Universitat Pompeu Fabra Barcelona

Humberto Llavador
Departament d'Economia i Empresa
humberto.llavador@upf.edu
www.upf.edu/web/humberto-llavador

Universitat Pompeu Fabra
Ramon Trias Fargas, 25-27
08005 BARCELONA (SPAIN)
Tel.: +34 93 542 23 81

Simposio de la Asociación Española de Economía-Spanish Economic Association (SAEe)
University of Salamanca
Salamanca, Spain, 37008

Subject: Declaration of Original Work - Simone Cigna

Dear SAEs committee,
I am writing to declare that the paper titled "*Work hard, Rest harder: the role of leisure for carbon emissions*" submitted by my PhD student, Simone Cigna to be considered for presentation at the upcoming Simposio de la Asociación Española de Economía-Spanish Economic Association (SAEe) on 14-16th of December 2023 is their original work.
As the supervisor of Simone Cigna, I have monitored their progress throughout their research and can attest to the authenticity and originality of their work. I have reviewed the paper and can confirm that it reflects Simone Cigna's independent research efforts, critical thinking, and intellectual contributions.
I affirm that Simone Cigna has diligently conducted his research and formulated the findings presented in the paper. They have appropriately acknowledged and referenced the contributions of other researchers where necessary, thereby adhering to ethical practices in academic writing.
Please do not hesitate to contact me if you require any further information or clarification regarding Simone Cigna's work or the originality of the submitted paper. I appreciate your consideration of Simone Cigna's submission and its potential inclusion in the conference program.
Thank you for your attention to this matter.

Sincerely,

Humberto Llavador
Associate Professor of Economics at Universitat Pompeu Fabra (UPF)
Affiliate Professor of the Barcelona School of Economics (BSE)
Researcher of the Institute for Political Economy and Governance (IPEG)

Work hard, Rest harder:

the role of leisure for carbon emissions

SIMONE CIGNA

Advisor: Prof. Humberto Llavador
Reader: Prof. Marti Mestieri

Introduction

I would predict that the standard of life in progressive countries one hundred years hence will be between four and eight times as high as it is to-day... For many ages to come the old Adam will be so strong in us that everybody will need to do some work if he is to be contented... But beyond this, we shall endeavor to spread the bread thin on the butter-to make what work there is still to be done to be as widely shared as possible. Three-hour shifts or a fifteen-hour week may put off the problem for a great while. For three hours a day is quite enough to satisfy the old Adam in most of us!

John Maynard Keynes

In advanced economies, individuals are increasingly choosing to allocate more time to leisure activities rather than working hours. Despite the rise in wages, the average weekly leisure time between 1965 and 2013 increased by an average of 4.5 hours (Boppart and Ngai (2021)). In 2021, the average US citizen spent approximately 5.3 hours on leisure activities, making it the most time-consuming category after personal care and sleep. This trend indicates a high value placed on leisure time by people. However, the standard working hours in advanced economies have not followed the trajectory suggested by Keynes, with many countries maintaining a 40-hour workweek, a standard established back in 1936 (Kallis et al. (2013)).

Given the changing patterns in time allocation and the increasing importance of leisure, this paper aims to explore the impact of leisure on carbon emissions. In order to do that, in this paper, leisure, as in Becker (1965) is modelled as a commodity, which requires both time and consumption to be produced. The carbon intensity of leisure will then depend on the ratio between time and leisure consumption. In the policy debate, scholars have argued for intervening in time allocation choices by changing working time regulations as a means to mitigate the climate crisis (King and Van Den Bergh (2017)). This policy has the potential to deliver a triple dividend: *economic*, through reduced unemployment; *social*, through increased well-being; and *environmental*, through lower emissions. To account for the environmental effects of this policy, carbon emissions should be considered from a time-allocation perspective. However, in the literature, carbon emissions have primarily been accounted for from the expenditure side, and only recently have scholars begun to adopt a time-allocation perspective (Jiang et al. (2023)). This paper aims to employ both an expenditure and time-allocation perspective to account for overall household carbon emissions.

