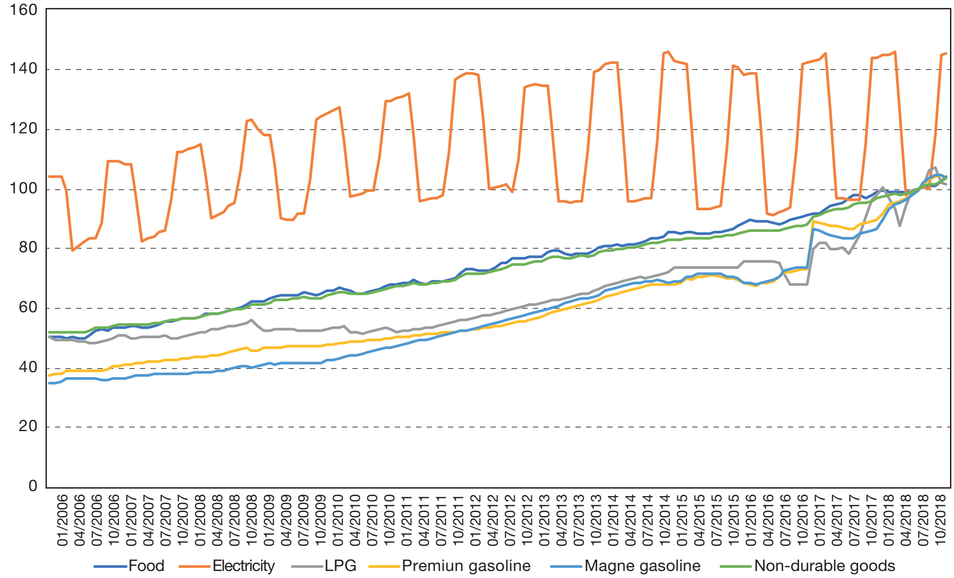
[8] We assign prices to Entidades Federativas as follows: in those Entidades Federativas with only one city, we consider that the prices of the city correspond to the prices of the Entidad Federativa. If there is a Entidad Federativa with several cities, we calculate a population-weighted average of prices for the whole Entidad Federativa and assign these prices to the municipalities of the Entidad Federativa, except to the cities because they have their own price index.

[9] We do not have separated data for LPG and natural gas up to 2011, so from 2006 to 2010 we use the aggregate of two expenditures.

[10] We have a problem to calculate or impute prices for other energy sources (petrol and diesel for housing, carbon, wood, natural gas and other fuels). We have tried several alternatives as impute averages (and minimum) prices of energy sources, weighted by expenditure shares of consumed goods by the household. We do have however an imputation problem with the final number of observations remaining. Since only 32,588 out of 251,437 observations provide positive expenditure on other non-durable goods, a second alternative is to impute average (or minimum) prices of other sources both by groups of expenditure and location. Real prices are again computed using regional RPI. The price of other non-durable goods is calculated as a weighted average of prices of all other non-durable goods outside this group, being the weights the household expenditure. Another alternative we try is to impute this price with the existing price of one (or several) of the components of the non-durables.

**FIGURE 1**

**PRICES EVOLUTION (SECOND HALF OF JULY 2018 = 100)**




NOTES: This graph shows the evolution of prices at the national level, although, as indicated above, we use city-level prices in our analysis. The electricity price profile is due to the existence of electricity subsidies in places that face high temperatures during the summer (minimum average temperature above 25 ºC, see CFE, 2022).

**SOURCE:** INEGI (2022c).

## 2.2. *Demand system*

We have proceeded in several steps to estimate the demand system.[11] All systems we estimate allow for quadratic effects (i.e., demand systems of rank three) to allow for flexible income responses. So, we base our theoretical model on the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) and the Quadratic Almost

[11] Applied general equilibrium models permit analysis of the impacts of policy measures on an economy-wide scale. They are therefore a powerful instrument for analysing efficiency as well as other macroeconomic effects of public policies. Nevertheless, despite their potential, in a non-integrated context with microdata, their capacity of evaluating the distributional effects of such policies on households is limited to the number of different household-types included in the model. Therefore, it lacks the ability to calculate welfare related aspects. By contrast, microeconomic models represent the most usual approach to analysing distributional effects. The most interesting aspect of the use of this data is that it allows the large disparity existing between economic agents to be considered. The main drawback of microsimulation models is that their partial equilibrium setting does not allow relative prices to be endogenized, which leads to potentially biased results. Furthermore, they are not the most appropriate framework for analysing efficiency aspects deriving from public policies. As such, a trade-off must be acknowledged between the analysis of distributional effects and efficiency, and it will be up to researchers to choose from the diversity of instruments available (Labandeira et al., 2007). Since in this paper we are interested in analysing the distributional impacts of the reforms, rather than efficiency issues, we have chosen to link behavioural responses of households to a microsimulation tool.

Ideal Demand System (QUAIDS) of Banks et al. (1997).[12] The QUAIDS assumes the following cost function:

$$\ln c(u,p) = \ln a(p) + \frac{\ln u\, b(p)}{1 - \lambda(p) \ln u} \qquad [1]$$

where $u$ is utility, $p$ is a set of prices, $a(p)$ is a function that is homogenous of degree one in prices, $b(p)$ and $\lambda(p)$ are functions that are homogenous of degree zero in prices. Accordingly, the indirect utility function is:

$$\ln V = \left\{ \left[ \frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \qquad [2]$$

where $m$ is total expenditure, $\ln a(p)$ and $b(p)$ are the translog and Cobb-Douglas functions of prices defined as:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \qquad b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \qquad [3]$$

where $p_i$ and $p_j$ are price indices of goods $i$ and $j$, respectively. $\lambda(p)$ is a differentiable, homogenous function of degree zero in prices, and defined as $\lambda(p) = \sum_{i}^{n} \lambda_i \ln p_i$.

The model we estimate is expressed in expenditure shares for each of the goods within total non-durable expenditures. We can derive these equations by applying Shephard's lemma to the cost function [1] or Roy's identity to the indirect utility function [2]. As usual, the demand should satisfy additivity of budget shares, homogeneity of price responses and Slutsky symmetry. We impose additivity by omitting one equation out of the system during the estimation. Homogeneity in single equations is imposed by expressing prices in relative terms to the excluded good. System-homogeneity and Slutsky symmetry concern the whole demand system and cannot be imposed, but we test for them after estimation.

One additional feature of our system is that we have gasoline in our set of goods, for which we observe a non-negligible proportion of zero expenditures. The literature shows (see for instance Labeaga and López, 1997) that they correspond mainly to non-participants, i.e., individuals (households) who do not own a vehicle. So, we assume that households take owning before demand decisions. We propose to estimate a probit model in the first stage and calculate the Inverse Mills Ratio (IMR) that, in turn, is used to correct the budget share equations of all goods at the second stage (see Labeaga and López, 1997, or Labeaga et al., 2021). Given that, to simulate the proposed reforms, we need not only the estimated parameters for owners but for

[12] Details about these two demand models are provided in Deaton and Muellbauer (1980) and Banks et al. (1997) and we omit the details in this paper. It is possible to compare AIDS and QUAIDS elasticities with alternative more flexible results obtained using Exact Affine Stone Index (EASI) demand system proposed by Lewbel and Pendakur (2009). However, this is out of the scope of this paper.

the whole population, we also estimate the equations for non-owners (i.e., a kind of Roy model as described by Cameron and Trivedi, 2005, for instance), but for the whole system of equations.

## 3. Results

We faced several problems in the separate estimation of two very similar types of gasoline (premium and regular). Demand for these products is related to vehicle ownership in a complex manner, first of all to the type of vehicle (extensive margin) but also to the distance driven (intensive margin). We therefore propose the estimation of unconditional and conditional demand models in the spirit of Browning and Meghir (1991) but modelling the decision on ownership as explained before. Given the large number of zeros, we test our estimations and found that separating two different gasolines, magna and premium, does not produce adequate results. Hence, we estimate the demand for aggregate gasoline.

Tables B1-B3 in Appendix B show the estimation results. We observe that prices, household income and many household and housing characteristics are key factors explaining the expenditure shares on food and energy goods. Among sociodemographic variables, geographic location and vehicle ownership appear as relevant demand determinants.

We find, all other variables constant, that the expenditure shares on electricity, are higher in Northern Mexico than in the South. They are also higher in the center for households without a vehicle, but lower for households with a vehicle.

In the case of food, the expenditure share is lower in the north, and in the center but only for households without a vehicle, compared to the south. In turn, the share of LPG expenditure is higher in the north and in the center, while the share of gasoline expenditure is higher in the north and lower in the center, also compared to the south. On the other hand, the significance of income in quadratic terms in all models for all products shows that income effects are not linear.

With respect to price elasticities (see Table 2), the results show that both food and energy products are inelastic goods, with price elasticities being higher, in absolute value, for households without vehicle. Our guess is that the reason behind these results is that owners are richer than non-owners, so that, they are in a better position to face any price shocks. Those who are poor are more motivated –or obliged to adapt to changing prices and their price elasticities therefore higher, while those with more money can afford to pay less attention to price changes. We compare price elasticities across different papers in the literature and we find that our price elasticity of food is similar to that obtained by Ramírez et al. (2021) and it lies within the range of elasticities estimated by Attanasio et al. (2013) for different types of food in Mexico, while the price elasticity of gasoline is also similar to that obtained by Ramírez et al. (2021). The price elasticity of electricity is similar to that estimated by Rosas-Flores et al. (2017), Ortega and Medlock (2021) or Ramírez et al. (2021), while the price elasticity of LPG is in the range of the elasticities estimated by Rosas-Flores et al. (2017) and Labeaga et al. (2021).

For total expenditure elasticities (Table 2), the estimation results show that gasoline and electricity are luxury goods, while food and LPG are normal goods. This suggests that higher energy taxes would fall mainly on the rich. In the case of gasoline, Renner et al. (2018), Ortega and Medlock (2021), Labeaga et al. (2021) or Ramírez et al. (2021) also identify it as a luxury good, while for food the results are similar to those obtained by Renner et al. (2018). In the case of LPG, Rosas-Flores et al. (2017) also identify it as a normal good, while for electricity the results are like those obtained by Labeaga et al. (2021) for households without a vehicle.

If we compare the results of the non-conditional model with the results for households with and without a car, we see that, as indicated above, the price elasticities are higher for households without a vehicle than for households with a vehicle, with the price elasticities of the non-conditional model lying between these values. With respect to income elasticities, they are higher for households without a vehicle than for households with a vehicle (except in the case of food, which are similar). This result may be due to households without a vehicle are generally poorer than households with a vehicle, so their energy consumption is more likely to be below their desired consumption and also because richer households have more substitution possibilities. In this context, given an increase in income, their energy consumption can be expected to increase more (due to the acquisition of energy-consuming durables that were previously unavailable to them) than that of households with a car, which are more likely to already have such durables and are consuming the energy they desire[13].

**TABLE 2**

**MARSHALLIAN OWN-PRICE AND EXPENDITURE ELASTICITIES**

| | **Food** | **Gasoline** | **LPG** | **Electricity** | **Other non-durables** |
|---|---|---|---|---|---|
| **Unconditional demand system** | | | | | |
| Own-price | –0.907*** | –0.481*** | –0.476*** | –0.672*** | –1.804*** |
| Expenditure | 0.622*** | 1.774*** | 0.889*** | 0.271*** | 1.702*** |
| **Conditional on owning a vehicle** | | | | | |
| Own-price | –0.840*** | –0.557*** | –0.408*** | –0.671*** | –1.498*** |
| Expenditure | 0.600*** | 1.337*** | 0.818*** | 1.133*** | 1.481*** |
| **Conditional on not owning a vehicle** | | | | | |
| Own-price | –0.950*** | – | –0.663*** | –0.713*** | –2.220*** |
| Expenditure | 0.590*** | – | 0.963*** | 1.172*** | 1.883*** |

NOTE: *** indicates significance at 1 %.
**SOURCE:** Own calculations.

[13] In this sense, Ortega and Medlock (2021) estimate the demand for various energy products in Mexico by household income level, obtaining higher income elasticities for poorer households.

## 4. Simulation step

### *4.1. Simulation procedure*

Our simulation procedure is as follows: First, we calculate the new shares in 2018 using the parameters obtained from the estimation of the conditional model and the new prices. With the new expenditure shares, if we assume total expenditure on durable goods remains unchanged, we obtain the new expenditures on the different goods considered. Dividing the expenditure shares on the different energy products before and after the reform by their average price in 2018 we obtain the consumption before and after the reform, which allows us to evaluate their impact on energy consumption and associated emissions (using the emission factors), as well as the additional revenue generated by the reform.

We would also be interested in providing some welfare measure arising from the reforms. Despite the various conceptual drawbacks fully described in Banks et al. (1996), the change in household welfare is quantified through the equivalent gain, a money-metric impact of price changes and/or income changes. An equivalent gain (loss) is the amount of money that needs to be subtracted from (given to) the household to attain the pre-reform level of utility at final prices. We follow the method of King (1983) in computing this measure, although adapting it to the QAIDS, in a similar way to Thomas (2022). In this sense, we evaluate the equivalent loss (gain) for the case of a price change as:

$$EL^h = c(u_0, p^0) - c(u_0, p^1) \qquad [4]$$

where $u_0$ is pre-reform utility, $p^0$ and $p^1$ are the vector of pre- and post-reform prices, respectively, $c(u_0, p^0)$ the observed pre-shock expenditure and $c(u_0, p^1)$ the equivalent income, i.e., the expenditure level at pre-reform prices that is equivalent in utility terms to household expenditure at final prices. We calculate it from the expenditure function [1], using the parameters estimated in the conditional QUAIDS and the prices before and after the reform. The level of utility before the reform is calculated in [2] using the prices before the reform. Finally, to see the net distributional impact of the reforms we consider the index of Reynolds and Smolensky (1977).

### *4.2. Alternative scenarios*

We consider several scenarios for simulation based on the introduction of a carbon tax. We introduce a $CO_2$ emissions tax on energy products covered by our model, using two alternatives, a tax rate of \$25/t$CO_2$ and a tax rate of \$50/t$CO_2$. To calculate the tax rates on each of the energy products we use the emission factors from INECC (2014) for gasoline and LPG, and CRE (2019) for electricity, as well as the OECD exchange rate (2022), to express the tax rates in Mexican pesos. Table 3 summarizes the different alternatives.

**TABLE 3**
**ALTERNATIVE SCENARIOS**

| Energy product | $CO_2$ tax | |
|---|---|---|
| | **Reform 1 25 \$/t$CO_2$** | **Reform 2 50 \$/t$CO_2$** |
| Gasoline | 1.157 pesos/l | 2.314 pesos/l |
| Electricity | 262 pesos/MWh | 525 pesos/MWh |
| LPG | 1.495 pesos/kg | 2.989 pesos/kg |

**SOURCE:** Own calculations.

We consider 2018 prices of magna and premium gasoline from IEA (2019), as well as the price of LPG from SENER (2019), on which we apply the tax considered to obtain the corresponding price increase because of the reform, assuming full-pass-through to consumers. The results are presented in Table 4. In the case of residential electricity, as noted above, Mexican tariffs are heavily subsidized, so it is unrealistic to assume that the new tax on electricity will be fully passed on to consumers, so we assume that the 25(50) \$/t$CO_2$ tax will increase the residential price of electricity by 10(20)%.[14]

Since our proposed reforms generate additional tax revenue, we use it to reduce poverty and inequality. To do so, we consider two compensatory schemes: a lump-sum transfer to all households (Transfer 1) and a lump-sum transfer targeted only to the poorest households (defined as those in the bottom three deciles of income, Transfer 2).

**TABLE 4**
**PRICE IMPACT OF DIFFERENT ALTERNATIVES (PERCENT OF VARIATION)**

| Energy product | $CO_2$ tax | |
|---|---|---|
| | **Reform 1 25 \$/t$CO_2$** | **Reform 2 50 \$/t$CO_2$** |
| Gasoline | 5.73 | 12.13 |
| Electricity | 10.00 | 20.00 |
| LPG | 10.49 | 22.17 |

**SOURCE:** Own calculations.

### *4.3. Simulation results. Reform 1*

The introduction of a \$25/t $CO_2$ tax on energy products would reduce their demand 5.10%, with associated $CO_2$ emissions reduction of 3.52%. The additional revenue obtained would be 27,800 million pesos. In terms of welfare effects, the reform would lead to an average equivalent loss of 1.53%, and it has a progressive impact, with

[14] Renner et al. (2018) used data for 2014, and they estimate a 9% increase in price of residential electricity with a tax of \$25/t$CO_2$.

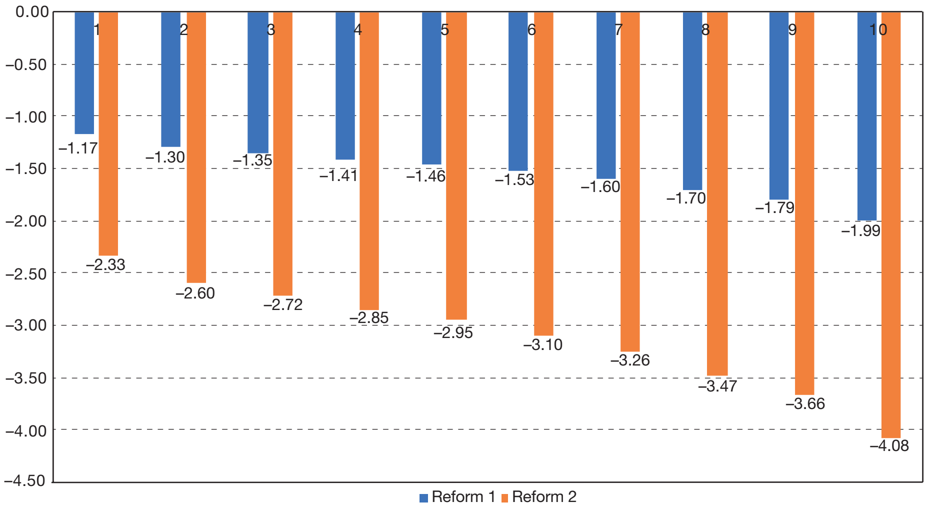
the equivalent gain decreasing as the income rises (or equivalent loss increasing with income, Figure 2). This result is because the progressive impact of the increase in the price of gasoline more than offsets the regressive impact derived from the increase in the price of electricity. Thus, if we consider the effect of the reform on each of the energy products separately (Table B4 in Appendix B), we see that the increase in the price of electricity has a clearly regressive impact, with the average equivalent gain increasing with income, while the increase in the price of gasoline has a progressive effect, since wealthy households are more likely to own a car (see Table A3 in Appendix A) and, also to consume more at the intensive margin. On the other hand, the impact of the price of LPG is progressive in the lower income deciles and regressive in the higher income deciles, because average LPG expenditure shares are increasing in the lower income deciles and decreasing in the higher income deciles. Finally, if we analyze the results by household type (Figure 3), we see that, although they are quite similar, the equivalent loss will be, on average, slightly higher for couples without children, and slightly lower for couples with children.

Although the reform affects richer households more, it also harms some poor households, which see their energy costs increase, so the net distributional effect of the reform is unclear. Furthermore, the reform would increase the poverty rate (Figures 4 and 5), except in the south, where it would be very slightly reduced, as well as inequality, both at the national level and in each of the different areas considered (Table 5). So, these results justify the need to introduce compensatory schemes.

**FIGURE 2**

**EQUIVALENT GAIN PER INCOME DECILE**

**(In %)**

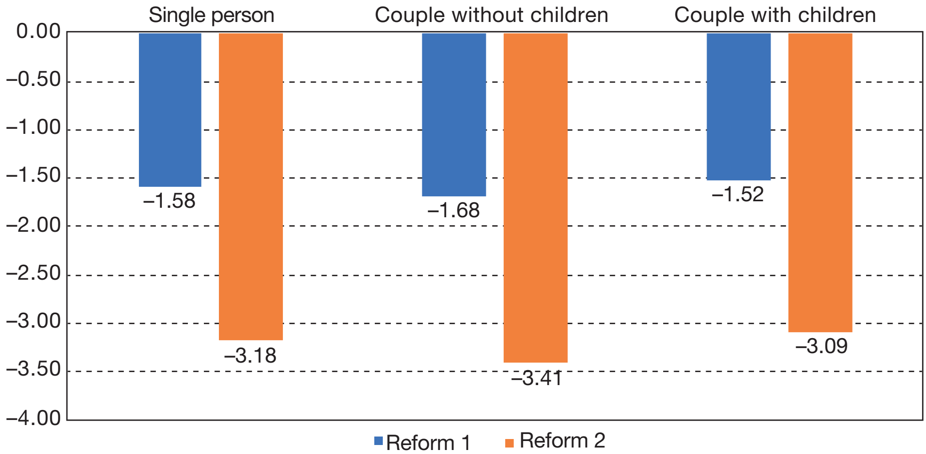



NOTE: Equivalent gain is defined as the percent of total non-durable expenditure.
**SOURCE:** Own calculations.

**FIGURE 3**

**EQUIVALENT GAIN BY HOUSEHOLD TYPE**

**(In %)**

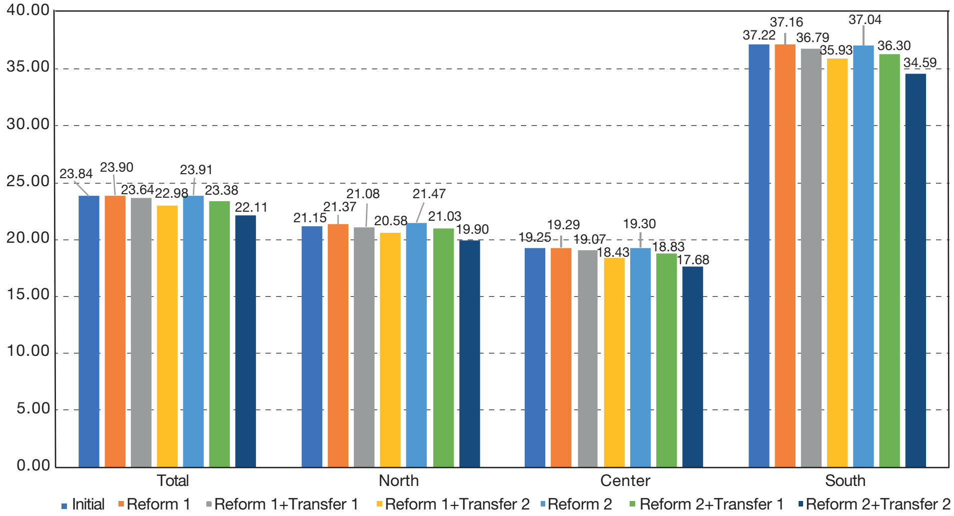



NOTE: Equivalent gain is defined as the percent of total non-durable expenditure.
**SOURCE:** Own calculations.

**FIGURE 4**

**POVERTY RATE BY GEOGRAPHICAL AREA**

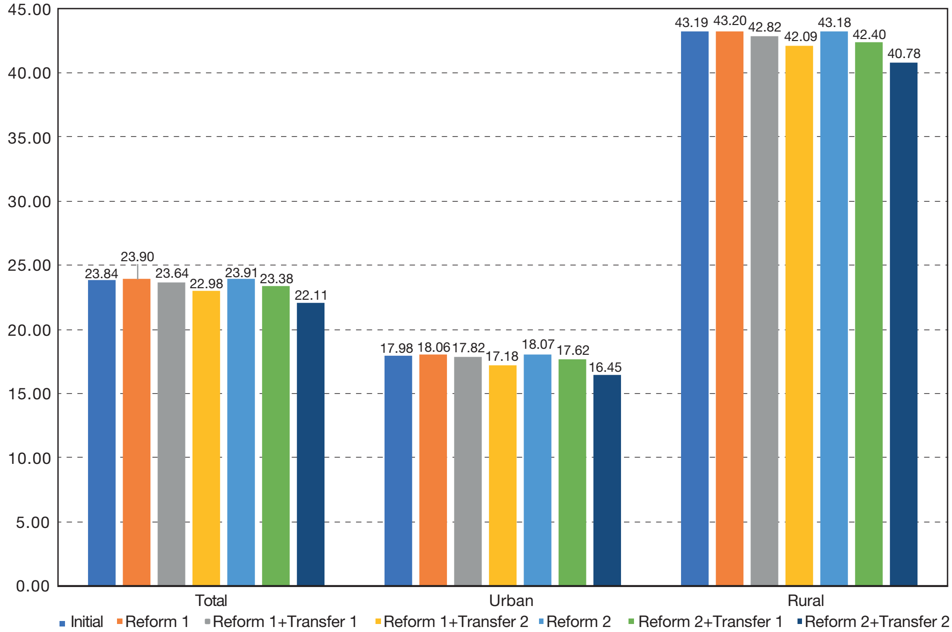
**(In %)**




**SOURCE:** Own calculations.

If the additional revenue is used to compensate all households through a lump sum transfer, each household would receive an annual amount of 888 pesos. This scheme would reduce inequality and the poverty rate with respect to the situation before the reform, both at the aggregate level and in the different areas considered. However, we can see that average reductions are not very large. On the other hand, if we introduce the scheme to compensate households in the three bottom deciles of income, each household will receive 2958 pesos per year and the measure would make it possible to achieve greater reductions in inequality and in the poverty rate. In both cases the Reynolds-Smolensky index would become positive (0.0024 and 0.0067, respectively), so that the compensatory package converts a regressive into a net progressive reform,[15] while at the same time reducing inequality and poverty (Figures 4 and 5 for geographical area and urban-rural divide respectively, and Table 5).

**FIGURE 5**
**POVERTY RATE BY URBAN-RURAL DIVIDE**
**(In %)**




**SOURCE:** Own calculations.

15 Gonzalez (2012), using a general equilibrium model to assess the distributional effects of a carbon tax in Mexico, also shows that recycling revenue through transfers to households (in his case through a food subsidy) allows the carbon tax to have a progressive impact. He provides global measures of redistribution at the cost of losing detailed heterogeneity.

**TABLE 5**
**GINI INDEX**

| | Total | North | Center | South | Urban | Rural |
|---|---|---|---|---|---|---|
| Initial | 0.3711 | 0.3618 | 0.3594 | 0.3881 | 0.3547 | 0.3686 |
| **Reform 1** | | | | | | |
| No compensation | 0.3716 | 0.3625 | 0.3599 | 0.3884 | 0.3552 | 0.3688 |
| Transfer to all households | 0.3688 | 0.3598 | 0.3573 | 0.3846 | 0.3527 | 0.3646 |
| Transfer to households in the three bottom deciles | 0.3644 | 0.3564 | 0.3540 | 0.3767 | 0.3496 | 0.3548 |
| **Reform 2** | | | | | | |
| No compensation | 0.3721 | 0.3631 | 0.3604 | 0.3886 | 0.3557 | 0.3689 |
| Transfer to all households | 0.3665 | 0.3579 | 0.3554 | 0.3813 | 0.3509 | 0.3608 |
| Transfer to households in the three bottom deciles | 0.3582 | 0.3513 | 0.3490 | 0.3662 | 0.3449 | 0.3421 |

**SOURCE:** Own calculations.

### *4.4 Simulation results. Reform 2*

If instead of a carbon tax of \$25/t$CO_2$, we double the rate to \$50/t$CO_2$, the demand for the energy products considered would fall by 11.33 % and the associated $CO_2$ emissions by 9.74 %, generating an excess revenue of 54026 million pesos. The welfare impacts (Figure 2) would be as expected of greater magnitude than in the previous simulation, with an average equivalent loss of –3.10 %, although they would also be progressive, with an equivalent gain decreasing with income, due, once again, to the progressive impact of the increase in the price of gasoline, which offsets the regressive impact of the increase in the price of electricity (see Table B5 in Appendix B). Also, as in Reform 1, the results by household type show an equivalent loss, on average, slightly lower for couples with children and slightly higher for couples without children (Figure 3).

Anyway, this reform would also have a net regressive distributive effect (Reynolds-Smolensky of –0.0009) and would increase the poverty rate (except in the south, where it is slightly reduced, and in rural areas, where it hardly varies), increasing inequality in each of the areas considered to a greater extent than with Reform 1 (Figures 4-5 and Table 5), which justifies the application of a compensatory scheme here as well. In the same scenarios as before for the transfer schemes, now a lump-sum transfer to all households spending all additional revenue represents each household would receive 1725.6 pesos per year, while if the transfer is targeted only to households in the three bottom income deciles, each household would receive 5751.8 pesos per year. Again, with the compensatory schemes (and as before especially the second compensatory package) the reform would contribute to reduce inequality and poverty (Figures 4-5 and Table 5), with a progressive net distributional impact (the Reynolds-Smolensky index with the compensations would be 0.0046 and 0.0129, respectively).

## 5. Summary and conclusions

This paper analyzes the effects on households of a carbon tax on energy products in Mexico trying to achieve significant reductions in $CO_2$ emissions associated with domestic energy consumption. First, we estimate a complete demand system for Mexican households, then we use the results to simulate the revenue and distributional effects of the application of a carbon tax within two scenarios, \$25 and \$50/t$CO_2$. Then, we propose to use the additional revenue generated to compensate households for the negative impacts of the reform.

The results show that the reforms considered would reduce energy consumption and associated emissions, and would also have a progressive impact on welfare, affecting richer households more, because of the progressive effect of the gasoline tax, which offsets the regressive impact of the electricity tax. In any case, the reforms, by increasing the energy expenditure of poor households, would increase poverty and inequality in Mexico. The use of the revenue generated through lump-sum transfers, especially if these are targeted to the poorest households, would reduce inequality and poverty relative to the baseline situation without reform, making the reforms with compensatory packages have a net progressive distributional impact.

Therefore, the implementation of a carbon tax on energy goods with properly defined compensation schemes would achieve reductions in energy consumption and associated $CO_2$ emissions of households, contributing to meet the Mexican commitments derived from the Paris agreement, while at the same time reducing inequality and poverty.

## References

Akimaya, M., & Dahl, C.A. (2018). Estimating the cross-price elasticity of regular gasoline with respect to the price of premium gasoline. *Journal of Transport Economics and Policy*, *52*(2), 157-180. https://www.jstor.org/stable/90019708

Álvarez, J., & Valencia, F. (2015). Made in Mexico: energy reform and manufacturing growth. *Energy Economics*, *55*, 253-265. https://doi.org/10.1016/j.eneco.2016.01.016

Attanasio, O., Di Mario, V., Lechene, V., & Phillips, D. (2013). Welfare consequences of food prices increases: Evidence from rural Mexico. *Journal of Development Economics*, *104*, 136-151. https://doi.org/10.1016/j.jdeveco.2013.03.009

Banks, J., Blundell, R., & Lewbel, A. (1996). Tax reform and welfare measurement: Do we need demand system estimation? *The Economic Journal*, *106* (438), 1227-1241. https://doi.org/10.2307/2235517

Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Review of Economics and Statistics*, *79*(4), 527-539. https://doi.org/10.1162/003465397557015

Bauer, M., Mar, E., & Elizalde, A. (2003). Transport and energy demand in Mexico: the personal income shock. *Energy Policy*, *31*(14), 1475-1780. https://doi.org/10.1016/S0301-4215(02)00203-3

Berndt, E., & Botero, G. (1985). Energy demand in the transportation sector of Mexico. *Journal of Development Economics*, *17*(3), 219-238. https://doi.org/10.1016/0304-3878(85)90091-4

Berndt, E., & Samaniego, R. (1984). Residential electricity demand in Mexico: a model distinguishing access from consumption. *Land Economics*, *60*(3), 268-277. https://doi.org/10.2307/3146187

Browning, M., & Meghir, C. (1991). The effects of male and female labor supply on commodity demands. *Econometrica*, *59*(4), 925-951. https://doi.org/10.2307/2938167

Cameron, C., & Trivedi, P. (2005). *Microeconometrics. Methods and Applications*. Cambridge University Press.

Chang, Y., & Martinez-Chambo, E. (2003). *Electricity demand analysis using cointegration and error-correction models with time varying parameters: the Mexican case*. Rice University, WP2003-10.

CFE, Comisión Federal de Electricidad. (2022, August 8). *Tarifas*. https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/TarifasCRECasa/Casa.aspx

CRE, Comisión Reguladora de Energía. (2019, February 28). *Factor de emisión del sistema eléctrico nacional.* https://www.gob.mx/cms/uploads/attachment/file/442910/Aviso_Factor_de_Emisiones_2018.pdf

Crôtte, A., Noland, R. B., & Graham, D. J. (2010). An analysis of gasoline demand elasticities at the national and local levels in Mexico. *Energy Policy*, *38*(8), 4445-4456. https://doi.org/10.1016/j.enpol.2010.03.076

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, *70*(3), 312-326. https://www.jstor.org/stable/1805222

Eskeland, G., & Feyzioglu, T. (1997a). Is demand for polluting goods manageable? An econometric study of car ownership and use in Mexico. *Journal of Development Economics*, *53*(2), 423-445. https://doi.org/10.1016/S0304-3878(97)00017-5

Eskeland, G., & Feyzioglu, T. (1997b). Rationing can backfire: the "day without a car" in Mexico City. *The World Bank Economic Review*, *11*(3), 383-408. https://doi.org/10.1093/wber/11.3.383

Foster, J., Greer, J., & Thorbecke, E. (1984). A class of decomposable poverty measures. *Econometrica*, *52*(3), 761–766. https://doi.org/10.2307/1913475

Fujiwara, N., Núñez-Ferrer, J., & Egenhofer, C. (2006). *The political economy of environmental taxation in European countries.* CEPS Working Document, 245. https://www.ceps.eu/ceps-publications/political-economy-environmental-taxation-european-countries/

Fullerton, T.M., Ibarra, J., & Elizalde, M. (2015). Microeconomic gasoline consumption anomalies in Mexico: 1997-2007. *Asian Economic and Financial Review*, *5*(4), 709-722. https://doi.org/10.18488/journal.aefr/2015.5.4/102.4.709.722

Gago, A., Labandeira, X., Labeaga, J.M., & López-Otero, X. (2021). Transport taxes and decarbonization in Spain: Distributional impacts and compensation. *Hacienda Pública Española/Review of Public Economics*, *238*(3), 101-136. https://dx.doi.org/10.7866/HPE-RPE.21.3.5

Galindo, L.M. (2005). Short- and long-run demand for energy in Mexico: a cointegration approach. *Energy Policy*, *33*(9), 1179-1185. https://doi.org/10.1016/j.enpol.2003.11.015

Galindo, L.M., & Salinas, E. (1997). La demanda de gasolinas en México, la condición de exogeneidad y el comportamiento de los agentes económicos. In INE-SEMARNAP, *Instrumentos económicos y medio ambiente* (pp. 21-45). Dirección General de Regulación Ambiental, Instituto Nacional de Ecología.

Gately, D., & Streifel, S. (1997). *Demand for oil products in developing countries.* World Bank Discussion Paper 359. The World Bank.

Gonzalez, F. (2012). Distributional effects of carbon taxes: The case of Mexico. *Energy Economics, 34*(6), 2012-2115.

Government of Mexico. (2019). *Primer Informe de Gobierno 2018-2019*. Gobierno de México, Presidencia de la República.

Goverment of Mexico. (2020). *Contribución determinada a nivel nacional. Actualización 2020*. Secretaría de Medio Ambiente y Recursos Naturales, Gobierno de México.

Government of Mexico. (2022, August 8). *Presupuesto de egresos de la Federación. Ejercicio fiscal 2022*. https://www.pef.hacienda.gob.mx/es/PEF2022/home

Guevara, Z., Sebastian, A., & Dumon, F.C. (2022). Economy-wide impact of conventional development policies in oil-exporting developing countries: The case of Mexico. *Energy Policy*, *161*, 112679. https://doi.org/10.1016/j.enpol.2021.112679

Hancevic, P.I., & Lopez-Aguilar, J. (2019). Energy efficiency programs in the context of increasing block tariffs: The case of residential electricity in Mexico. *Energy Policy*, *131*, 320-331. https://doi.org/10.1016/j.enpol.2019.04.015

Hancevic, P., Núñez, H., & Rosellón, J. (2019). *Tariff schemes and regulations: What changes are needed in the Mexican residential electricity sector to support efficient adoption of green technologies?.* Inter-American Development Bank, IBD-WP-1020. http://dx.doi.org/10.18235/0001871

Haro, R.A., & Ibarrola, J.L. (2000). Cálculo de la elasticidad precio de la demanda de gasolina en la zona fronteriza norte de México. *Gaceta de Economía*, *6*(11), 237-262.