On the one hand, expenditure is crucial in determining carbon emissions. Chancel (2022) shows that in North America, for instance, the top 10% of the income distribution emits almost 7 times more per capita compared to the bottom 50% and 3.5 times more than the middle 40%. While this difference may also be attributed, in theory, to the carbon intensity of consumption, the author finds carbon inequality remains lower than income and wealth inequality, suggesting the prevalence of a scale effect (Chancel (2022)). On the other hand, time allocation also plays a significant role in determining carbon emissions (Fitzgerald et al. (2018a)). For the 50 US states, the authors find that working time is positively associated with carbon emissions. Altogether, this evidence highlights the importance of considering both expenditure and time allocation when accounting for carbon emissions.

In light of these factors, this paper develops a theoretical framework to summarize the different channels of interaction between expenditure, time-allocation choices, and carbon emissions. To simplify the analysis, this paper assumes that leisure encompasses all time spent outside the workplace. This assumption aligns with reality if we consider the time households allocate to personal care, eating, and household activities as fixed, given that these are the remaining time-intensive categories. In the model, the income of household is key to determine the type of leisure that agents will choose. This setup can replicate the observed inequality in leisure consumption (Boppart and Ngai (2021)). Moreover, in the model more productive agents engage in leisure activities that are more consumption-intensive, given their higher opportunity cost for leisure time. This suggests a potential explanation for the rising trend in carbon inequality.

Examining the policy dimension, this paper finds that under mild assumptions, working time regulations have the potential to reduce carbon emissions. The rationale is that households with lower available income will reduce their overall consumption. This will be called *extensive* margin. However, in this model, working time regulations primarily affect higher-income households, as lower-income households already choose to work fewer hours. This may reverse the effect on carbon emissions if affluent households increase their leisure consumption in response to the additional available time. This will be called *intensive* margin. The overall effect on carbon emissions will depend on the relative elasticities of different types of consumption to emissions and on complementary policies. Similar findings are discussed when analyzing a tax on leisure consumption.

The remainder of this paper is structured as follows: Section 1 provides a review of the literature in economics and political economy on the value of leisure and the empirical evidence on the relationship between leisure time and carbon emissions. Section 2 outlines the model used in this paper for the analysis. Section 3 examines the policy implications arising from the model results. Finally, the paper concludes by outlining potential avenues for further research in this field.

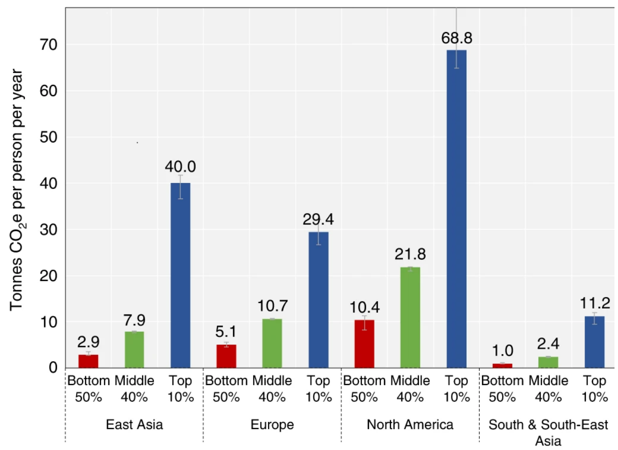

Figure 1: Carbon inequality withing continent (Chancel (2022))

Table 4. Longitudinal Regression Models of the Effect of Average Hours Worked per Week on CO_2 Emissions in All 50 US States, 2007–2013