Heindl, P. (2015). Measuring fuel poverty: general considerations and application to German household data. *FinanzArchiv/Public Finance Analysis*, *71*(2), 178-215. https://www.jstor.org/stable/24807488

IEA, International Energy Agency. (2016), *Partner Country Series - Fossil Fuel Subsidy Reform in Mexico and Indonesia*. IEA, Paris. https://www.iea.org/reports/partner-country-series-fossil-fuel-subsidy-reform-in-mexico-and-indonesia

IEA, International Energy Agency. (2019), *Energy Prices and Taxes for OECD Countries - 2nd Quarter 2019: An Overview*. IEA, Paris. https://www.iea.org/reports/energy-prices-and-taxes-for-oecd-countries-2nd-quarter-2019-an-overview

IMF, International Monetary Fund. (2019). *Fiscal monitor: How to mitigate climate change*. https://www.imf.org/en/Publications/FM/Issues/2019/09/12/fiscal-monitor-october-2019

IMF/OECD (2021). *Tax policy and climate change*. IMF/OECD REPORT FOR THE G20 FINANCE MINISTERS AND CENTRAL BANK GOVERNORS. https://www.oecd.org/tax/tax-policy/tax-policy-and-climate-change-imf-oecd-g20-report-september-2021.pdf

INECC, Instituto Nacional de Ecología y Cambio Climático. (2014). *Factores de emisión para los diferentes tipos de combustibles fósiles y alternativos que se consumen en México*. Secretaría de Medio Ambiente y Recursos Naturales.https://www.gob.mx/cms/uploads/attachment/file/110131/CGCCDBC_2014_FE_tipos_combustibles_fosiles.pdf

INEGI, Instituto Nacional de Estadística y Geografía. (2022a). *Catálogo único de claves de áreas geoestadísticas estatales, municipales y localidades.* https://www.inegi.org.mx/app/ageeml/

INEGI, Instituto Nacional de Estadística y Geografía. (2022b). *Encuesta nacional de ingresos y gastos de los hogares (ENIGH)*.

INEGI, Instituto Nacional de Estadística y Geografía. (2022c). *Índice nacional de precios al consumidor.* https://www.inegi.org.mx/temas/inpc/

King, M. A. (1983). Welfare analysis of tax reforms using household data. *Journal of Public Economics*, *21*(2), 183-214. https://doi.org/10.1016/0047-2727(83)90049-X

Labandeira, X., Labeaga, J.M., & Rodríguez, M. (2007). Microsimulation in the analysis of environmental tax reforms. An application for Spain. In A. Spadaro, *Microsimulation as a tool for the evaluation of public policies. Methods and applications* (pp. 149-176). Fundación BBVA.

Labeaga, J. M., Labandeira, X., & López-Otero, X. (2021). Energy taxation, subsidy removal and poverty in Mexico. *Environment and Development Economics*, *26*(3), 239-260. https://doi.org/10.1017/S1355770X20000364

Labeaga, J.M. & López, A. (1997). A study of petrol consumption using Spanish panel data. *Applied Economics, 29*(6), 795-802. https://doi.org/10.1080/000368497326714

Lewbel, A., & Pendakur, K. (2009). Tricks with Hicks: The EASI demand system. *American Economic Review*, *99*(3), 827-863. https://doi.org/10.1257/aer.99.3.827

Moshiri, S., & Martinez, M. A. (2018). The welfare effects of energy price changes due to energy market reform in Mexico. *Energy Policy*, *113*, 663-672. https://doi.org/10.1016/j.enpol.2017.11.035

Muñoz Piña, C. (2013). *El impuesto a los combustibles fósiles por contenido de carbono en México*. Secretaría de Hacienda y Crédito Público. https://www.senado.gob.mx/comisiones/cambio_climatico/reu/docs/SHCP.pdf

OECD, Organisation for Economic Co-operation and Development. (2021a). *Carbon pricing in times of covid-19: What has changed in G20 economies?* https://www.oecd.org/tax/tax-policy/carbon-pricing-in-times-of-covid-19-what-has-changed-in-g20-economies.htm

OECD, Organisation for Economic Co-operation and Development. (2021b). *Effective carbon rates 2021: Pricing carbon emissions through taxes and emissions trading*. https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2021-0e8e24f5-en.htm

OECD, Organisation for Economic Co-operation and Development. (2022, February 15). *Exchange rates.*https://data.oecd.org/conversion/exchange-rates.htm

Ortega, A., & Medlock, K. B. (2021). Price elasticity of demand for fuels by income level in Mexican households. *Energy Policy*, *151*, 112132. https://doi.org/10.1016/j.enpol.2021.112132

Parry, I. (2019). Putting a price on pollution. *Finance & Development, 56*(4), 16-19.

Ramírez, J. C., Ortiz-Arango, F., & Rosellón, J. (2021). Impact of Mexico's energy reform on consumer welfare. *Utilities Policy*, *70*, 101191. https://doi.org/10.1016/j.jup.2021.101191

Renner, S., Lay, J., & Greve, H. (2018). Household welfare and CO2 emission impacts of energy and carbon taxes in Mexico. *Energy Economics*, *72*, 222-235. https://doi.org/10.1016/j.eneco.2018.04.009

Reyes, O., Escalante, R., & Matas, A. (2010). La demanda de gasolinas en México: efectos y alternativas ante el cambio climático. *Economía: Teoría y Práctica*, 32, 83-111.

Reynolds, M., & Smolensky, E. (1977). *Public expenditure, taxes and the distribution of income: The United States, 1950, 1961, 1970*. Academic Press.

Rodriguez-Oreggia, E., & Yepez-Garcia, R.A. (2014). *Income and energy consumption in Mexican households*. World Bank Policy Research, Working Paper 6864.

Rosas-Flores, J. A., Bakhat, M., Rosas-Flores, D., & Zayas, J. L. F. (2017). Distributional effects of subsidy removal and implementation of carbon taxes in Mexican households. *Energy economics*, *61*, 21-28. https://doi.org/10.1016/j.eneco.2016.10.021

Salgado, H., & Bernal, L.E. (2007). *Translog cost functions: an application for Mexican manufacturing*. Banco de México, Working Paper nº 2007-08.

SENER, Secretaría de Energía. (2015). *Prospectiva del sector eléctrico 2015–2029.* http://www.gob.mx/cms/uploads/attachment/file/44328/Prospectiva_del_Sector_Electrico.pdf

SENER, Secretaría de Energía. (2019). *Balance nacional de energía 2018*.

SEGOB, Secretaría de Gobernación. (2022, 22 de abril). *Acuerdo por el que se dan a conocer los porcentajes, los montos del estímulo fiscal y las cuotas disminuidas del impuesto especial sobre producción y servicios.* http://www.dof.gob.mx/nota_detalle.php?codigo=5649873&fecha=22/04/2022

SEMARNAT, Secretaría de Medio Ambiente y Recursos Naturales. (2021). *Programa de prueba del sistema de comercio de emisiones.*

SEMARNAT, Secretaría de Medio Ambiente y Recursos Naturales. (2022). *Inventario nacional de emisiones de gases y compuestos de efecto invernadero (INEGyCEI).*

Sheinbaum, C., Martínez, M., & Rodríguez, L. (1996). Trends and prospects in Mexican residential energy use. *Energy*, *21*(6), 493-504. https://doi.org/10.1016/0360-5442(96)00011-4

Solís, J.C., & Sheinbaum, C. (2013). Energy consumption and greenhouse gas emission trends in Mexican road transport. *Energy for Sustainable Development*, *17*(3), 280-287. https://doi.org/10.1016/j.esd.2012.12.001

Somanathan, E., Sterner, T., Sugiyama, T., Chimanikire, D., Dubash, N.K., Essandoh-Yeddu, J., Fifita, S., Goulder, L., Jaffe, A., Labandeira, X., Managi, S., Mitchell, C., Montero, J. P., Teng, F., & Zylicz, T. (2014). National and sub-national policies and institutions. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx, *Climate change 2014: Mitigation of climate change. Contribution of working group III to the fifth assessment report of the Intergovernmental Panel on Climate Change,* (pp. 1141-1205). Cambridge University Press

Speck, S., & Paleari, S. (2016). *Environmental taxation and EU environmental policies.* Report nº 16, European Environment Agency.

Sterner, T. (1985). Structural change and technology choice: Energy use in Mexican manufacturing industry, 1970–1981. *Energy Economics*, *7*(2), 77-86. https://doi.org/10.1016/0140-9883(85)90022-2

Sterner, T., 1989. Factor demand and substitution in a developing country: energy use in Mexican manufacturing. *Scandinavian Journal of Economics*, *91*(4), 723-739. https://doi.org/10.2307/3440216

Thomas, A. (2022). Who would win from a multi-rate GST in New Zealand: evidence from a QUAIDS model. *New Zealand Economic Papers*, *56*(2), 1-28. https://doi.org/10.1080/00779954.2021.2020324

UN, United Nations. (2015). *Paris agreement.* https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Vallés-Giménez, J., & Zárate-Marco, A. (2020). A dynamic spatial panel of subnational GHG emissions: Environmental effectiveness of emissions taxes in Spanish regions. *Sustainability, 12*(7), 2872. https://doi.org/10.3390/su12072872

Vargas, R. (2015). La reforma energética: a 20 años del TLCAN. *Problemas del Desarrollo*, *46*(180), 103–127. Recuperado en 04 de agosto de 2022, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0301-70362015000100006&lng=es&tlng=es.

World Bank (2021). *State and trends of carbon pricing 2021*. https://openknowledge.worldbank.org/handle/10986/35620

World Bank (2022). *Carbon pricing dashboard*. https://carbonpricingdashboard.worldbank.org

# APPENDIX A

# DATA DESCRIPTION

## TABLE A1
## DESCRIPTIVE STATISTICS OF MAIN VARIABLES

| | Observa-tions | Mean | Standard deviation | Mini-mum | Maxi-mum |
|---|---|---|---|---|---|
| Food share | 230,295 | 0.5344 | 0.1788 | 0.0020 | 1 |
| Magna gasoline share | 230,295 | 0.0775 | 0.1234 | 0 | 0.9894 |
| Premium gasoline share | 230,295 | 0.0076 | 0.0459 | 0 | 0.8229 |
| LPG share | 230,295 | 0.0410 | 0.0567 | 0 | 0.7865 |
| Electricity share | 230,295 | 0.0507 | 0.0599 | 0 | 0.9301 |
| Other non-durable goods share | 230,295 | 0.2888 | 0.1364 | 0 | 0.9955 |
| Gasoline share | 230,295 | 0.0851 | 0.1278 | 0 | 0.9894 |
| Food price | 230,295 | 0.8337 | 0.1673 | 0.4792 | 1.0468 |
| Magna gasoline price | 230,295 | 0.7294 | 0.2306 | 0.3474 | 1.0793 |
| Premium gasoline price | 230,295 | 0.7213 | 0.2492 | 0.3386 | 1.0865 |
| LPG price | 230,295 | 0.7439 | 0.2092 | 0.3949 | 1.0968 |
| Electricity price | 230,295 | 1.0584 | 0.3357 | 0.5533 | 2.9848 |
| Other non-durable goods price | 230,295 | 0.8577 | 0.1420 | 0.4288 | 1.1123 |
| Gasoline price | 230,295 | 0.7265 | 0.2367 | 0.3397 | 1.0865 |
| Total expenditure on non-durables | 230,295 | 12,429.10 | 7,454.99 | 1,497.42 | 44,821.69 |
| Income | 230,295 | 36,954.51 | 28,754.24 | 4,065.05 | 182,587.4 |
| Gender | 230,295 | 0.2593 | 0.4382 | 0 | 1 |
| Age | 230,295 | 48.7931 | 15.6677 | 12 | 110 |
| Members ≥12 years | 230,295 | 2.9560 | 1.4244 | 1 | 33 |
| Members <12 years | 230,295 | 0.8615 | 1.0809 | 0 | 13 |
| Urban | 230,295 | 0.6784 | 0.4671 | 0 | 1 |
| Rural | 230,295 | 0.3216 | 0.4671 | 0 | 1 |
| North | 230,295 | 0.3175 | 0.4655 | 0 | 1 |
| Center | 230,295 | 0.4399 | 0.4964 | 0 | 1 |
| South | 230,295 | 0.2426 | 0.4287 | 0 | 1 |
| Less than primary education | 230,295 | 0.2660 | 0.4419 | 0 | 1 |
| Primary education | 230,295 | 0.2307 | 0.4213 | 0 | 1 |
| Secondary education | 230,295 | 0.4013 | 0.4902 | 0 | 1 |
| Higher education | 230,295 | 0.1021 | 0.3027 | 0 | 1 |
| Number of rooms | 230,295 | 3.7005 | 1.5414 | 0 | 23 |
| Rented housing | 230,295 | 0.1268 | 0.3327 | 0 | 1 |

**SOURCE:** Own calculations.

**TABLE A1 *(Cont.)***
**DESCRIPTIVE STATISTICS OF MAIN VARIABLES**

| | Observations | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Owned house with mortgage | 230,295 | 0.0834 | 0.2765 | 0 | 1 |
| Owned house without mortgage | 230,295 | 0.6332 | 0.4819 | 0 | 1 |
| Dwelling in other situation | 230,295 | 0.1567 | 0.3635 | 0 | 1 |
| Van | 230,295 | 0.1160 | 0.3202 | 0 | 1 |
| Car | 230,295 | 0.2703 | 0.4441 | 0 | 1 |
| Radio recorder | 230,295 | 0.2002 | 0.4002 | 0 | 1 |
| Radio | 230,295 | 0.2039 | 0.4029 | 0 | 1 |
| TV | 230,295 | 0.9295 | 0.2560 | 0 | 1 |
| Videotape player | 230,295 | 0.0855 | 0.2796 | 0 | 1 |
| Blender | 230,295 | 0.8548 | 0.3523 | 0 | 1 |
| Microwave | 230,295 | 0.4189 | 0.4934 | 0 | 1 |
| Refrigerator | 230,295 | 0.8576 | 0.3494 | 0 | 1 |
| Stove | 230,295 | 0.8905 | 0.3122 | 0 | 1 |
| Washing machine | 230,295 | 0.6589 | 0.4741 | 0 | 1 |
| Iron | 230,295 | 0.7803 | 0.4141 | 0 | 1 |
| Fan | 230,295 | 0.5495 | 0.4975 | 0 | 1 |
| Vacuum cleaner | 230,295 | 0.0640 | 0.2447 | 0 | 1 |
| Computer | 230,295 | 0.2372 | 0.4254 | 0 | 1 |
| Vehicle | 230,295 | 0.4793 | 0.4996 | 0 | 1 |

**SOURCE:** Own calculations.

## Definition of variables

- Geographical area:
  - North (Baja California, Baja California Sur, Coahuila de Zaragoza, Chihuahua, Durango, Nuevo León, Sinaloa, Sonora, Tamaulipas, Zacatecas)
  - Centre (Aguascalientes, Colima, DF, Guanajuato, Hidalgo, Jalisco, México, Michoacán, Morelos, Nayarit, Puebla, Querétaro, San Luis Potosí, Tlaxcala)
  - South (Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz de Ignacio de la Llave, Yucatán)
- Area of residence:
  - urban (municipality ≥ 2500 inhabitants)
  - rural (municipality < 2500 inhabitants)
- Quarterly household income
- Gender of household head: female (gender = 1), male (gender = 0)
- Age of household head

– Level of education of household head: Less than primary education, primary education, secondary education, higher education
– Number of household members ≥12 years
– Number of household members <12 years
– Number of rooms in the dwelling
– Housing tenure: rented, owned with mortgage, owned without mortgage, other situation
– Ownership of car, van, radio recorder, radio, television, videotape player, blender, microwave, refrigerator, stove, washing machine, iron, fan, vacuum cleaner, computer, vehicle (car, van, pickup and/or motorbike).

## Comparison of samples by type of gasoline demand

**TABLE A2**
**DIFFERENCES IN SAMPLES BY TYPE OF GASOLINE CONSUMPTION**

| | **Magna gasoline consumers** | **Premium gasoline consumers** |
|---|---|---|
| Real income | 56,541.17 | 79,502.37 |
| Real expenditure on non-durables | 18,763.66 | 22,231.6 |
| Gender (female=1) | 0.1796 | 0.2102 |
| Age of head of household | 47.9586 | 48.1070 |
| Members ≥12 years | 3.1277 | 2.8565 |
| Members <12 years | 0.8573 | 0.7044 |
| Urban | 0.7028 | 0.8141 |
| North | 0.4161 | 0.3672 |
| Center | 0.4113 | 0.4189 |
| South | 0.1725 | 0.2140 |
| Below primary school | 0.1746 | 0.1075 |
| Primary education | 0.2021 | 0.1400 |
| Secondary education | 0.4555 | 0.4160 |
| Higher education | 0.1678 | 0.3365 |

**SOURCE:** Own calculations.

Households that consume premium gasoline have on average higher incomes and expenditures on non-durables, a lower number of members (both older and younger), a higher percentage of female-headed households, of households living in urban areas, of households living in the south (and a lower percentage of households living in the north) and of households in which the head has higher education (and a lower percentage of households with less than primary, elementary or secondary education). More than half of the households that consume premium gasoline belong to the two highest income and expenditure deciles.

## Comparison of samples by ownership of vehicles

**TABLE A3**
**DIFFERENCES IN SAMPLES BY VEHICLE OWNERSHIP**

| | With vehicle | Without vehicle |
|---|---|---|
| Real income | 56,662.24 | 30,840.98 |
| Real expenditure on non-durables | 18,321.7 | 10,911.75 |
| Gender (female=1) | 0.1845 | 0.3281 |
| Age of head of household | 48.2813 | 49.2641 |
| Members ≥12 years | 3.1093 | 2.8150 |
| Members <12 years | 0.8404 | 0.8810 |
| Urban | 0.7063 | 0.6528 |
| North | 0.4041 | 0.2378 |
| Center | 0.4213 | 0.4570 |
| South | 0.1747 | 0.3052 |
| Below primary school | 0.1797 | 0.3454 |
| Primary education | 0.2032 | 0.2559 |
| Secondary education | 0.4468 | 0.3594 |
| Higher education | 0.1703 | 0.0393 |

**SOURCE:** Own calculations.

Households with vehicles have higher average incomes and expenditures on non-durables, a higher number of older members (but fewer younger members), a higher percentage of male-headed households, of households living in urban areas, of households living in the north (and a lower percentage of households living in the south), and of households in which the head has higher or secondary education (and a lower percentage of households with less than primary or elementary education).

More than half of the households without a vehicle belong to the first four deciles of income or expenditure on non-durables, while households with a vehicle belonging to the first four deciles account for just over 20% of these households. Therefore, we can assume that households without vehicles, mostly poor households, have higher price elasticities because their consumption is so tight that they must reduce their consumption in the face of any price increase. On the other hand, their income elasticity is lower because they cannot do anything about a marginal increase in their income and would need a significant increase in income to be able to change their consumption.

# APPENDIX B

# ESTIMATION AND SIMULATION RESULTS

## TABLE B1
## UNCONDITIONAL QUAIDS ESTIMATES

| | Food | Gasoline | LPG | Electricity | Other non-durables |
|---|---|---|---|---|---|
| Log price food | –0.1088*** | –0.0106* | 0.0016 | –0.0476*** | 0.1655*** |
| Log price gasoline | –0.0106** | 0.0427*** | –0.0139*** | –0.0185*** | 0.0003 |
| Log price LPG | 0.0016 | –0.0139*** | 0.0224*** | 0.0029** | –0.0130*** |
| Log price electricity | –0.0476*** | –0.0185*** | 0.0029*** | 0.0134*** | 0.0499*** |
| Log price other non–durables | 0.1655*** | 0.0003 | –0.0130*** | 0.0499*** | –0.2027*** |
| Log expenditure | –0.1672*** | 0.0853*** | 0.0123*** | –0.0657*** | 0.1354*** |
| Log expenditure$^2$ | –0.0125*** | –0.0061*** | –0.0058*** | 0.0066*** | 0.0179*** |
| IV total expenditure | 0.2471*** | –0.0546*** | –0.0063*** | 0.0226*** | –0.2089*** |
| Gender | –0.0078*** | –0.0129*** | 0.0024*** | 0.0028*** | 0.0156*** |
| Age | 0.0029*** | 0.0001* | 0.0001*** | 0.0004*** | –0.0036*** |
| Age$^2$ | –0.0000*** | –0.0000*** | 0.0000*** | –0.0000*** | 0.0000*** |
| Members ≥ 12 years | 0.0327*** | –0.0113*** | –0.0007*** | 0.0020*** | –0.0227*** |
| Member < 12 years | 0.0252*** | –0.0088*** | –0.0013*** | 0.0022*** | –0.0173*** |
| Urban | 0.0215*** | –0.0213*** | 0.0007** | 0.0110*** | –0.0118*** |
| North | –0.0906*** | 0.0253*** | 0.0085*** | 0.0261*** | 0.0308*** |
| Center | –0.0078*** | –0.0045*** | 0.0119*** | –0.0017*** | 0.0021** |
| Less than primary education | –0.0052*** | –0.0150*** | 0.0003 | 0.0004 | 0.0194*** |
| Primary education | 0.0026 | –0.0203*** | 0.0013*** | 0.0009* | 0.0155*** |
| Secondary education | 0.0116*** | –0.0212*** | 0.0005 | –0.0006 | 0.0096*** |
| Number of rooms | –0.0005 | 0.0009*** | 0.0009*** | 0.0013*** | –0.0026*** |
| Rented house | –0.0075*** | 0.0023*** | –0.0018*** | –0.0026*** | 0.0095*** |
| Owned house with mortgage | –0.0066*** | 0.0077*** | –0.0062*** | –0.0012** | 0.0064*** |
| Owner house without mortgage | 0.0048*** | 0.0026*** | –0.0010*** | 0.0017*** | –0.0082*** |
| Van | –0.0260*** | 0.0903*** | –0.0035*** | 0.0016*** | –0.0625*** |
| Car | –0.0303*** | 0.1084*** | –0.0058*** | –0.0002 | –0.0721*** |
| Radio recorder | 0.0032*** | –0.0052*** | 0.0008*** | 0.0008*** | 0.0004 |
| Radio | –0.0006 | –0.0022*** | 0.0010*** | 0.0010*** | 0.0007 |
| TV | 0.0124*** | 0.0039*** | 0.0016*** | 0.0057*** | –0.0158*** |
| Videotape player | 0.0074*** | –0.0097*** | 0.0016*** | 0.0039*** | –0.0032** |
| Blender | 0.0241*** | –0.0035*** | 0.0050*** | 0.0007* | –0.0263*** |
| Microwave | –0.0010 | 0.0044*** | –0.0008*** | 0.0025*** | –0.0051*** |
| Refrigerator | 0.0023 | –0.0008 | 0.0015*** | 0.0080*** | –0.0110*** |
| Stove | 0.0097*** | –0.0090*** | 0.0340*** | 0.0065*** | –0.0412*** |
| Washing machine | 0.0098*** | 0.0011** | 0.0005* | 0.0012*** | –0.0125*** |
| Iron | 0.0152*** | –0.0026*** | 0.0018*** | 0.0013*** | –0.0157*** |
| Fan | –0.0023** | –0.0013*** | –0.0103*** | 0.0098*** | 0.0041*** |
| Vacuum cleaner | 0.0095*** | –0.0004 | –0.0009* | 0.0039*** | –0.0121*** |
| Computer | 0.0163*** | 0.0042*** | –0.0011*** | 0.0004 | –0.0197*** |
| Constant | 0.5774*** | 0.0283*** | –0.0131*** | 0.0657*** | 0.3417*** |

NOTE: ***, **, * report significance at 1%, 5% and 10%, respectively.
**SOURCE:** Own calculations.

## TABLE B2
## CONDITIONAL QUAIDS ESTIMATES (OWNERS)

| | **Food** | **Gasoline** | **LPG** | **Electricity** | **Other non-durables** |
|---|---|---|---|---|---|
| Log price food | –0.0563*** | –0.0303*** | 0.0068* | –0.0247*** | 0.1044*** |
| Log price gasoline | –0.0303*** | 0.0778*** | –0.0183*** | –0.0225*** | –0.0068 |
| Log price LPG | 0.0068 | –0.0183*** | 0.0232*** | 0.0007 | –0.0125*** |
| Log price electricity | –0.0247*** | –0.0225*** | 0.0007 | 0.0181*** | 0.0284*** |
| Log price other non-durables | 0.1044*** | –0.0068 | –0.0125*** | 0.0284*** | –0.1136*** |
| Log expenditure | –0.1295*** | 0.0951*** | 0.0099*** | –0.0243*** | 0.0487*** |
| Log expenditure$^2$ | –0.0160*** | –0.0101*** | –0.0049*** | 0.0090*** | 0.0220*** |
| IV total expenditure | 0.2264*** | –0.0602*** | –0.0049*** | –0.0265*** | –0.1349*** |
| Gender | –0.0181*** | 0.0122*** | –0.0000 | –0.0105*** | 0.0164*** |
| Age | 0.0035*** | –0.0012*** | 0.0003*** | 0.0008*** | –0.0034*** |
| Age$^2$ | –0.0000*** | 0.0000*** | 0.0000 | –0.0000*** | 0.0000*** |
| Members ≥ 12 years | 0.0303*** | –0.0149*** | 0.0000 | –0.0021*** | –0.0133*** |
| Member < 12 years | 0.0246*** | –0.0149*** | –0.0004** | –0.0006*** | –0.0087*** |
| Urban | 0.0166*** | 0.0005 | –0.0028*** | –0.0027*** | –0.0116*** |
| North | –0.0776*** | 0.0234*** | 0.0071*** | 0.0377*** | 0.0093*** |
| Center | –0.0009 | –0.0042*** | 0.0098*** | –0.0030*** | –0.0016 |
| Less than primary education | –0.0098*** | –0.0095*** | 0.0003 | –0.0077*** | 0.0268*** |
| Primary education | –0.0011 | –0.0157*** | 0.0017*** | –0.0054*** | 0.0205*** |
| Secondary education | 0.0081*** | –0.0158*** | –0.0001 | –0.0045*** | 0.0122*** |
| Number of rooms | 0.0021*** | –0.0030*** | 0.0013*** | 0.0033*** | –0.0038*** |
| Rented house | –0.0099*** | 0.0137*** | –0.0016*** | –0.0038*** | 0.0016 |
| Owned house with mortgage | –0.0056** | 0.0084*** | –0.0050*** | 0.0022*** | 0.0001 |
| Owner house without mortgage | 0.0077*** | –0.0104*** | –0.0001 | 0.0086*** | –0.0058*** |
| Radio recorder | 0.0058*** | –0.0037*** | 0.0007* | –0.0024*** | –0.0003 |
| Radio | 0.0019 | –0.0035*** | 0.0017*** | 0.0003 | –0.0003 |
| TV | 0.0173*** | –0.0193*** | –0.0011 | 0.0078*** | –0.0047* |
| Videotape player | 0.0056*** | –0.0070*** | 0.0017*** | 0.0011* | –0.0013 |
| Blender | 0.0254*** | –0.0136*** | 0.0043*** | 0.0019*** | –0.0180*** |
| Microwave | –0.0002 | –0.0018* | 0.0001 | 0.0077*** | –0.0057*** |
| Refrigerator | 0.0089*** | –0.0219*** | 0.0012 | 0.0162*** | –0.0044** |
| Stove | 0.0194*** | –0.0239*** | 0.0257*** | 0.0109*** | –0.0321*** |
| Washing machine | 0.0196*** | –0.0207*** | 0.0013*** | 0.0101*** | –0.0103*** |
| Iron | 0.0170*** | –0.0072*** | 0.0017*** | 0.0002 | –0.0118*** |
| Fan | 0.0034*** | –0.0105*** | –0.0091*** | 0.0122*** | 0.0040*** |
| Vacuum cleaner | 0.0096*** | –0.0083*** | –0.0008 | 0.0072*** | –0.0077*** |
| Computer | 0.0168*** | –0.0023** | –0.0011*** | 0.0054*** | –0.0188*** |
| Heckman's lambda | 0.0333*** | –0.0771*** | 0.0011 | 0.0559*** | –0.0132*** |
| Constant | 0.4110*** | 0.3222*** | –0.0135*** | –0.0699*** | 0.3502*** |

NOTE: ***, **, * report significance at 1 %, 5 % and 10 %, respectively.
**SOURCE:** Own calculations.

**TABLE B3**

**CONDITIONAL QUAIDS ESTIMATES (NON-OWNERS)**

| | **Food** | **GLP** | **Electricity** | **Other non-durables** |
|---|---|---|---|---|
| Log price food | –0.3142*** | –0.0298*** | –0.0595*** | 0.4034*** |
| Log price LPG | –0.0298*** | –0.0142*** | 0.0063*** | 0.0377*** |
| Log price electricity | –0.0595*** | 0.0063*** | 0.0212*** | 0.0320*** |
| Log price other non-durables | 0.4034*** | 0.0377*** | 0.0320*** | –0.4731*** |
| Log expenditure | 0.0186 | 0.0987*** | –0.0137*** | –0.1035*** |
| Log expenditure$^2$ | –0.0214*** | –0.0080*** | 0.0021*** | 0.0273*** |
| IV total expenditure | 0.3135*** | –0.0077*** | –0.0392*** | –0.2666*** |
| Gender | 0.0103*** | 0.0037*** | –0.0212*** | 0.0073** |
| Age | 0.0020*** | 0.0000 | 0.0012*** | –0.0032*** |
| Age$^2$ | 0.0000*** | 0.0000*** | –0.0000*** | 0.0000*** |
| Members ≥ 12 years | 0.0389*** | –0.0014*** | –0.0038*** | –0.0338*** |
| Member < 12 years | 0.0281*** | –0.0018*** | –0.0017*** | –0.0246*** |
| Urban | 0.0292*** | 0.0030*** | –0.0071*** | –0.0251*** |
| North | –0.1171*** | 0.0081*** | 0.0509*** | 0.0582*** |
| Center | –0.0185*** | 0.0120*** | 0.0092*** | –0.0026 |
| Less than primary education | 0.0177*** | 0.0023* | –0.0112*** | –0.0087** |
| Primary education | 0.0225*** | 0.0026** | –0.0100*** | –0.0151*** |
| Secondary education | 0.0288*** | 0.0021** | –0.0085*** | –0.0225*** |
| Number of rooms | –0.0050*** | 0.0004** | 0.0053*** | –0.0008 |
| Rented house | –0.0044** | –0.0021*** | –0.0069*** | 0.0134*** |
| Owned house with mortgage | –0.0107*** | –0.0072*** | 0.0046*** | 0.0134*** |
| Owner house without mortgage | –0.0008 | –0.0011* | 0.0093*** | –0.0073*** |
| Radio recorder | 0.0015 | 0.0012** | –0.0032*** | 0.0005 |
| Radio | –0.0038** | 0.0006 | 0.0008** | 0.0024* |
| TV | 0.0097*** | 0.0019*** | 0.0085*** | –0.0201*** |
| Videotape player | 0.0106*** | 0.0018** | –0.0021*** | –0.0103*** |
| Blender | 0.0229*** | 0.0049*** | 0.0018*** | –0.0295*** |
| Microwave | –0.0040** | –0.0014*** | 0.0090*** | –0.0037** |
| Refrigerator | –0.0023 | 0.0010 | 0.0188*** | –0.0175*** |
| Stove | 0.0103*** | 0.0351*** | 0.0073*** | –0.0527*** |
| Washing machine | 0.0020 | 0.0001 | 0.0117*** | –0.0138*** |
| Iron | 0.0169*** | 0.0020*** | 0.0004 | –0.0193*** |
| Fan | –0.0069*** | –0.0115*** | 0.0127*** | 0.0057*** |
| Vacuum cleaner | –0.0061 | –0.0035** | 0.0155*** | –0.0059 |
| Computer | 0.0104*** | –0.0012* | 0.0073*** | –0.0165*** |
| Heckman's lambda | 0.0570*** | 0.0027 | –0.0589*** | –0.0008 |
| Constant | 1.1100*** | –0.3036*** | –0.0172 | 0.2108*** |

NOTE: ***, **, * report significance at 1%, 5% and 10%, respectively.
**SOURCE:** Own calculations.

## TABLE B4
## EQUIVALENT GAIN (REFORM 1). IMPACT BY ENERGY GOOD

| | Electricity | | Gasoline | | | | LPG | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Whole sample | | Households with vehicle | | Whole sample | | Households with positive spending in LPG | |
| | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers |
| **Total** | –0.57 | 99.7 | –0.50 | 47.5 | –1.09 | 99.9 | –0.46 | 98.2 | –0.50 | 99.8 |
| **Income deciles** | | | | | | | | | | |
| **1** | –0.72 | 100 | –0.05 | 10.9 | –0.50 | 97.9 | –0.39 | 90.6 | –0.54 | 99.6 |
| **2** | –0.67 | 99.9 | –0.14 | 20.5 | –0.71 | 99.9 | –0.48 | 97.4 | –0.57 | 99.9 |
| **3** | –0.63 | 99.9 | –0.22 | 27.4 | –0.82 | 100 | –0.50 | 98.5 | –0.57 | 99.7 |
| **4** | –0.60 | 99.7 | –0.31 | 36.3 | –0.88 | 100 | –0.50 | 99.0 | –0.54 | 99.9 |
| **5** | –0.58 | 99.8 | –0.39 | 41.7 | –0.95 | 100 | –0.49 | 99.2 | –0.53 | 99.9 |
| **6** | –0.55 | 99.7 | –0.49 | 49.1 | –1.01 | 100 | –0.49 | 99.3 | –0.52 | 99.9 |
| **7** | –0.52 | 99.6 | –0.61 | 57.7 | –1.07 | 100 | –0.47 | 99.3 | –0.50 | 99.9 |
| **8** | –0.49 | 99.2 | –0.76 | 67.5 | –1.14 | 100 | –0.46 | 99.4 | –0.47 | 99.7 |
| **9** | –0.46 | 99.7 | –0.90 | 75.8 | –1.20 | 100 | –0.43 | 99.6 | –0.45 | 99.9 |
| **10** | –0.46 | 99.6 | –1.15 | 88.0 | –1.31 | 100 | –0.39 | 99.5 | –0.40 | 99.8 |

NOTES: Equivalent loss is expressed as a percentage of total expenditure on non-durables. Losers: Equivalent loss < 0. For each energy product the equivalent gain is calculated assuming that the reform only affects the price of the energy product considered.

**SOURCE:** Own calculations.

## TABLE B5
## EQUIVALENT GAIN (REFORM 2). IMPACT BY ENERGY GOOD

| | Electricity | | Gasoline | | | | LPG | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Whole sample | | Households with vehicle | | Whole sample | | Households with postive spending in LPG | |
| | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers | Equivalent gain | % losers |
| **Total** | –1.11 | 99.8 | –1.06 | 47.5 | –2.28 | 99.9 | –0.95 | 98.4 | –1.03 | 99.8 |
| **Income deciles** | | | | | | | | | | |
| **1** | –1.39 | 100 | –0.11 | 10.9 | –1.05 | 98.4 | –0.81 | 91.1 | –1.11 | 99.6 |
| **2** | –1.30 | 99.9 | –0.30 | 20.5 | –1.49 | 99.9 | –0.99 | 97.7 | –1.16 | 99.9 |
| **3** | –1.23 | 99.9 | –0.46 | 27.4 | –1.72 | 100 | –1.03 | 98.6 | –1.16 | 99.7 |
| **4** | –1.17 | 99.7 | –0.66 | 36.3 | –1.86 | 100 | –1.03 | 99.1 | –1.11 | 99.9 |
| **5** | –1.12 | 99.8 | –0.82 | 41.7 | –1.99 | 100 | –1.01 | 99.3 | –1.09 | 99.9 |
| **6** | –1.07 | 99.8 | –1.03 | 49.1 | –2.12 | 100 | –1.01 | 99.5 | –1.07 | 99.9 |
| **7** | –1.02 | 99.6 | –1.28 | 57.7 | –2.24 | 100 | –0.98 | 99.4 | –1.03 | 99.9 |
| **8** | –0.96 | 99.2 | –1.60 | 67.5 | –2.38 | 100 | –0.94 | 99.6 | –0.98 | 99.9 |
| **9** | –0.91 | 99.8 | –1.89 | 75.8 | –2.51 | 100 | –0.89 | 99.6 | –0.92 | 99.9 |
| **10** | –0.91 | 99.8 | –2.40 | 88.0 | –2.74 | 100 | –0.80 | 99.6 | –0.82 | 99.8 |

NOTES: Equivalent loss is expressed as a percentage of total expenditure on non-durables. Losers: Equivalent loss <0. For each energy product the equivalent gain is calculated assuming that the reform only affects the price of the energy product considered.