	Model 1		Model 2		Model 3		Model 4	
	Scale (FE)		Comp. (FE)		Scale (RE)		Comp. (RE)	
Working hours	0.668***	(0.179)	0.675***	(0.202)	0.654**	(0.243)	0.552*	(0.235)
Employed pop. %	0.519***	(0.120)			0.209	(0.218)		
GDP per hour	0.06	(0.094)			0.129	(0.089)		
GDP per capita			0.108	(0.067)			0.134	(0.090)
Total population	0.918***	(0.167)	0.806***	(0.174)	0.747***	(0.033)	0.758***	(0.038)
Manufacturing (% of GDP)	−0.024	(0.042)	−0.028	(0.041)	−0.054	(0.034)	−0.046	(0.033)
Energy production	0.070*	(0.029)	0.068*	(0.027)	0.139***	(0.017)	0.121***	(0.018)
Average household size	−0.288	(0.225)	−0.262	(0.240)	−0.312	(0.244)	−0.336	(0.234)
Working-age population	1.034	(0.700)	1.008	(0.745)	0.73	(0.707)	0.912	(0.687)
State environmentalism					−0.311***	(0.064)	−0.338***	(0.076)
Midwest					0.443***	(0.088)	0.461***	(0.104)
South					0.256**	(0.097)	0.267*	(0.115)
West					−0.029	(0.096)	−0.013	(0.115)
Constant	−18.743***	(3.813)	−15.853***	(3.963)	−14.027***	(3.156)	−14.365***	(3.058)
N	350		350		350		350	
R-Squared	0.998		0.998		0.923		0.919	

Note: All continuous variables are logged (ln). All models are calculated with AR(1) correction. All models contain unreported year-specific intercepts. Models 1 and 2 also contain unreported unit-specific intercepts. Standard errors in parentheses. *$p < 0.05$ **$p < 0.01$ ***$p < 0.001$

Figure 2: Working hours and carbon emissions (Fitzgerald et al. (2018a))

1 Literature Review

In the field of economics, the value of time has been recognized as a key element in economic analysis since the seminal contribution by Becker (1965). Becker introduced the concept that agents derive utility from commodities that require both money and time for their "production" by households. However, the concept of time value has primarily been analyzed from a singular perspective, focusing solely on the opportunity cost of work time, which is equivalent to the wage rate. This narrow viewpoint, which disregards the inclusion of work time in utility, has faced criticism from Johnson (1966) and Oort (1969). In 1971, DeSerpa (1971) identified three distinct notions of time value: the value of time as a resource, the value of allocating time to an activity, and the value of time saved in a constrained activity.

Moreover, the analysis of time allocation is of significant importance due to the changing patterns of time use by households over the last few decades, as documented by newly available data on time use. Aguiar and Hurst (2007) document a dramatic increase in leisure time between 1965 and 2003. The authors also find, using various definitions for leisure, a growing inequality that mirrors the increasing wage gap across different skill levels. Ramey and Francis (2009), in a comprehensive study of the past 106 years in the US, finds that leisure time has increased by 5 hours per week during the last century. Kopytov et al. (2023), using a macroeconomic model with general preferences and OECD data, estimate that the fall in recreation prices can explain a significant portion of the decline in working hours.

Given the documented change in time-use patterns, a related question arises: Could such a change have had an impact on individuals' carbon footprint? The intuition is that reducing working time will lead to lower energy use and environmental pressure, partly due to the resulting reduction in income that prompts people to adopt more contained consumption and energy use behavior. Additionally, more leisure time may alleviate time constraints and allow for more time-intensive, yet environmentally friendly, consumption and leisure choices.

At the empirical level, Knight et al. (2013), using a panel of 29 countries, find that reducing working hours may lead to lower ecological footprints, carbon footprints, and carbon dioxide emissions. Similarly, Hayden and Shandra

(2009) find that higher working hours are associated with a higher carbon footprint and higher energy consumption per capita (Rosnick and Weisbrot (2007)). More recently, Fitzgerald et al. (2018a) argue that reducing working hours may be a multiple dividend policy by decreasing carbon emissions and protecting employment. The authors support their claim with an empirical analysis for the period 2007-2013 in the US at the state level. In a quasi-natural experiment conducted in Switzerland, Neubert et al. (2022) find that reducing working time reduces the environmental footprint not only as a result of reduced income but also due to more environmentally friendly choices.

However, other scholars have pointed out that aggregate analysis may conceal significant heterogeneity across income groups regarding the carbon intensity of the time employed outside of work. As an anecdotal example, when Henry Ford introduced an additional leisure day for his workers, the purpose was to give them time to consume more, which could potentially increase households' ecological footprint. Kallis et al. (2013) argue that environmental benefits from reduced working hours can only arise if the government taxes leisure consumption and invests in convivial infrastructures. King and Van Den Bergh (2017) find that only specific designs of working time reduction policies deliver significant environmental benefits. Fremstad et al. (2019) argue that while reducing working hours may decrease carbon footprints, such effects account for a small fraction of the differences in per capita carbon footprints across high-income countries, and they may be irrelevant in achieving carbon emissions targets.

To shed light on this mixed evidence, it is argued that carbon footprints in the models need to be examined not only from an expenditure perspective but also from a time-use perspective. Jiang et al. (2023) are the first to estimate carbon footprints from a time-use perspective. Cieplinski et al. (2021) are the first to apply a dynamic macro-simulation model to investigate the role of working time reduction in CO2 emissions reduction. While these models can be helpful simulation tools for different policy scenarios, they do not provide a comprehensive understanding of the channels through which time-allocation choices can affect carbon emissions.

To address this gap, this paper aims to develop a simple consumption/leisure model that takes into account carbon inequality patterns based on both expenditure and time allocation choices. The main contribution of this paper is to provide policymakers with a simple framework to consider working time regulations and leisure consumption taxes and their effects on carbon emissions.

2 The model: simplified version

The model is based on Boppart and Ngai (2021). I consider a continuum of infinitely lively household that derives utility from consumption of market goods, leisure and environmental quality. Households differ in their work efficiency s. Firms use capital and labour to produce. Carbon emissions are accounted from the demand side, through both households' consumption and time allocation choices.

Households

$$\max_{c_m, z} \sum_{t=0}^{\infty} U_i(c_m, z, E)$$

$$s.t. \;\; a_i(t+1) + c_{i,m} + c_{i,z} = (1 + r - \delta)a_i(t) + (\bar{l} - l_{iz})w_i \tag{1}$$

with:

$c_{i,m}$: consumption of market goods

z_i: leisure commodity

where households can produce the leisure commodity z_i according to the following production function:

$$z_i = c_{i,z}^{\alpha} l_{i,z}^{1-\alpha}$$

From now on, if a variable does not have a time subscript we consider it at time t. The assumptions we hold are standard:
$\frac{\delta U}{\delta c_m}, \frac{\delta U}{\delta l} > 0$
$\frac{\delta U}{\delta^2 c_m}, \frac{\delta U}{\delta^2 z} < 0$
In order to provide some intuition, market goods consumption is considered all that consumption indispensable to live with (e.g. eating, clothing, housing etc..), Leisure consumption instead here refers to "higher-level consumption demand after one's basic living needs are met. Leisure consumption usually includes cultural and entertainment supplies, visits to exhibitions, fitness activities, group travel, and other recreational activities" (Yao (2019)).
The controls for the household i are: $a_i(t+1), c_{i,m}(t), c_{i,z}(t), l_{i,z}(t)$ and the state is $a_i(t)$. Rewriting it with the Lagrangian:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t U_i(c_m, z) + \sum_{t=0}^{\infty} \beta^t \lambda_t \Big((1 + r - \delta) a_i(t) + (\bar{l} - l_z) w_i - a_i(t+1) - c_{im} - c_{iz} \Big)$$

The FOC for agent i can be written as follows:

$$(a_{t+1}) : \lambda_t = (1 + r(t+1) - \delta) \lambda_{t+1}$$
$$(c_{i,m}) : U_{i,c_m} = \lambda_t$$
$$(c_{i,z}) : U_{i,z} \frac{\delta z_i}{\delta c_{i,z}} = \lambda_t$$
$$(l_{i,z}) : U_{i,z} \frac{\delta z_i}{\delta l_{i,z}} = \lambda_t w_i$$