**SOURCE:** Own calculations.

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# La influencia de la orientación competitiva de los trabajadores en los progresos medioambientales de la empresa

# *The influence of employees' competitive orientation on a firm's environmental progress*

J. Alberto Aragón Correa
Manuel Bueno
Universidad de Granada

***Resumen***

*La literatura avala una relación entre ciertas prácticas de gestión de recursos humanos y la estrategia medioambiental de la empresa. Sin embargo, la influencia de los desarrollos individuales de cada trabajador ha recibido una atención limitada. Este trabajo analiza si la orientación competitiva de los trabajadores de una empresa, reflejada a través de sus carreras profesionales, se relaciona con los avances medioambientales de su empresa. Nuestra metodología se basó en la construcción de una base de datos con las carreras profesionales completas de 10.564 trabajadores pertenecientes a 94 empresas del índice S&P100. Un análisis multinivel encuentra que las empresas muestreadas mejoran su proactividad medioambiental si cuentan con un mayor número de empleados con experiencia en altos niveles jerárquicos y que la dispersión salarial en la empresa intensifica ese efecto. Aunque existe un riesgo de que la rivalidad entre trabajadores obstaculice la colaboración, nuestros resultados apoyan una relación positiva entre la competitividad interna entre trabajadores y progresos medioambientales en la empresa.*

***Palabras clave:*** *proactividad medioambiental, competitividad interna, capital humano, microfundamentos.*

***Clasificación JEL:*** *J24, J41, Q51.*

***Abstract***

*Management literature supports a relationship between certain human resource management practices and a firm's environmental strategy. However, the influence of the individual experience of employees has received limited attention. This paper analyzes the effect of employees' competitive orientation, captured through employees' experience at high hierarchical levels in their professional careers, on a firm's environmental progress. We use a proprietary database containing information about the professional careers of 10,564 employees from 94 firms on the S&P100 index. Using multilevel analysis, we find that the sampled firms improve their environmental proactivity if they have more employees with a working experience at high hierarchical levels. We also find that a higher firm's pay dispersion level will intensify this effect. Although there is a risk that employees' competitive orientation hinders collaboration, our results support a positive relationship between employees' internal competition and the firm's environmental progress.*

***Keywords:*** *environmental proactivity, internal competition, human capital, microfoundations.*


DOI: https://doi.org/10.32796/cice.2022.104.7477
Recibido: Marzo 2022 · Aceptado: Mayo 2022

## 1. Introducción

La influencia del capital humano de la empresa en la gestión medioambiental ha ganado una considerable importancia en la última década tanto para académicos como para responsables de recursos humanos (De Stefano *et al*., 2018). Numerosos trabajos han analizado esta relación basándose en la teoría de recursos y capacidades, argumentando que aquellas empresas que cuenten con mejores recursos internos podrán desarrollar mejores estrategias medioambientales (Darnall *et al*., 2010; Ergene *et al*., 2021; Verbeke *et al*., 2006). Sin embargo, la literatura suele centrarse en la influencia de las prácticas de recursos humanos (formación interna, selección, retribución) en el desarrollo de esos recursos internos (Jackson *et al*., 2011; Ones y Dilchert, 2012; Renwick *et al*., 2013), obviando que los perfiles individuales de los propios trabajadores contribuyen sustancialmente a dicho desarrollo (Ployhart *et al*., 2014) y, específicamente, a sus contribuciones en el desarrollo de estrategias medioambientales. Este trabajo analiza si la orientación competitiva de los trabajadores influye en lo avanzado de los planteamientos medioambientales de la empresa.

La literatura sobre capital humano ha subrayado que la tendencia de los empleados a querer superar a otros, para obtener más estatus o mayores pagos, es un rasgo diferencial de los recursos humanos de la empresa con repercusiones importantes en ella (Bidwell y Mollick, 2015; Coff y Kryscynski, 2011; Nickerson y Zenger, 2008; Ridge *et al*., 2015). Nosotros estudiamos este aspecto desde el punto de vista de *microfoundations*, que se basa en una mejor comprensión de cómo las características individuales de las carreras de los trabajadores explican los resultados organizacionales (Barney y Felin, 2013; Bridoux y Stoelhorst, 2014; Coff y Kryscynski, 2011; Felin *et al*., 2015; Foss, 2011). El enfoque de *microfoundations* contrasta con el análisis tradicionalmente dominante en gestión medioambiental de la empresa basado en las características de los directivos (Phillips *et al*., 2010; Tantalo y Priem, 2016). En el presente trabajo analizamos el impacto de la orientación competitiva del capital humano de la empresa (Balliet *et al*., 2009) en la proactividad medioambiental. Además, estudiamos la influencia de la dispersión salarial de la empresa en esta relación.

La dispersión salarial está relacionada con las diferencias en las recompensas económicas que los trabajadores reciben en diferentes rangos jerárquicos (Bloom, 1999; Bloom y Michel, 2002; Siegel y Hambrick, 2005). Por tanto, una mayor dispersión salarial puede intensificar el efecto de la competencia entre los trabajadores para lograr un mayor estatus y pagos más altos (Lim, 2019; Ridge *et al*., 2015). Nuestras hipótesis plantean que la mentalidad competitiva de los trabajadores facilita los cambios para los avances medioambientales y que la dispersión salarial refuerza ese efecto.

Empíricamente, aplicamos una metodología original utilizando información pública disponible en LinkedIn, para realizar un análisis detallado de toda la vida laboral de 10.564 personas que trabajaban en 94 de las 100 empresas del índice Standard y Poor’s (S&P100). Utilizamos la trayectoria profesional de los empleados para construir una variable que capture la orientación competitiva del capital humano. Específicamente, nos basamos en la idea de que los empleados con una orientación competitiva más fuerte son aquellos que más ascendieron en la escala jerárquica de la empresa (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017), por lo que usaremos la experiencia total del empleado en los diferentes rangos jerárquicos en los que ha trabajado a lo largo de su carrera profesional como indicador de su mentalidad competitiva. Los resultados obtenidos respaldan nuestra hipótesis con respecto al efecto positivo que tiene un capital humano formado por empleados con una mayor mentalidad competitiva en la proactividad medioambiental de la empresa. Además, nuestros resultados muestran que un mayor nivel de dispersión salarial en la empresa fortalece esta relación.

Nuestro trabajo hace tres grandes contribuciones a la investigación previa. Primero, reforzamos la literatura de *microfoundations* mediante la confirmación de la influencia de las características de los trabajadores en comportamientos organizacionales relacionados con los progresos ambientales. Segundo, extendemos la literatura en gestión medioambiental al analizar el efecto diferencial que tiene un capital humano más competitivo. Y tercero, destacamos la relevancia de la dispersión salarial para administrar la mentalidad competitiva del capital humano.

El presente trabajo está estructurado de la siguiente manera. A continuación, presentamos nuestra perspectiva de *microfoundations* como marco teórico y desarrollamos nuestras hipótesis de investigación. Luego, presentamos la muestra empleada para contrastar nuestras hipótesis, así como la técnica estadística multinivel que aplicamos y los resultados obtenidos. Finalmente, discutimos las implicaciones de nuestro estudio y sugerimos futuras líneas de investigación.

## 2. Marco teórico

### *2.1. Un enfoque de microfoundations del capital humano: introducción*

La teoría de recursos y capacidades de la empresa (RVB, por sus siglas en inglés) postula que los recursos se distribuyen de manera heterogénea entre las empresas competidoras y, de manera crucial, esas heterogeneidades explican las diferencias en el desempeño que permiten a las empresas lograr y mantener una ventaja competitiva sobre sus rivales (Barney, 1991; Ghemawat, 1986; Hansen y Wernerfelt, 1989; Peteraf, 1993). En relación al medioambiente, esta visión hace, además, énfasis en que una gestión más avanzada que la de sus competidores implica unas capacidades internas de innovación y relación que ofrecen una ventaja competitiva (Hart, 1995; Russo y Fouts, 1997). Múltiples trabajos han demostrado que este avanzado desempeño ambiental se basa en recursos internos especializados generados por la organización de la empresa (Darnall *et al*., 2010; Ergene *et al*., 2021; Verbeke *et al*., 2006).

La perspectiva de *microfoundations* ha ganado una atención exponencial en la última década debido a su potencial para explicar ese desarrollo de los recursos de las empresas a nivel global como una particular combinación de habilidades individuales de sus trabajadores (Barney y Felin, 2013; Felin *et al*., 2012; Felin *et al*., 2015; Foss, 2011). Por ello, el capital humano juega un papel clave en este contexto porque la experiencia de un individuo puede generar recursos y capacidades claves para la empresa si se encauzan debidamente (Eggers y Kaplan, 2013).

Las interacciones entre los trabajadores han sido también reconocidas como una parte importante del proceso de emergencia de dichos recursos diferenciales en el ámbito del capital humano (Barney y Felin, 2013; Bridoux *et al*., 2017; Lindenberg y Foss, 2011; Ployhart *et al.*, 2014). Específicamente, las características de los empleados a nivel individual conducirán a la aparición de un comportamiento organizacional diferente dependiendo de cómo los empleados se relacionen y se comporten entre sí en el lugar de trabajo (Collins y Smith, 2006; Gooderham *et al*., 2011; Raffiee y Byun, 2020), y en cómo se relacionen con las estructuras y prácticas organizativas de la empresa (Eggers y Kaplan, 2013; Mawdsley y Somaya, 2016; Ployhart *et al.*, 2014).

En resumen, las características individuales de los trabajadores y sus interacciones configuran el capital humano de la empresa que es la base de su comportamiento organizacional. Así pues, nos enmarcamos en este enfoque de *microfoundations* para estudiar el surgimiento de una estrategia medioambiental más avanzada a partir de la orientación competitiva de su capital humano.

### *2.2. La mentalidad competitiva de los empleados y avances estratégicos medioambientales en la empresa*

La proactividad medioambiental es un concepto que se entiende como un comportamiento estratégico de las empresas orientado a desarrollar avances por encima de los mínimos legales establecidos, mediante la implementación de prácticas más sostenibles (Hart, 1995; Sharma y Vredenburg, 1998). Por tanto, la proactividad medioambiental es una estrategia que implica mayores inversiones en innovación (Cormier y Magnan, 2015; Radu y Francoeur, 2017) y busca reforzar legitimidad y reputación (Aragón-Correa *et al.*, 2016; Berrone *et al.*, 2013; Kock *et al*., 2012). Si bien las tecnologías y el capital han sido tradicionalmente aceptados como factores relevantes para mejorar dicha estrategia medioambiental de las empresas (Bansal, 2005; Berrone *et al.*, 2013; González-Benito y González-Benito, 2006), los recursos humanos han ganado recientemente una atención especial, ya que forman un pilar fundamental del comportamiento de la empresa también en lo medioambiental (De Stefano *et al*., 2018; Jackson *et al*., 2014).

La mayoría de los estudios se han centrado en examinar cómo las empresas pueden organizar a nivel organizacional sus prácticas de recursos humanos para obtener un mejor rendimiento ambiental (Jackson *et al*., 2011; Ones y Dilchert, 2012; Renwick *et al*., 2013; Skoglund y Böhm, 2020). Por ejemplo, la capacitación y formación de los empleados en materia medioambiental está ampliamente demostrada como una herramienta clave para proporcionar y transformar las habilidades y el conocimiento, que permiten un mejor comportamiento ecológico de la organización (Jabbour *et al*., 2010; Ramus, 2002; Wagner, 2011). Es necesario prestar más atención a cómo esos resultados medioambientales a nivel organizacional surgen de determinadas características de los trabajadores a nivel individual que componen el capital humano de la empresa (De Stefano *et al*., 2018).

La orientación competitiva de los trabajadores es una de las dimensiones sociales más relevantes identificadas por los psicólogos que estudian los comportamientos de los individuos en las interacciones sociales (Balliet *et al*., 2009). Por ejemplo, la tendencia de los empleados a querer superar a otros para obtener más estatus tiene importantes repercusiones en la configuración del capital humano de la empresa (Bidwell y Mollick, 2015; Coff y Kryscynski, 2011; Nickerson y Zenger, 2008; Ridge *et al.*, 2015). Los individuos exhiben una orientación competitiva cuando tienen preferencia por superar a los demás para mantener su estatus o alcanzar un nivel superior (Van Lange, 1999), lo que modifica la forma en que se relacionan con los demás en el lugar de trabajo (Heaphy *et al.*, 2018). En este sentido, los trabajadores con mentalidad más competitiva tienden a hacer mayores esfuerzos para conseguir un puesto específico puesto que deben «ganar» una competición con otros candidatos internos y externos (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017). Luego, una vez logrado un puesto, tienen que continuar con sus esfuerzos para mantener su estatus de éxito (Gehman y Grimes, 2017) y los incentivos económicos relacionados (Kacperczyk y Balachandran, 2018). En consecuencia, estos trabajadores necesitarán una mayor orientación hacia la consecución de retos y objetivos.

Los desarrollos de los trabajadores con mentalidad más competitiva tienen implicaciones en su forma de abordar sus trabajos. Tienen que desarrollar con éxito acciones más arriesgadas dentro de un lugar de trabajo competitivo (Chattopadhyay y Choudhury, 2017; Gruys *et al.*, 2008), es decir, en esa competición con otros candidatos tuvieron que asumir riesgos para tener mayor éxito en ese proceso (Bidwell, 2011; Bidwell y Mollick, 2015). Estos esfuerzos más arriesgados se llevaron a cabo debido a que la competitividad también les permite identificar más fácilmente los beneficios de ellos (Campbell *et al.*, 2012; Coff y Kryscynski, 2011). En general, los trabajadores con orientación competitiva perciben con claridad las recompensas individuales de sus acciones.

Así pues, una fuerza laboral altamente competitiva generalmente se ha relacionado con el interés en las recompensas económicas y la reputación propia, que surge de los empleados que buscan promociones e incentivos económicos individuales (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017; Fehr y Gächter, 2000), y que configura un capital humano con una mayor orientación a la consecución de objetivos a pesar de los riesgos.

Nosotros proponemos que una organización que cuente con empleados más competitivos tendrá un capital humano más dispuesto a asumir los riesgos para atender demandas sociales competitivas en los mercados, como son los retos medioambientales. Bajo esta lógica, empleados más competitivos tratarán de obtener mayor notoriedad dentro de su equipo o de la organización a partir de sus nuevas ideas para mejorar los productos y procesos comerciales (Grosser *et al.*, 2018; Tong *et al.*, 2018; Yuan y Woodman, 2010), pudiendo centrarse en objetivos social y medioambientalmente más responsables (Dionisio y de Vargas, 2020), y así alcanzar el mayor estatus que otorgan este tipo de acciones innovadoras. Por tanto, los empleados con una mentalidad más competitiva identifican el interés por los aspectos ambientales como una vía de obtener un mayor estatus dentro de la organización e incluso en el ámbito social.

En consecuencia, una fuerza laboral más competitiva puede llevar a una mayor proactividad medioambiental de la empresa, ya que se construye a partir de empleados más propensos a identificar los beneficios de crear nuevos productos y procesos que les proporcionen una mayor reputación (Gao y Bansal, 2013; Oeij *et al.*, 2019; Voegtlin y Scherer, 2017). Incluso, actitudes proactivas medioambientalmente pueden proporcionar un estatus más alto que otras innovaciones, ya que satisfacer las demandas medioambientales proporciona una mejor reputación social y notoriedad en la comunidad (Bansal, 2005; Berrone *et al.*, 2013).

Además, los trabajadores con mentalidad competitiva están más dispuestos a asumir los cambios necesarios para los avances medioambientales. La literatura previa respalda la noción de que las empresas deben ser lo suficientemente flexibles para cambiar sus rutinas y cumplir con los objetivos ambientales que surgen de las crecientes expectativas regulatorias del mercado (Eggers y Kaplan, 2013; Gilbert, 2005; Kaplan y Henderson, 2005; Tripsas y Gavetti, 2000). En este sentido, las características de los empleados están en el origen de los recursos diferenciales que se necesitan para cumplir con dichas exigencias cambiantes del mercado (Eggers y Kaplan, 2013; Teece, 2007; Nayak *et al*., 2020).

En conclusión, las empresas que cuenten con más mentalidad competitiva entre sus trabajadores generarán un capital humano con mayor potencial para lograr proactividad medioambiental. Específicamente, esos trabajadores tienen más disponibilidad para superar los retos de cambios e innovación medioambientales gracias a su percepción sobre las ventajas que pueden suponer y su flexibilidad para identificar, desarrollar y conseguir los cambios necesarios. Por tanto, podemos presentar la siguiente hipótesis:

> Hipótesis 1: Un capital humano formado por empleados con una mayor orientación competitiva permitirá una mayor proactividad medioambiental de la empresa.

### *2.3. La dispersión salarial como refuerzo de la competitividad.*

Los marcos salariales de las empresas están diseñados para impactar en los incentivos de los empleados para colaborar en el logro de mejores resultados corporativos (Kale *et al*., 2009; Ridge *et al.*, 2015), incluidos los retos sociales de una organización (Amore y Failla, 2020; Kini y Williams, 2012). Por un lado, las dispersiones salariales horizontales se refieren a las diferencias en las recompensas económicas de los empleados dentro del mismo rango jerárquico (Bloom y Michel, 2002; Fredrickson *et al*., 2010). Por otro lado, la dispersión salarial vertical se entiende como las diferencias en las recompensas económicas de los trabajadores a través de diferentes rangos jerárquicos (Bloom, 1999; Bloom y Michel, 2002; Siegel y Hambrick, 2005). Las grandes diferencias en los pagos horizontales producen un sentimiento de inequidad (Hambrick, 1995; Ridge *et al.*, 2015), mientras que las verticales son las que más se relacionan con la competencia entre los empleados para alcanzar un nivel de rango más alto (Lim, 2019; Ridge *et al.*, 2015). Nuestro estudio se centra en la dispersión salarial vertical, como el sistema económico que incentiva la competitividad de los empleados orientada a la consecución de los objetivos de la empresa. Por tanto, en adelante, nos referiremos a esa dispersión salarial vertical cuando hablemos de dispersión salarial.

La dispersión salarial vertical de las empresas actúa como una práctica organizacional que estimula los efectos de la competencia interna. De hecho, una mayor compensación relacionada con el desempeño lleva a asumir más riesgos en las carreras empresariales (Linn y Park, 2005; Patel *et al.*, 2018), ya que los empleados verán mayores incentivos para hacerlo. Desde este punto de vista, ya que mayores niveles de dispersión salarial en la empresa dan como resultado mayores recompensas económicas (Henderson y Fredrickson, 2001; Siegel y Hambrick, 2005), los empleados encontrarán mayores incentivos para asumir los riesgos necesarios para alcanzar esos mayores pagos (Amore y Failla, 2020; Patel *et al.*, 2018).

Como resultado, una mayor dispersión salarial reforzará el impacto positivo de la orientación competitiva de los trabajadores en la proactividad medioambiental de la empresa. Debido a que la dispersión salarial aumenta la competencia entre los empleados para lograr un mayor estatus en los pagos (Henderson y Fredrickson, 2001; Lazear y Rosen, 1981), puede generar una mayor orientación hacia los retos sociales y medioambientales de la empresa (Amore y Failla, 2020; Kini y Williams, 2012) en lugar de al desempeño financiero de la empresa (Fredrickson *et al.*, 2010; Kale *et al.*, 2009; Siegel y Hambrick, 2005), ya que empleados más competitivos, que están más orientados a tomar riesgos para cumplir los objetivos, lo estarán todavía más si los beneficios por hacerlo son mayores. Como tal, mayores incentivos económicos conducirán colectivamente a una fuerza laboral más propensa a participar en actividades de mayor riesgo en los mercados, pero de las que obtengan mayores beneficios y reputación (Grigoriou y Rothaermel, 2014; Zhou *et al*., 2019), como es la proactividad medioambiental de la empresa.