Environmental quality

To this standard consumption/leisure model, I add the carbon production component. In particular, I assume that the emissions produced by households depend on both consumption and time allocation choices. Yet, such externalities are not internalized in their maximization problem, as in a classical Pigouvian set-up. I assume the following forms:

$$E = \bar{E} - \int_i e_i di$$

$$e_i = g(c_m, c_z, l_z)$$

with: $\bar{E}$ representing the pre-industrial environmental quality and:

- $g_{c_m} > 0 \ \forall i$: individuals emissions are increasing in the consumption of market goods;
- $g(c_z) > 0 \ \forall i$: individuals emissions are increasing in consumption of leisure goods;
- $g(c_z) > g(c_m)b \ \forall i$: leisure consumption is more polluting than market goods consumption c_m. This is intuitive given the different nature of the two types of consumption. As an example, travelling, included in leisure consumption, is by far the most polluting activity by individuals.
- $g(l_z) < g(c_z) \ \forall i$. In other words, consumption in leisure is always marginally more polluting than leisure time. The intuition is that spending time on an activity is not by itself polluting. The only way in which time available in leisure can increase pollution given the same amount of leisure expenditure is by changing the consumption choices. As an example, agents with more leisure time will choose to take a flight with the same price as a train

to reach their destination. If anything I would expect the opposite. Individuals with more time can, while keeping constant the expenditure, make more environmentally friendly choices which are often more time intensive. In this case $g(l_z) < 0$ and time in leisure will actually decrease the environmental footprint by agents. At the aggregate level, this can be justified through empirical evidence such Rosnick and Weisbrot (2007),Hayden and Shandra (2009) and Knight et al. (2013). Using different methods, they all find that lower working hours (i.e. more time for leisure in our simple model) decreases the carbon footprint. This takes place not only through a scale effect (i.e. less income due to reduced working hours) but also through an intensive margin (i.e. lower Co2 emissions per dollar spent).

Production side

There is a representative firm which produces according to the following and standard production function:

$$Y_t = f(K(t), \bar{L} - L_z)$$

with $L - L_z = L_m$ and $f_k > 0, f_{kk} < 0, f_{L_m} > 0, f_{L_m,L_m} < 0$

Market clearing

Market clearing on the capital and labor market requires:

$$\int_0^1 a_i(t)di = K(t)$$

and

$$\int_0^1 (\bar{l} - l_{z,i}(t))s_i(t)di = \bar{L} - \bar{L_z}(t) = L_m(t)$$

The resource constraint is given by:

$$Y(t) = \int_0^1 c_{m,i}(t)di + \int_0^1 c_{z,i}(t)di + \int_0^1 (a_i(t+1) - (1-\delta)a_i(t))di$$

In other words, all the resources of the economy ($Y(t)$) must either be spent in market goods (c_m), in leisure goods (c_z) or invested.

Social planner

The social planner recognizes that, consumption and time allocation choices have an effect on carbon emissions:

$$\max_{l_z, c_z} \sum_{t=0}^{1} \beta^t \int_0^1 U_i(c_m, c_z^{\alpha} l_z^{1-\alpha}, E)di + \sum_{t=0}^{1} \beta^t$$
$$\lambda_t(f(K(t), L_m) - C_m - C_z - (K(t+1) - (1-\delta)(K(t))$$

FOC:

$$(c_{i,m}) : U_{i,c_m} + U_{i,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta c_{im}} + \int_{j \neq i} U_{j,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta c_{i,m}}dj = \lambda_t$$
$$(c_{i,z}) : U_{i,z}\frac{\delta z_i}{\delta c_{i,z}} + U_{i,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta c_{i,z}} + \int_{j \neq i} U_{j,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta c_{i,z}}dj = \lambda_t$$
$$(l_{i,z}) : U_{i,z}\frac{\delta z_i}{\delta l_{i,z}} + U_{i,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta l_{i,z}} + \int_{j \neq i} U_{j,E}\frac{\delta E}{\delta e_i}\frac{\delta e_i}{\delta l_{i,z}}dj = \lambda_{i,t} f_{l_{i,z}}$$
$$(K) : \lambda_{i,t}(f_k - 1 + \delta) = \beta\lambda_{i,t+1}$$

Rewriting it with elasticities:

$$
\begin{aligned}
&(c_{i,m}) : U_{i,c_m} + \int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\epsilon_{(e_i c_{im})}\frac{U_j}{c_{im}}dj = \lambda_t \\
&(c_{i,z}) : \epsilon_{u_i,z_i}\epsilon_{z_i,c_{iz}}\frac{U_i}{c_{iz}} + \int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\epsilon_{(e_i c_{iz})}\frac{U_j}{c_{iz}}dj = \lambda_t \\
&(l_{i,z}) : \epsilon_{u_i,z_i}\epsilon_{z_i,l_{iz}}\frac{U_i}{l_{iz}} + \int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\epsilon_{(e_i l_{iz})}\frac{U_j}{l_{iz}}dj = \lambda_{i,t} f_{l_{i,z}} \\
&(K_m) : \lambda_{i,t}(f_{km} - 1 + \delta) = \beta\lambda_{i,t+1}
\end{aligned}
$$

Substituting and simplifying the FOCs we get:

$$
U_{i,c_m} = U_{i,c_m}(t+1) + \int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\left(\epsilon_{(e_i c_{im})}(t+1)\frac{U_j}{c_{im}}(t+1) - (\epsilon_{(e_i c_{im})}(t)\frac{U_j}{c_{im}}(t)\right)dj \tag{2}
$$

$$
U_{i,c_z} = U_{i,c_m} + \int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\left(\epsilon_{(e_{iz} c_{iz})}\frac{U_j}{c_{iz}} - \epsilon_{(e_i c_{im})}\frac{U_j}{c_{im}}\right) \tag{3}
$$

$$
\epsilon_{u_i,z}(\epsilon_{z,l_{iz}}\frac{U_i}{l_{iz}} - \epsilon_{z,c_{iz}}\frac{U_i}{c_{iz}}U_{i,l_z}) = f_{li,z}\left[\int_0^1 \epsilon_{(u_j,e)}\epsilon_{(e,e_i)}\left(\epsilon_{(e_i c_{iz})}\frac{U_j}{c_{iz}} - \epsilon_{(e_i l_{iz})}\frac{U_j}{l_{iz}}\right)\right] \tag{4}
$$

(5)

where we used in (2) the simplifying assumption that $\frac{\beta}{f_k - 1 + \delta} = 1$ and that the elasticities of utility to environmental quality ($\epsilon_{u_j,e}$) and of environmental quality to individuals carbon emissions (ϵ_{e,e_i}) are constant over time.

Eq (2) is a modified Euler equation where we take into account the potential differences in carbon impact of consumption between today and tomorrow. Eq (3) summarize the trade offs between consumption in market good and leisure consumption. Lastly, eq (3) will determine the composition of leisure between time and consumption.

Key observations

- **Income dependent leisure:** From the FOC of the HH problem combining the FOC on $(l_{i,z})$ and the FOC on $(c_{i,z})$ we get the following:

$$\frac{U_{i,z} z_{i,l_z}}{U_{i,z} z_{i,c_z}} = \frac{\lambda_i w_i}{\lambda_i} \tag{6}$$

$$\frac{z_{i,l_z}}{z_{i,c_z}} = w_i \tag{7}$$

Intuition: given the assumption on the function z, richer households (i.e. higher w_i will use relative more consumption (c_z) in leisure compared to poorer households who will compensate using more time (l_z)). This derives from the fact that the price of leisure is different across households, with richer households paying a higher price due to a higher wage given up.