En conclusión, una mayor dispersión salarial fortalecerá la relación entre la orientación competitiva de los empleados y la proactividad medioambiental, al aumentar la disponibilidad del capital humano de la empresa a asumir los riesgos necesarios para ello. Mayores diferencias en los pagos entre los distintos niveles jerárquicos de la empresa harán que los trabajadores sean más ambiciosos para lograr un mayor estatus y, por tanto, mayores retribuciones económicas. Por todas estas razones, planteamos en nuestro estudio la siguiente hipótesis moderadora:

Hipótesis 2: Un mayor nivel de dispersión salarial fortalecerá el efecto positivo de un capital humano formado por empleados con orientación competitiva en la proactividad medioambiental de la empresa.

## 3. Metodología

### *3.1. Muestra empleada*

Nuestro análisis comprende empleados que actualmente trabajan en una empresa perteneciente al índice bursátil S&P100, un índice de referencia que representa a las 100 empresas más importantes en el mercado de los Estados Unidos. Nuestro análisis de *microfoundations* requiere datos tanto a nivel de trabajadores como organizacional para explicar comportamientos empresariales a partir de características de individuos (Felin *et al*., 2015; Foss y Linder, 2019).

En primer lugar, descargamos información de la base de datos Thomson Reuters Eikon sobre la proactividad medioambiental y sobre las características de las empresas, como la edad, el tamaño y la situación financiera. También, consultamos información sobre la dispersión salarial de esas empresas en la sección Execomp de la base de datos Compustat. En segundo lugar, consultamos los perfiles públicos de LinkedIn de empleados de esas empresas del S&P100 seleccionados aleatoriamente, para obtener información sobre su experiencia laboral a lo largo de su carrera profesional. Realizamos estas descargas en abril de 2019, por lo que los datos de los empleados y de las empresas se relacionan con esa fecha, que consideramos el «tiempo presente» para el análisis.

Nuestro análisis inicial involucró a 10.760 empleados de 96 empresas del índice S&P100, ya que no pudimos acceder a la información de los empleados de cuatro de las cien empresas. Además, faltaban datos ambientales para dos empresas. Nuestra muestra final, por tanto, está compuesta por 10.564 empleados de 94 empresas diferentes, donde el número más bajo de empleados analizados para una empresa fue de 79 y el número más alto fue de 181, lo que resultó en un promedio de 112 empleados analizados por empresa en nuestra muestra. La permanencia promedio de los empleados en sus organizaciones actuales en nuestra muestra fue de 79,96 meses (es decir, 6,66 años en promedio). Aunque los datos tomados de LinkedIn no están exentos de riesgos, ya que algunos datos pueden resultar falsos o incorrectos, la naturaleza pública y profesional de esta información puede proporcionar una descripción mucho más precisa que las encuestas tradicionales. Para minimizar este riesgo, confirmamos la validez del contenido de los perfiles de un número limitado de altos directivos, comparando nuestra información obtenida de LinkedIn con la información disponible a través de otras fuentes. Debido a que utilizamos búsquedas automatizadas en internet para encontrar los perfiles públicos de trabajadores, evitamos los problemas tradicionales de sesgo de selección en las encuestas y en la recopilación de datos sobre las experiencias pasadas de los empleados.

## *3.2. Variables del estudio*

### 3.2.1. Proactividad medioambiental

Medir la proactividad ambiental implica un gran desafío, ya que requiere registrar una estrategia de la empresa en ir más allá de los mínimos legales en materia medioambiental (Aragón-Correa *et al.*, 2016; Hart, 1995; Sharma y Vredenburg, 1998). Por tanto, un comportamiento medioambientalmente proactivo implica una mayor inversión y orientación de la empresa hacia la consecución de nuevos productos y la mejora de procesos productivos que mejoren el comportamiento ambiental de la organización (Cormier y Magnan, 2015). Por ello, la literatura señala diferencias entre proactividad medioambiental (una mayor inversión en innovación verde) y los resultados medioambientales que efectivamente se obtengan, por lo que una empresa muy proactiva medioambientalmente no tiene por qué implicar que presente buenos niveles de contaminación (Aragón-Correa *et al*., 2016; Radu y Francoeur, 2017) o viceversa. Algunos autores han medido la proactividad ambiental utilizando indicadores ambientales, como el Carbon Disclosure Project, basado en la tendencia de la empresa a divulgar más datos sobre sus resultados ambientales (Calza *et al*., 2016). Sin embargo, las diferencias entre suministrar información ambiental y las iniciativas reales han despertado ciertas reticencias sobre este tipo de indicadores basados en la divulgación de información medioambiental (Aragón-Correa *et al*., 2016). En consecuencia, trabajos más recientes empezaron a usar la innovación medioambiental de la empresa como una buena forma de medir la proactividad ambiental (Berrone *et al.*, 2013; Bueno-Garcia *et al*., 2021). Siguiendo estos estudios, hemos seleccionado el «índice de innovación medioambiental» que encontramos en la base de datos Thompson Reuters Eikon, que se define como una categoría que «refleja la capacidad de una empresa para reducir los costes y las cargas medioambientales para sus clientes, a través de nuevas tecnologías y procesos medioambientales, o productos que cuentan con un ecodiseño». Este índice oscila entre 0 y 100, donde mayores valores de este índice implican mayores niveles de proactividad medioambiental de las empresas.

### 3.2.2. Orientación competitiva de los trabajadores

Nos basamos en la literatura de capital humano (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017; Coff y Kryscynski, 2011; Ridge *et al.*, 2015) para utilizar la experiencia de los empleados en niveles jerárquicos de mayor rango como una aproximación a la orientación competitiva de los trabajadores. El rango jerárquico de un trabajador se refiere a la posición que ocupa en la escala jerárquica de una organización (Bidwell, 2011; Bidwell y Mollick, 2015). Los empleados con más experiencia en niveles jerárquicos altos están más familiarizados con la orientación competitiva que requiere poder alcanzarlos en organizaciones con otros múltiples candidatos potenciales tanto internos como externos (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017). Además, los trabajadores de alto rango jerárquico tienen que continuar con sus esfuerzos competitivos para mantener su estatus (Gehman y Grimes, 2017) y los incentivos económicos relacionados con él (Kacperczyk y Balachandran, 2018). Por ello, los empleados con más experiencia en niveles jerárquicos más altos tienen necesariamente una orientación más competitiva como media y esa mentalidad configurará sus relaciones en el lugar de trabajo.

Para medir satisfactoriamente la experiencia en los distintos niveles jerárquicos, primero tuvimos que construir una estructura jerárquica para clasificar cada puesto que ocupó un empleado a lo largo de su carrera; luego, tuvimos que construir un índice que pondere el tiempo de permanencia en cada rango jerárquico. Así pues, este índice se construyó como:

$$\text{Log}(\Sigma\ (\text{meses en el } \textit{nivel i} \text{ X } \textit{valor de la categoría i})) \qquad [1]$$

En primer lugar, para calcular *valor de la categoría i*, establecemos una estructura jerárquica con siete categorías para asignarle un valor numérico a cada categoría, de manera similar a Bidwell y Mollick (2015), desde el nivel A como el nivel de rango más alto, hasta el nivel G como el nivel de rango más bajo. Específicamente, clasificamos los puestos de los empleados en esos distintos niveles jerárquicos de acuerdo al nivel de responsabilidad: el nivel A en nuestro análisis incluye directores generales, presidentes, presidentes de juntas y fundadores; el nivel B está formado por altos ejecutivos, como CTO (Chief Technology Officer), CIO (Chief Information Officer), COO (Chief Operating Officer) o CFO (Chief Financial Officer); el nivel C cuenta para otros puestos ejecutivos y miembros de la junta; el nivel D está formado por aquellos en el nivel intermedio de dirección, como los empleados cuyos perfiles los identifican como *senior director*; el nivel E sigue en un nivel intermedio pero para aquellos puestos gerenciales sin experiencia sénior, como gerente o jefe; el nivel F comprende trabajos profesionales como ingenieros o arquitectos; finalmente, el nivel G registra niveles júnior y trabajos como voluntario o asistente. Después, establecemos el siguiente valor numérico para cada nivel jerárquico: el nivel A toma el valor 7, el nivel B el valor 6, y así sucesivamente hasta la categoría más baja, el nivel G, con el valor 1.

Adicionalmente, tenemos en cuenta toda la experiencia del empleado en un rango determinado incluyendo su tiempo en ese puesto medido en meses (Bidwell y Mollick, 2015). Finalmente, calculamos el logaritmo natural de la multiplicación de los dos términos en la ecuación para normalizar los valores resultantes. Proporcionamos así un índice para cada empleado, donde mayores valores del índice implicarán mayor orientación competitiva del empleado.

#### 3.2.3. Dispersión salarial.

La medida más usada en la literatura de gestión de la empresa para calcular una aproximación de la dispersión salarial es la diferencia entre el pago total del director ejecutivo (CEO) de una empresa y el promedio del pago total de los ejecutivos (Amore y Failla, 2020; Henderson y Fredrickson, 2001; Lim, 2019). Los datos para esta variable se descargaron de la sección Execomp de la base de datos Compustat, donde el pago total de los directores ejecutivos y del resto de los ejecutivos se refiere a valores que incluyen la suma de salario, bonificaciones, opciones de distinta índole, incentivos a largo plazo, derecho de acciones restringidas y otros pagos anuales. También usamos el logaritmo natural para reescalar los valores de esta diferencia.

#### 3.2.4. Variables de control

La literatura ambiental señala algunas variables internas que pueden influir en el desempeño ambiental de una empresa. Para tener en cuenta el efecto que las distintas características de las empresas pueden introducir en nuestro estudio, seleccionamos las siguientes variables de control: *el tamaño* de la empresa, ya que las empresas más grandes tienen más recursos para gastar en mejoras ecológicas (Berrone *et al.*, 2013; Walls *et al.*, 2012), midiendo esta categoría como el logaritmo natural del total de empleados de una empresa (Collins y Smith, 2006); también controlamos por el desempeño financiero de la empresa, utilizando el retorno sobre el capital (ROE) de la empresa, ya que las empresas con mejores resultados económicos pueden invertir mayores cantidades en mejoras ambientales (Berrone y Gomez-Mejia, 2009); y para la *edad* de la empresa, como el número total de años desde su fundación (Kacperczyk, 2012), en línea con estudios previos que muestran que las empresas más antiguas tienden a presentar mejores resultados ambientales (Calza *et al.*, 2016; Doluca *et al.*, 2018). Finalmente, controlamos el *sector* económico al que pertenece la empresa, utilizando el Estándar de Clasificación de la Industria Global (SIC, por sus siglas en inglés) para categorizar los diferentes sectores económicos (Pucheta-Martínez y López-Zamora, 2018).

Por otra parte, también incluimos variables de control para las características de los empleados, y así tener en cuenta distintos rasgos de los empleados que pudieran generar diferentes dinámicas organizacionales. Incluimos el logaritmo natural del total de meses que el trabajador ha estado empleado en su empresa actual, para tener en cuenta la *permanencia* del empleado, en línea con trabajos anteriores (Gruys *et al.*, 2008; Raffiee y Byun, 2020). Controlamos el número de *puestos* distintos en la empresa actual (Dokko *et al.*, 2009), porque los traslados internos dentro de la misma empresa pueden modificar el desempeño de los empleados. Además, tuvimos en cuenta la experiencia de los empleados en empresas *top* a lo largo de sus carreras, de forma similar a otros estudios (Balsvik, 2011), utilizando el logaritmo natural del total de meses que el empleado pasó trabajando en cualquiera de las empresas del S&P100 durante su carrera, como una aproximación a esta característica.

### *3.3. Técnica estadística*

Siguiendo las recomendaciones metodológicas para análisis empíricos que la literatura de *microfoundations* hace (Felin *et al*., 2015), exploramos técnicas multinivel para contrastar nuestras hipótesis. Específicamente, mediante el *software* STATA 16 para construir nuestros modelos estadísticos, nos decantamos por modelos de ecuaciones estructurales multinivel (MSEM) como el estimador más eficiente a la hora de captar la aparición de fenómenos macro a partir de características micro. Los modelos MSEM parecen más adecuados que la alternativa con modelos HLM originalmente usada en la literatura multinivel para tratar la emergencia de fenómenos organizacionales a partir de las características de los trabajadores (Preacher *et al.*, 2010). En nuestro caso, comprobamos que el sentido general de los resultados no difiere significativamente en función del método utilizado (HLM o MSEM).

## **4. Resultados**

El Cuadro 1 presenta los estadísticos descriptivos y las correlaciones para cada variable presente en este estudio. Realizamos pruebas adicionales para asegurar que no existe multicolinealidad entre nuestras variables, usando los factores de inflación de la varianza (VIF), que en nuestro estudio oscilan entre 1,02 y 1,85, con una media de 1,29, lo que sugiere que la correlación entre variables no genera relevantes problemas de multicolinealidad en nuestro análisis (Hair *et al.*, 1998).

El Cuadro 2 presenta los resultados de los modelos de regresión MSEM utilizados para contrastar nuestras hipótesis de investigación. El Modelo 1 ofrece los resultados de las variables de control para nuestra variable dependiente. Algunas de las variables de control muestran resultados estadísticamente significativos en nuestro análisis, como en el caso del tamaño de la empresa, el ROE de la empresa y la antigüedad de la empresa, que se relacionan positiva y significativamente con la proactividad medioambiental de la empresa. Además, encontramos una influencia negativa y estadísticamente significativa de la permanencia de los empleados en la empresa actual sobre la proactividad medioambiental.

El Modelo 2 se usa para contrastar nuestra Hipótesis 1, donde planteamos que cuanto mayor sea el nivel de competitividad de los empleados que forman el capital humano de la empresa, mayor será la proactividad medioambiental. Vemos un efecto estadísticamente significativo y positivo al 10% (0,302, con un p-valor igual a 0,056), y, por tanto, encontramos apoyo estadístico para nuestra Hipótesis 1.

**CUADRO 1**
**ESTADÍSTICOS DESCRIPTIVOS Y CORRELACIONES**

| Variables | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Proactividad medioambiental | 70,855 | 26,75 | 1 | | | | | | | |
| (2) Orientación competitiva de los empleados | 7,515 | 1,374 | 0,015 | 1 | | | | | | |
| (3) Dispersión salarial | 9,181 | 1,133 | –0,050*** | –0,012 | 1 | | | | | |
| (4) Permanencia | 3,887 | 1,02 | –0,009 | 0,155*** | 0,012 | 1 | | | | |
| (5) Top | 1,123 | 1,818 | 0,022** | 0,056*** | 0,021** | –0,127*** | 1 | | | |
| (6) Puestos | 2,102 | 1,76 | –0,008 | 0,128*** | –0,009 | 0,583*** | –0,141*** | 1 | | |
| (7) ROE | 44,581 | 290,049 | –0,061*** | –0,009 | –0,102*** | 0,029*** | –0,012 | 0,041*** | 1 | |
| (8) Tamaño | 11,238 | 1,154 | 0,353*** | 0,052*** | –0,001 | 0,004 | 0,015 | 0,002 | –0,100*** | 1 |
| (9) Edad | 6,021 | 1,054 | 0,054*** | –0,028*** | –0,050*** | 0,015 | 0,002 | 0,020** | 0,107*** | 0,156*** |

NOTA: * p<0,1; ** p<0,05; *** p<0,01.
**FUENTE:** Elaboración propia.

**CUADRO 2**
**MODELOS ESTADÍSTICOS PARA CONTRASTE DE HIPÓTESIS**

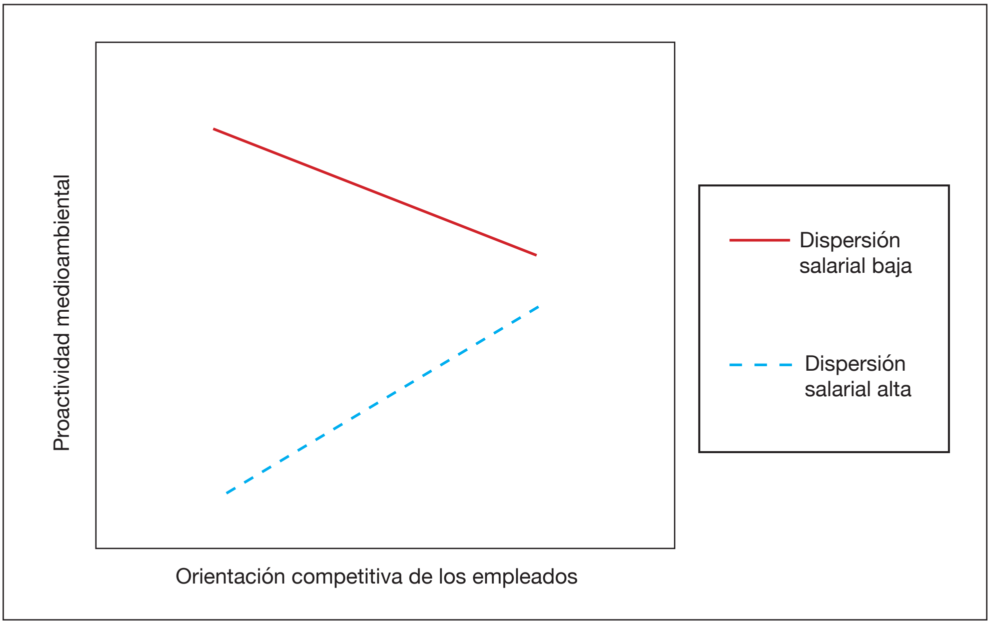
| Variable | Modelo 1 | Modelo 2 | Modelo 3 |
|---|---|---|---|
| *Variables de control* | | | |
| Permanencia | –0,647**<br>(0,256) | –0,711***<br>(0,257) | –0,700***<br>(0,257) |
| Top | 0,131<br>(0,118) | 0,121<br>(0,118) | 0,12<br>(0,118) |
| Puestos | 0,194<br>(0,15) | 0,183<br>(0,15) | 0,181<br>(0,15) |
| ROE | 0,002**<br>(0,001) | 0,002**<br>(0,001) | 0,002**<br>(0,001) |
| Tamaño | 6,674***<br>(0,232) | 6,817***<br>(0,233) | 6,829***<br>(0,233) |
| Edad | 0,840***<br>(0,229) | 0,843***<br>(0,228) | 0,842***<br>(0,228) |
| Sector | YES | YES | YES |
| *Variables principales* | | | |
| Orientación competitiva de los empleados | | 0,302*<br>(0,157) | –3,17**<br>(1,386) |
| Dispersión salarial | | –1,42***<br>(0,215) | –4,287***<br>(1,158) |
| Interacción | | | 0,376**<br>(0,149) |
| Constante | 13,041***<br>(2,919) | 8,458***<br>(3,464) | 34,737***<br>(10,986) |

NOTA: Errores entre paréntesis. * p<0,1; ** p<0,05; *** p<0,01.
**FUENTE:** Elaboración propia.