- **Optimal leisure time:** From the FOC on $l_{i,z}$ of the social planner, we have:

$$(l_{i,z}) : \epsilon_{u_i,z_i} \epsilon_{z_i,l_{iz}} \frac{U_i}{l_{iz}} + \int_0^1 \epsilon_{(u_j,e)} \epsilon_{(e,e_i)} (\epsilon_{(e_i l_{iz})} \frac{U_j}{l_{iz}} - f_{l_{iz}} \epsilon_{e_i,c_{iz}} \frac{U_j}{c_{iz}}) dj = f_{l_{i,z}} U_{i,c_m}$$

This implies that, in the case the SP does not intervene in the market for market goods consumption, it would be optimal reduce working hours for *all* households and increase leisure time. This is due to $\epsilon_{e,e_i} < 0$ and by assumption the impact of unit of time more in leisure is less carbon intense than one unit more of consumption on it (i.e. $\epsilon_{e_i,l_{iz}} < \epsilon_{e_i,c_{iz}}$). The intuition is the following: by increasing leisure time, households give up 1 unit of wage. The social planner considers this an additional benefit of leisure time as this unit of wage is not directed towards polluting leisure consumption. In this model this prescription would be stronger for richer and more skilled households for the following reason: the greater $f_{l_{iz}}$ the greater would be the potential wage directed to polluting activities (LHS of the formula). The potential for different policies is explored in the next section.

- **Leisure consumption:** given eq. (3) and given the assumption that $g(c_z) > g(c_m)$ (i.e. leisure consumption is more environmentally harmful than market goods consumption), the social planner would like to decrease leisure consumption relative to market goods one. The potential policy options to achieve this outcome are explored in the next section.

3 Policy implications

In this section, I propose some policy tools to achieve the SP solution.

3.1 Optimal policy

The first best would be to intervene in the market for goods, leisure consumption and time allocation by adjusting the incentive structure of agents. Yet, in this paper I consider only interventions for market and leisure goods consumption. This would be as if we hold the assumption, that $\epsilon_{e_i,l_{iz}}$ is 0 for all households. In other words, leisure time does not have an effect on average emissions. As we have discussed in Section 2, this assumption is considered conservative. The objective of taxation would be, as usual, to make the agents internalize their externalities on environmental quality. The budget constraint of agent i will be:

$$a(t+1) + (1+\tau_{i,cm})c_{i,m} + (1+\tau_{i,cz})c_{iz} = (1+r_t-\delta)a_i(t) + (\bar{l} - l_z(t))w_i(t)$$

where:

$$\tau_{i,c_m} = \frac{f_{i,l}}{U_{i,z} z_{i,l_z}} \int_0^1 \epsilon_{(u_j,e)} \epsilon_{(e,e_i)} \epsilon_{(e_i c_{im})} \frac{U_j}{c_{iz}} dj$$
$$\tau_{i,c_z} = \frac{f_{i,l}}{U_{i,z} z_{i,l_z}} \int_0^1 \epsilon_{(u_j,e)} \epsilon_{(e,e_i)} \epsilon_{(e_i c_{iz})} \frac{U_j}{c_{iz}} dj$$

Comments on the solution:

- Taxation will be progressive, as given by the term $f_{i,l}$. More productive households (i.e. higher $f_{i,l}$) will pay a higher tax since their carbon impact is higher.
- As a consequence of taxation, the marginal benefit of leisure time will increase. Indeed consumption is now more expensive and as a result, the opportunity cost of leisure time is lower. In this way, even without regulating directly working time, agents will prefer to work less.
- The effect on the environmental quality E will be positive as by reducing working hours, the labor supply will lower, reducing overall production and, therefore, consumption.

Yet, this optimal policy is difficult to apply in practice. Policy makers should have perfect information on marginal utilities for each individual in order to identify the optimal taxation. In the following subsections, I will explore more viable policy tools.