Finalmente, el Modelo 3 se usa para contrastar la Hipótesis 2, con respecto al efecto moderador de la dispersión salarial de la empresa en la relación entre el nivel de competitividad de los empleados que forman el capital humano de la empresa y la proactividad medioambiental. En este caso, encontramos un efecto estadísticamente significativo con un coeficiente de 0,376 (con un p-valor <0,05), por lo que encontramos soporte estadístico para la Hipótesis 2. La Figura 1 presenta gráficamente este efecto, mostrando que los valores de proactividad medioambiental de la empresa son más altos a medida que aumenta el nivel de competitividad de los empleados del capital humano para una dispersión salarial alta, y menor para valores bajos de dispersión salarial de la empresa, apoyando nuestra Hipótesis 2.

**FIGURA 1**

**EFECTO MODERADOR DE LA DISPERSIÓN SALARIAL DE LA EMPRESA EN LA RELACIÓN ENTRE LA ORIENTACIÓN COMPETITIVA DE LOS EMPLEADOS Y LA PROACTIVIDAD MEDIOAMBIENTAL**




**FUENTE:** Elaboración propia.

## 5. Discusión y conclusiones

### *5.1. Aportaciones a la literatura*

El presente trabajo muestra una serie de contribuciones a la literatura existente sobre gestión empresarial. En primer lugar, nuestro trabajo refuerza la perspectiva de *microfoundations* (Eggers y Kaplan, 2013; Foss y Linder, 2019; Ployhart y Hendricks, 2019) al confirmar la importancia de las características individuales del capital humano en los desarrollos organizacionales. Este enfoque contrasta con la literatura tradicional de gestión de recursos humanos, que se centra en cómo mejorar las prácticas de gestión a nivel de empresa para impulsar mejores resultados medioambientales (Jackson *et al*., 2011; Ones y Dilchert, 2012; Renwick *et al*., 2013). Respondemos, por tanto, a las llamadas de la perspectiva de *microfoundations* (Felin *et al*., 2015; Foss y Linder, 2019; Ployhart y Hendricks, 2019) para desarrollar más trabajos empíricos que consideren los vínculos entre los antecedentes del capital humano de una empresa y distintas dimensiones del desempeño de una empresa. Así pues, nuestros resultados contribuyen a la visión de que el capital humano de una empresa se basa en las experiencias individuales que sus empleados tienen a lo largo de sus carreras profesionales, y que son la clave a la hora de constituir un recurso organizacional que genere una ventaja competitiva en la empresa.

En segundo lugar, nuestro trabajo contribuye sustancialmente a la perspectiva de los recursos y capacidades de la empresa que ha venido analizando cómo los activos internos influyen en los resultados ambientales de una empresa (Hart, 1995). Esta literatura ha mostrado consistentemente la importancia de los recursos organizacionales como la tecnología (Bansal, 2005; Berrone *et al.*, 2013; González-Benito y González-Benito, 2006), los gastos de I+D (Surroca *et al*., 2010) o el tamaño de la empresa (Aragón-Correa *et al*., 2008), entre otros; sin embargo, múltiples trabajos más recientes basados en esta perspectiva teórica han pedido una atención adicional al papel de los recursos humanos en la transición hacia organizaciones más responsables medioambientalmente (Skoglund y Böhm, 2020). Así pues, mientras la mayoría de estos trabajos sobre gestión medioambiental y recursos humanos se han centrado en cómo prácticas empresariales como los sistemas de compensación (Berrone y Gomez-Mejia, 2009), de motivación (Martínez-del-Río *et al.*, 2012) o de capacitación (Ji *et al.*, 2012) tienen un impacto significativo a la hora de orientar a los empleados a la consecución de los objetivos medioambientales, nuestro trabajo señala la importancia de tener en cuenta también los rasgos particulares de los empleados para contribuir a dichos retos medioambientales de la empresa.

En tercer lugar, aportamos luz a la forma en que la orientación competitiva de los trabajadores constituye un aspecto clave en los estudios de gestión de recursos humanos (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017; Kacperczyk y Balachandran, 2018). Nuestros resultados contribuyen a identificar y mostrar esta característica específica de los empleados como una de las claves a la hora configurar el capital humano de la empresa, y, por tanto, como un factor diferencial para superar los resultados ambientales de sus competidores. Específicamente, nuestros resultados muestran que un capital humano formado por un mayor número de empleados con orientación competitiva llevará a una mayor proactividad medioambiental en las empresas. Los resultados obtenidos sugieren que la mentalidad competitiva impulsará una visión más orientada a lograr objetivos específicos también en el ámbito ambiental. Por otro lado, la orientación competitiva de los empleados también conducirá a un mayor empoderamiento para asumir riesgos y cambios, incluyendo los necesarios para mejoras medioambientales que supongan beneficios para la empresa en los mercados. Es decir, los empleados más competitivos están más acostumbrados a luchar por su estatus personal e identificarán con mayor facilidad los beneficios para ellos mismos de satisfacer las oportunidades de mercado que suponen las mejoras medioambientales. Así pues, nuestros resultados también proporcionan nuevas evidencias empíricas a los trabajos sobre la mentalidad competitiva del capital humano de la empresa (Bidwell y Mollick, 2015; Chattopadhyay y Choudhury, 2017; Fehr y Gächter, 2000) y, por tanto, aportamos nuevas implicaciones a tener en cuenta a la hora de gestionar de forma exitosa los recursos humanos de la empresa hacia la consecución de sus objetivos medioambientales.

Finalmente, contribuimos a la literatura previa sobre el efecto de la dispersión salarial vertical en los resultados de las empresas (Amore y Failla, 2020; Henderson y Fredrickson, 2001; Kacperczyk y Balachandran, 2018; Lim, 2019; Patel *et al.*, 2018) mostrando la dispersión salarial como el mecanismo organizacional que refuerza el comportamiento de los individuos que compiten por mayor estatus y retribuciones económicas. En concreto, nuestros resultados apoyan nuestros argumentos sobre que efectivamente ese mayor nivel de dispersión salarial potencia los efectos positivos de la competencia entre empleados, haciendo que estén más orientados todavía a la consecución de objetivos y a tomar los riesgos necesarios, ya que los beneficios por hacerlo serán aún mayores. En consecuencia, se potenciará más todavía la orientación competitiva del capital humano, traduciéndose en mayor proactividad medioambiental en la empresa, ya que, al estar más estimulada dicha orientación competitiva, habrá una mayor orientación a identificar y luchar por los beneficios de mostrar un comportamiento de liderazgo medioambiental en los mercados. De esta forma, mostramos la relevancia que tiene la estructura retributiva de una empresa en la orientación competitiva de la fuerza laboral a la hora de desarrollar una estrategia medioambiental más exitosa.

Nuestro trabajo pone de manifiesto las implicaciones prácticas de conocer las diferentes cualidades de los empleados, y así considerar qué características particulares de estos son cruciales para lograr objetivos específicos de la empresa. En concreto, nos enfocamos en una de las características más importantes en el comportamiento de los empleados en el lugar de trabajo: su mentalidad competitiva. Por un lado, si bien la orientación competitiva de la fuerza laboral a menudo se ha relacionado con una mejor orientación hacia el desempeño financiero de la empresa, nuestros resultados muestran a los directivos y gestores de recursos humanos que las empresas con una fuerza laboral más competitiva también pueden encontrar más facilidad para mejoras operativas en aspectos que requieren cambios e innovaciones, tales como la estrategia medioambiental. Adicionalmente, nuestro trabajo muestra las importantes implicaciones prácticas del diseño de un sistema retributivo en la empresa que potencie en los empleados comportamientos orientados a la consecución de objetivos.

### *5.2. Limitaciones y futuras líneas de investigación*

Aunque este estudio proporciona una perspectiva pionera sobre el impacto de la trayectoria profesional de los empleados en la estrategia ambiental de una empresa, tiene una serie de limitaciones. Primero, futuros trabajos podrían introducir variables mediadoras para estudiar qué recursos o capacidades organizacionales intermedian la relación propuesta entre las características individuales de los trabajadores y los resultados medioambientales organizacionales. Además, no poseemos variables que tengan en cuenta los rasgos personales de los empleados que puedan influir en su mentalidad competitiva, por lo que ampliar este trabajo con dichos datos, si estuvieran disponibles, sería un interesante trabajo a desarrollar en el futuro. No obstante, nuestra metodología multinivel confirma la solidez empírica de nuestras conclusiones. En segundo lugar, no prestamos atención detallada a la importancia de otras prácticas de gestión de recursos humanos diferentes a una dispersión salarial, como la capacitación, dinámicas específicas en el lugar de trabajo, u otros incentivos específicos que pueden llevar a resultados diferentes. En este sentido, los futuros artículos pueden estudiar cómo diferentes políticas de recursos humanos pueden afectar a la relación entre los individuos y los resultados organizacionales. Además, futuros trabajos podrían analizar qué practicas organizacionales estimulan la competitividad de los empleados y qué políticas consiguen encauzar esta mentalidad competitiva hacia los retos de la empresa de forma exitosa. Finalmente, nuestros datos registran la trayectoria profesional de una media de 112 empleados por empresa, mientras que el número total de empleados en estas empresas es claramente superior. También, la muestra obtenida es de empleados que trabajan en empresas americanas, y que, por tanto, operan en un mercado muy concreto; futuros trabajos podrían extender este estudio y analizar los efectos que presentamos para empresas basadas en otros países y que operen en otros mercados. Aunque nuestra metodología es particularmente poderosa para evitar sesgos de selección, futuras investigaciones podrían completar el número y el perfil de los empleados analizados. Los estudios cualitativos de empleados de una sola organización podrían ser también una fuente útil de conocimientos adicionales para futuros estudios empíricos.

Además, futuras investigaciones podrían considerar el posible impacto de otras características de los empleados en el comportamiento medioambiental de la empresa. Nuestra investigación se centró en la competitividad, pero la participación en redes profesionales, la movilidad, o la experiencia internacional de los empleados, entre otros, también pueden tener una amplia gama de potenciales efectos en las capacidades organizacionales y la estrategia medioambiental de la empresa.

### *5.3. Conclusión final*

La estrategia medioambiental de una empresa se construye no solo en función de planteamientos organizacionales generales, sino según las propias características individuales de sus trabajadores, adquiridas a lo largo de su vida laboral. Nuestro trabajo muestra que la orientación competitiva de los trabajadores a lo largo de su carrera profesional configura el capital humano de una empresa y, específicamente, tiene efectos favorables en la estrategia medioambiental proactiva de las empresas muestreadas. Además, la estructura salarial juega un papel fundamental, al ser una poderosa herramienta para reforzar los efectos de la orientación competitiva de los trabajadores.

## Referencias bibliográficas

Amore, M. D., & Failla, V. (2020). Pay dispersion and executive behaviour: Evidence from innovation. *British Journal of Management*, *31*(3), 487-504.

Aragón-Correa, J. A., Hurtado-Torres, N., Sharma, S., & García-Morales, V. J. (2008). Environmental strategy and performance in small firms: A resource-based perspective. *Journal of environmental management*, *86*(1), 88-103.

Aragón-Correa, J. A., Marcus, A., & Hurtado-Torres, N. (2016). The natural environmental strategies of international firms: Old controversies and new evidence on performance and disclosure. *Academy of Management Perspectives*, *30*(1), 24-39.

Balliet, D., Parks, C., & Joireman, J. (2009). Social value orientation and cooperation in social dilemmas: A meta-analysis. *Group Processes & Intergroup Relations*, *12*(4), 533-547.

Balsvik, R. (2011). Is labor mobility a channel for spillovers from multinationals? Evidence from Norwegian manufacturing. *The review of economics and statistics*, *93*(1), 285-297.

Bansal, P. (2005). Evolving sustainably: A longitudinal study of corporate sustainable development. *Strategic management journal*, *26*(3), 197-218.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99-120.

Barney, J. B., & Felin, T. (2013). What are microfoundations? *Academy of Management Perspectives*, *27*(2), 138-155.

Berrone, P., & Gomez-Mejia, L. R. (2009). Environmental performance and executive compensation: An integrated agency-institutional perspective. *Academy of Management Journal*, *52*(1), 103-126.

Berrone, P., Fosfuri, A., Gelabert, L., & Gomez-Mejia, L. R. (2013). Necessity as the mother of 'green'inventions: Institutional pressures and environmental innovations. *Strategic Management Journal*, *34*(8), 891-909.

Bidwell, M. (2011). Paying more to get less: The effects of external hiring versus internal mobility. *Administrative Science Quarterly*, *56*(3), 369-407.

Bidwell, M., & Mollick, E. (2015). Shifts and ladders: Comparing the role of internal and external mobility in managerial careers. *Organization Science*, *26*(6), 1629-1645.

Bloom, M. (1999). The performance effects of pay dispersion on individuals and organizations. *Academy of Management Journal*, *42*(1), 25-40.

Bloom, M., & Michel, J. G. (2002). The relationships among organizational context, pay dispersion, and among managerial turnover. *Academy of Management Journal*, *45*(1), 33-42.

Bridoux, F., & Stoelhorst, J. W. (2014). Microfoundations for stakeholder theory: Managing stakeholders with heterogeneous motives. *Strategic Management Journal*, *35*(1), 107-125.

Bridoux, F., Coeurderoy, R., & Durand, R. (2017). Heterogeneous social motives and interactions: The three predictable paths of capability development. *Strategic Management Journal*, *38*(9), 1755-1773.

Bueno-Garcia, M., Ortiz-Perez, A., & Mellado-Garcia, E. (2021). Shareholders' environmental profile and its impact on firm's environmental proactivity: An institutional approach. *Business Strategy and the Environment*, *30*(1), 374-387.

Calza, F., Profumo, G., & Tutore, I. (2016). Corporate ownership and environmental proactivity. *Business Strategy and the Environment*, *25*(6), 369-389.

Campbell, B. A., Coff, R., & Kryscynski, D. (2012). Rethinking sustained competitive advantage from human capital. *Academy of Management Review*, *37*(3), 376-395.

Chattopadhyay, S., & Choudhury, P. (2017). Sink or swim: The role of workplace context in shaping career advancement and human-capital development. *Organization Science*, *28*(2), 211-227.

Coff, R., & Kryscynski, D. (2011). Invited editorial: Drilling for micro-foundations of human capital-based competitive advantages. *Journal of Management*, *37*(5), 1429-1443.

Collins, C. J., & Smith, K. G. (2006). Knowledge exchange and combination: The role of human resource practices in the performance of high-technology firms. *Academy of management journal*, *49*(3), 544-560.

Cormier, D., & Magnan, M. (2015). The economic relevance of environmental disclosure and its impact on corporate legitimacy: An empirical investigation. *Business Strategy and the Environment*, *24*(6), 431-450.

Darnall, N., Henriques, I., & Sadorsky, P. (2010). Adopting proactive environmental strategy: The influence of stakeholders and firm size. *Journal of management studies*, *47*(6), 1072-1094.

De Stefano, F., Bagdadli, S., & Camuffo, A. (2018). The HR role in corporate social responsibility and sustainability: A boundary-shifting literature review. *Human Resource Management*, *57*(2), 549-566.

Dionisio, M., & de Vargas, E. R. (2020). Corporate social innovation: A systematic literature review. *International Business Review*, *29*(2), 101641.

Dokko, G., Wilk, S. L., & Rothbard, N. P. (2009). Unpacking prior experience: How career history affects job performance. *Organization Science*, *20*(1), 51-68.

Doluca, H., Wagner, M., & Block, J. (2018). Sustainability and environmental behaviour in family firms: A longitudinal analysis of environment-related activities, innovation and performance. *Business Strategy and the Environment*, *27*(1), 152-172.

Eggers, J. P., & Kaplan, S. (2013). Cognition and capabilities: A multi-level perspective. *Academy of Management Annals*, *7*(1), 295-340.

Ergene, S., Banerjee, S. B., & Hoffman, A. J. (2021). (Un) sustainability and organization studies: Towards a radical engagement. *Organization Studies*, *42*(8), 1319-1335.

Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives*, *14*(3), 159-181.

Felin, T., Foss, N. J., Heimeriks, K. H., & Madsen, T. L. (2012). Microfoundations of routines and capabilities: Individuals, processes, and structure. *Journal of Management Studies*, *49*(8), 1351-1374.

Felin, T., Foss, N. J., & Ployhart, R. E. (2015). The microfoundations movement in strategy and organization theory. *Academy of Management Annals*, *9*(1), 575-632.

Foss, N. J. (2011). Why micro-foundations for resource-based theory are needed and what they may look like. *Journal of Management*, *37*(5), 1413-1428.

Foss, N. J., & Linder, S. (2019). *Microfoundations: Nature, debate and promise (elements in business strategy)*. Cambridge University Press.

Fredrickson, J. W., Davis-Blake, A., & Sanders, W. G. (2010). Sharing the wealth: Social comparisons and pay dispersion in the CEO's top team. *Strategic Management Journal*, *31*(10), 1031-1053.

Gao, J., & Bansal, P. (2013). Instrumental and integrative logics in business sustainability. *Journal of Business Ethics*, *112*(2), 241-255.

Gehman, J., & Grimes, M. (2017). Hidden badge of honor: How contextual distinctiveness affects category promotion among certified B corporations. *Academy of Management Journal*, *60*(6), 2294-2320.

Ghemawat, P. (1986). Sustainable Advantage. *Harvard Business Review*, *64*(5), 53-58.

Gilbert, C. G. (2005). Unbundling the structure of inertia: Resource versus routine rigidity. *Academy of Management Journal*, *48*(5), 741-763.

González-Benito, J., & González-Benito, Ó. (2006). A review of determinant factors of environmental proactivity. *Business Strategy and the environment*, *15*(2), 87-102.

Gooderham, P., Minbaeva, D. B., & Pedersen, T. (2011). Governance mechanisms for the promotion of social capital for knowledge transfer in multinational corporations. *Journal of Management Studies*, *48*(1), 123-150.

Grigoriou, K., & Rothaermel, F. T. (2014). Structural microfoundations of innovation: The role of relational stars. *Journal of Management*, *40*(2), 586-615.

Grosser, T. J., Obstfeld, D., Choi, E. W., Woehler, M., Lopez-Kidwell, V., Labianca, G., & Borgatti, S. P. (2018). A sociopolitical perspective on employee innovativeness and job performance: The role of political skill and network structure. *Organization Science*, *29*(4), 612-632.

Gruys, M. L., Stewart, S. M., Goodstein, J., Bing, M. N., & Wicks, A. C. (2008). Values enactment in organizations: A multi-level examination. *Journal of Management*, *34*(4), 806-843.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis*. Prentice Hall.

Hambrick, D. C. (1995). Fragmentation and the other problems CEOs have with their top management teams. *California Management Review*, *37*(3), 110-127.

Hansen, G. S., & Wernerfelt, B. (1989). Determinants of firm performance: The relative importance of economic and organizational factors. *Strategic Management Journal*, *10*(5), 399-411.

Hart, S. L. (1995). A Natural-Resource-Based View of the Firm. *Academy of Management Review*, *20*(4), 986-1014.

Heaphy, E. D., Byron, K., Ballinger, G. A., Gittell, J. H., Leana, C., & Sluss, D. M. (2018). Introduction to special topic forum: The changing nature of work relationships. *Academy of Management Review*, *43*(4), 558-569.

Henderson, A. D., & Fredrickson, J. W. (2001). Top management team coordination needs and the CEO pay gap: A competitive test of economic and behavioral views. *Academy of Management Journal*, *44*(1), 96-117.

Jabbour, C. J. C., Santos, F. C. A., & Nagano, M. S. (2010). Contributions of HRM throughout the stages of environmental management: methodological triangulation applied to companies in Brazil. *The International Journal of Human Resource Management*, *21*(7), 1049-1089.

Jackson, S. E., Renwick, D. W., Jabbour, C. J., & Muller-Camen, M. (2011). State-of-the-art and future directions for green human resource management: Introduction to the special issue. *German Journal of Human Resource Management*, *25*(2), 99-116.

Jackson, S. E., Schuler, R. S., & Jiang, K. (2014). An aspirational framework for strategic human resource management. *Academy of Management Annals*, *8*(1), 1-56.

Ji, L., Huang, J., Liu, Z., Zhu, H., & Cai, Z. (2012). The effects of employee training on the relationship between environmental attitude and firms' performance in sustainable development. *The International Journal of Human Resource Management*, *23*(14), 2995-3008.

Kacperczyk, A. J. (2012). Opportunity structures in established firms: Entrepreneurship versus intrapreneurship in mutual funds. *Administrative Science Quarterly*, *57*(3), 484-521.

Kacperczyk, A. J., & Balachandran, C. (2018). Vertical and horizontal wage dispersion and mobility outcomes: Evidence from the Swedish microdata. *Organization Science*, *29*(1), 17-38.

Kale, J. R., Reis, E., & Venkateswaran, A. (2009). Rank-order tournaments and incentive alignment: The effect on firm performance. *The Journal of Finance*, *64*(3), 1479-1512.

Kaplan, S., & Henderson, R. (2005). Inertia and incentives: Bridging organizational economics and organizational theory. *Organization Science*, *16*(5), 509-521.

Kini, O., & Williams, R. (2012). Tournament incentives, firm risk, and corporate policies. *Journal of Financial Economics*, *103*(2), 350-376.

Kock, C. J., Santaló, J., & Diestre, L. (2012). Corporate governance and the environment: What type of governance creates greener companies? *Journal of Management Studies*, *49*(3), 492-514.

Lazear, E. P., & Rosen, S. (1981). Rank-order tournaments as optimum labor contracts. *Journal of Political Economy*, *89*(5), 841-864.

Lim, E. (2019). Attainment discrepancy and new geographic market entry: The moderating roles of vertical pay disparity and horizontal pay dispersion. *Journal of Management Studies*, *56*(8), 1605-1629.

Lindenberg, S., & Foss, N. J. (2011). Managing joint production motivation: The role of goal framing and governance mechanisms. *Academy of Management Review*, *36*(3), 500-525.

Linn, S. C., & Park, D. (2005). Outside director compensation policy and the investment opportunity set. *Journal of Corporate Finance*, *11*(4), 680-715.

Martínez-del-Río, J., Céspedes-Lorente, J., & Carmona-Moreno, E. (2012). High-involvement work practices and environmental capabilities: How HIWPS create environmentally based sustainable competitive advantages. *Human Resource Management*, *51*(6), 827-850.

Mawdsley, J. K., & Somaya, D. (2016). Employee mobility and organizational outcomes: An integrative conceptual framework and research agenda. *Journal of Management*, *42*(1), 85-113.

Nayak, A., Chia, R., & Canales, J. I. (2020). Noncognitive Microfoundations: Understanding Dynamic Capabilities as Idiosyncractically Refined Sensitivities and Predispositions. *Academy of Management Review*, *45*(2), 280-303.

Nickerson, J. A., & Zenger, T. R. (2008). Envy, comparison costs, and the economic theory of the firm. *Strategic Management Journal*, *29*(13), 1429-1449.

Oeij, P. R., van der Torre, W., Vaas, F., & Dhondt, S. (2019). Understanding social innovation as an innovation process: Applying the innovation journey model. *Journal of Business Research*, *101*(8), 243-254.

Ones, D. S., & Dilchert, S. (2012). Environmental sustainability at work: A call to action. *Industrial and Organizational Psychology*, *5*(4), 444-466.

Patel, P. C., Li, M., Triana, M. C., & Park, H. D. (2018). Pay dispersion among the top management team and outside directors: Its impact on firm risk and firm performance. *Human Resource Management*, *57*(1), 177-192.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource-based view. *Strategic management journal*, *14*(3), 179-191.

Phillips, R. A., Berman, S. L., Elms, H., & Johnson-Cramer, M. E. (2010). Strategy, stakeholders and managerial discretion. *Strategic Organization*, *8*(2), 176-183.

Ployhart, R. E., & Hendricks, J. L. (2019). The missing levels of microfoundations: A call for bottom-up theory and methods. In S. E. Humphrey, & J. M. LeBreton (Eds.), *The handbook of multilevel theory, measurement, and analysis* (pp. 141-162). American Psychological Association.

Ployhart, R. E., Nyberg, A. J., Reilly, G., & Maltarich, M. A. (2014). Human capital is dead; long live human capital resources! *Journal of management*, *40*(2), 371-398.

Preacher, K. J., Zyphur, M. J., & Zhang, Z. (2010). A general multilevel SEM framework for assessing multilevel mediation. *Psychological methods*, *15*(3), 209.

Pucheta-Martínez, M. C., & López-Zamora, B. (2018). Engagement of directors representing institutional investors on environmental disclosure. *Corporate Social Responsibility and Environmental Management*, *25*(6), 1108-1120.

Radu, C., & Francoeur, C. (2017). Does innovation drive environmental disclosure? A new insight into sustainable development. *Business Strategy and the Environment*, *26*(7), 893-911.

Raffiee, J., & Byun, H. (2020). Revisiting the portability of performance paradox: Employee mobility and the utilization of human and social capital resources. *Academy of Management Journal*, *63*(1), 34-63.

Ramus, C. A. (2002). Encouraging innovative environmental actions: What companies and managers must do. *Journal of World Business*, *37*(2), 151-164.

Renwick, D. W., Redman, T., & Maguire, S. (2013). Green human resource management: A review and research agenda. *International Journal of Management Reviews*, *15*(1), 1-14.

Ridge, J. W., Aime, F., & White, M. A. (2015). When much more of a difference makes a difference: Social comparison and tournaments in the CEO's top team. *Strategic Management Journal*, *36*(4), 618-636.

Russo, M. V., & Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. *Academy of management Journal*, *40*(3), 534-559.

Sharma, S., & Vredenburg, H. (1998). Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. *Strategic Management Journal*, *19*(8), 729-753.

Siegel, P. A., & Hambrick, D. C. (2005). Pay disparities within top management groups: Evidence of harmful effects on performance of high-technology firms. *Organization Science*, *16*(3), 259-274.

Skoglund, A., & Böhm, S. (2020). Prefigurative partaking: Employees' environmental activism in an energy utility. *Organization Studies*, *41*(9), 1257-1283.

Surroca, J., Tribó, J. A., & Waddock, S. (2010). Corporate responsibility and financial performance: The role of intangible resources. *Strategic Management Journal*, *31*(5), 463-490.

Tantalo, C., & Priem, R. L. (2016). Value creation through stakeholder synergy. *Strategic Management Journal*, *37*(2), 314-329.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319-1350.

Tong, L., Liu, N., Zhang, M., & Wang, L. (2018). Employee protection and corporate innovation: Empirical evidence from China. *Journal of Business Ethics*, *153*(2), 569-589.

Tripsas, M., & Gavetti, G. (2000). Capabilities, cognition, and inertia: Evidence from digital imaging. *Strategic Management Journal*, *21*(10), 1147-1161.

Van Lange, P. A. M. (1999). The pursuit of joint outcomes and equality in outcomes: An integrative model of social value orientation. *Journal of Personality and Social Psychology*, *77*(2), 337-349.

Verbeke, A., Bowen, F., & Sellers, M. (2006). *Corporate environmental strategy: Extending the natural resource-based view of the firm*. Paper presented at the Annual Meeting of the Academy of Management, Atlanta.

Voegtlin, C., & Scherer, A. G. (2017). Responsible innovation and the innovation of responsibility: Governing sustainable development in a globalized world. *Journal of Business Ethics*, *143*(2), 227-243.

Wagner, M. (2011). Environmental management activities and sustainable HRM in German manufacturing firms–incidence, determinants, and outcomes. *German Journal of Human Resource Management*, *25*(2), 157-177.

Walls, J. L., Berrone, P., & Phan, P. H. (2012). Corporate governance and environmental performance: Is there really a link? *Strategic Management Journal*, *33*(8), 885-913.

Yuan, F., & Woodman, R. W. (2010). Innovative behavior in the workplace: The role of performance and image outcome expectations. *Academy of Management Journal*, *53*(2), 323-342.

Zhou, Y., Fan, X., & Son, J. (2019). How and when matter: Exploring the interaction effects of high-performance work systems, employee participation, and human capital on organizational innovation. *Human Resource Management*, *58*(3), 253-268.

MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO

ICE

CUADERNOS ECONÓMICOS

## NORMAS DE PUBLICACIÓN

Los manuscritos que se envíen para publicar en Cuadernos Económicos de ICE deberán ser originales, no publicados, ni en proceso de evaluación por otra publicación. Se aceptan trabajos en castellano o en inglés. Todos los trabajos recibidos serán sometidos para su aceptación a evaluación externa anónima.

1. Los originales se enviarán en formato Microsoft Word a la dirección de correo electrónico, revistasice.sscc@mincotur.es o directamente a la editora, María del Carmen Díaz Roldán (carmen.diazroldan@uclm.es), señalando en el asunto «Cuadernos Económicos de ICE». También pueden enviarse a través de la página web de *Revistas ICE*.
2. La extensión del trabajo, incluyendo cuadros, gráficos, tablas, notas y referencias bibliográficas, no excederá de 30 páginas. La fuente será Times New Roman 12, márgenes de 3 cm, espaciado doble y paginado en la parte inferior derecha.
3. Cada original incluirá en una primera página independiente el título del artículo y la fecha de conclusión del mismo; el nombre y apellidos de los autores, afiliación institucional, dirección, teléfono y correo electrónico de cada uno de ellos.
4. En la primera página del texto se incluirá:
   - El título en castellano y en inglés.
   - Un resumen del trabajo, en castellano y en inglés, con una extensión que no exceda de 100 palabras.
   - Una lista de 2 a 6 palabras clave
   - Los códigos (entre 1 y 5) de la clasificación del Journal of Economic Literature (JEL) que puede consultarse en el siguiente enlace https://www.aeaweb.org/jel/guide/jel.php
5. En las siguientes páginas se incorporará el texto, la información gráfica y la bibliografía con la siguiente organización:
   - Se incluirá, por este orden, introducción, desarrollo, conclusiones y referencias bibliográficas. Si hubiera anexos, se insertarán tras las referencias bibliográficas y deberán llevar título.
   - En un archivo Excel independiente se incluirá la representación gráfica (cuadros, gráficos, diagramas, figuras, etcétera), que debe llevar título, estar numerada y referenciada en el texto. En la parte inferior se incluirán la fuente de información y, en su caso, las notas aclaratorias.
   - Los apartados y subapartados se numerarán en arábigos según el siguiente modelo:

1. **Título del apartado** (primer nivel)
    *1.1. Subapartado (segundo nivel)*
        1.1.1. Sección del subapartado (tercer nivel)

- Las notas a pie de página irán integradas en el texto y su contenido debe estar al final de su misma página en tamaño 10, Times New Roman.
- En las citas en el texto, de acuerdo con las normas de la American Psychological Association (Normas APA), se indicará entre paréntesis el apellido del autor y el año. Ej.: (Martínez, 1991).
- Las referencias a siglas deben ir acompañadas, en la primera ocasión en que se citen, de su significado completo.
- Al final del texto se recogerá la bibliografía utilizada, bajo el título de «Referencias bibliográficas», ordenada alfabéticamente según las Normas APA. A continuación se recogen los ejemplos de referencias más utilizados:

***Libro***

Apellido, A. A. (Año). *Título*. Editorial.
Pilling, D. (2019). *El delirio del crecimiento*. Taurus.

***Libro electrónico con DOI (o URL)***

Apellido, A. A. (Año). *Título*. https://doi.org/xxx
Nicolleti, B. (2017). The Future of Fintech: Integrating Finance and Technology in Financial Services. Palgrave Macmillan. https://doi.org/10.1007/978-3-319-51415-4

***Capítulo de libro***

Apellido, A. A. (Año). Título del capítulo o la entrada. En C. C. Apellido (Ed.), *Título del libro* (pp. xx-xx). Editorial.
Demas, M., & Agnew, N. (2013). Conservation and sustainable development of archaeological sites. En I. Rizzo y A. Mignosa, *Handbook on the Economics of Cultural Heritage* (pp. 326-343). Edward Elgar.

***Publicaciones periódicas formato impreso***

Apellido, A. A. (Año). Título del artículo. *Nombre de la revista*, *volumen* (número), pp-pp.
Fernández-Blanco, V., Prieto-Rodríguez, J., & Suárez-Pandiello, J. (2017). A quantitative analysis of reading habits in Spain. *International Journal of Arts Management, 19*(3), 19-32.

***Publicaciones periódicas online con DOI (o URL)***

Apellido, A. A. (Año). Título del artículo. *Nombre de la revista*, *volumen*(número), pp-pp. https://doi.org/xxx
Amador, J., & Cabral, S. (2017). Networks of Value-added Trade. *The World Economy, 40*(7), 1265-1512. https://doi.org/10.1111/twec.12469

***Informe oficial en web***

Organismo. (Año). *Título del informe*. http://www…

Fondo Monetario Internacional. (2019). *Global Financial Stability Report*. https://www.imf.org/en/Publications/GFSR/Issues/2019/10/01/global-financial-stability-report-october-2019

***Ley/Reglamento***

Título de la ley. *Publicación*, número, fecha de publicación, pp-pp. http://www.boe.es....

Ley Orgánica 8/2013, de 9 de diciembre, para la mejora de la calidad educativa. *Boletín Oficial del Estado*, nº. 295, de 10 de diciembre de 2013, pp. 97858 a 97921. https://www.boe.es/buscar/pdf/2013/BOE-A-2013-12886-consolidado.pdf

**Orden de la lista de referencias bibliográficas**

Las referencias se ordenan alfabéticamente y, en caso de varios trabajos realizados por el mismo autor/a, el criterio es el siguiente:

- Primero los trabajos en los que el/la autor/a figura solo/a. Correlativos de año más antiguo al año más actual de publicación.
- Segundo, aquellos trabajos colectivos en los que el/la autor/a es el/la primero/a. Correlativos por fecha.
- Tercero, en caso de coincidencia exacta de autores y fechas, debe citarse cada trabajo añadiendo una letra a la fecha. Ej.: 2014a, 2014b, etc.

En la página web del grupo de revistas de Información Comercial Española se publican los artículos en formato electrónico y se recogen los principios editoriales de la publicación: ***www.revistasICE.com***

# CUADERNOS ECONÓMICOS DE INFORMACIÓN COMERCIAL ESPAÑOLA
(CICE) ISSN 0210-2633

## SUSCRIPCIÓN ANUAL

| CUADERNOS ECONÓMICOS DE INFORMACIÓN COMERCIAL ESPAÑOLA (2 NÚMEROS/AÑO) | | | |
|---|---|---|---|
| | **ESPAÑA 1 año** | **UNIÓN EUROPEA 1 año** | **RESTO DEL MUNDO 1 año** |
| SUSCRIPCIÓN | 30,00 € | 30,00 € | 30,00 € |
| Gastos de envío España | 1,12 € | 1,60 € | 2,08 € |
| Más 4% de IVA<br>Excepto Canarias, Ceuta y Melilla | 1,24 € | | |
| TOTAL | 32,36 € | 31,60 € | 32,08 € |

## EJEMPLARES SUELTOS

| CUADERNOS ECONÓMICOS DE INFORMACIÓN COMERCIAL ESPAÑOLA | | | |
|---|---|---|---|
| | **ESPAÑA 1 ejemplar** | **UNIÓN EUROPEA 1 ejemplar** | **RESTO DEL MUNDO 1 ejemplar** |
| NÚMERO SUELTO | 18,00 € | 18,00 € | 18,00 € |
| Gastos de envío España | 0,56 € | 0,80 € | 1,04 € |
| Más 4% de IVA<br>Excepto Canarias, Ceuta y Melilla | 0,74 € | | |
| TOTAL | 19,30 € | 18,80 € | 19,04 € |

**Suscripciones y venta de ejemplares sueltos**
Ministerio de Industria, Comercio y Turismo. Centro de Publicaciones
Calle Panamá, 1. Planta 0, despacho 3
Teléfono: 91 349 43 35 (ventas y suscripciones)
Correo electrónico: CentroPublicaciones@mincotur.es

GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO
SECRETARÍA GENERAL TÉCNICA
SUBDIRECCIÓN GENERAL DE DESARROLLO NORMATIVO, INFORMES Y PUBLICACIONES
CENTRO DE PUBLICACIONES

MINISTERIO DE INDUSTRIA,
COMERCIO Y TURISMO

CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

# CUADERNOS ECONÓMICOS

## ÚLTIMOS NÚMEROS PUBLICADOS

CUADERNOS ECONÓMICOS

ICE

INFORMACIÓN COMERCIAL ESPAÑOLA

GOBIERNO DE ESPAÑA

MINISTERIO DE INDUSTRIA, COMERCIO Y TURISMO

P.V.P.: 18 € + IVA

9 770210 263007 00104