3.2 Tax on leisure consumption

The policymaker decides to target only leisure consumption through a flat tax equal across income levels. To provide some intuition, this would be similar to a tax on tourists or a higher VAT on leisure goods. I assume that the policymakers would take the average of the optimal leisure consumption tax as:

$$T_{c_z} = \int_0^1 \tau_{i,c_z} = \int_0^1 \frac{f_{i,l}}{U_{i,z} z_{i,l_z}} \int_0^1 \epsilon_{(u_j,e)} \epsilon_{(e,e_i)} \epsilon_{(e_i c_{im})} \frac{U_j}{c_{iz}} dj di$$

Comments on the solution:

- The environmental effect of such a policy will depend on two margins:
  - *Extensive margin*: by reducing leisure consumption (through a tax) the marginal product of leisure time (z_{l_z}) will decrease and therefore agents will choose to work more. This will provide more income to households to increase their consumption and, as a consequence, their environmental impact. By holding the before-tax relative price of market goods and leisure consumption we have:

    $$\Delta E = \int_0^1 \epsilon_{e,e_i} (\epsilon_{e_i,c_{im}} \epsilon_{c_{im},I} \Delta I + \epsilon_{e,e_i} \epsilon_{e_i,c_{iz}} \epsilon_{c_{iz},I} \Delta I) di$$

    The effect on the environment will be negative. This works as a *scale effect*.
  - **Intensive margin:** by increasing the relative price of leisure consumption relative to markets goods consumption (which was not taxed), the expenditure composition of the agent will change. In particular the agent will choose to consume more market goods relative to leisure goods.

    $$\Delta E = \int_0^1 \epsilon_{e,e_i} (\epsilon_{e_i,c_{im}} \epsilon_{c_{im},\tau_{c_z}} \Delta T_{cz} + \epsilon_{e,e_i} \epsilon_{e_i,c_{iz}} \epsilon_{c_{iz},\tau_{c_Z}} \Delta T_{cz}) di$$

    If the elasticity of market goods consumption to changes in leisure goods consumption is high enough, the effect on the environment, holding the assumption that $\frac{\delta e_i}{\delta c_m} < \frac{\delta e_i}{\delta c_z}$ would then be positive.

- From a distributional point of view, this tax will be regressive. Indeed, this tax will be too little for high income which use consumption-intensive leisure and too high which instead use time-intensive leisure.

Overall, the effect on the environment is ambiguous. On the one side, by taxing leisure consumption, income can be redirected towards greener consumption (c_m). Yet, as leisure time is now less productive due to lower leisure consumption, agents will prefer to work more, increasing overall consumption and, as a consequence, emissions. The main message here is that a policy tool alone might be enough to reduce effectively emission and that different policy tools can be complementary. In the next subsection, I will explore such complementarities.

3.3 Working time regulation

The most relevant policy measure for the current policy debate is a reduction in working hours. The policymaker here would like to reduce working hours by choosing a $\bar{l_m} < \max l^*_{im}$. In other words, the SP would like to impose a working time which is below the optimum working chosen by, at least, one agent. This regulation would affect only agents for which $l^*_z < \bar{l_z}$. In mathematical terms, using the Kuhn-Tucker condition, the problem of the agent would be the following:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t U_i(c_m, z) + \sum_{t=0}^{\infty} \beta^t \lambda_t \Big((1 + r - \delta) a_i(t) + (\bar{l} - l_z) w_i - a_i(t+1) - c_{im} - c_{iz} \Big) + \gamma_i (l_{iz} \geq \bar{l_{iz}})$$

with:

$$\gamma_i = \begin{cases} 0 & \text{if} \quad l^*_{iz} > \bar{l_{iz}} \\ 1 & \text{otherwise} \end{cases}$$

Comments on the solution

- Overall, we expect high skilled workers to be constrained. As we have seen in previous section, they choose to work more and choose to have less leisure time given their high productivity.

- In terms of welfare this measure will have different effects across households:

  - if anything, I argue that households for which $l_z^* > \bar{z}$ are the ones who can, potentially benefit the most. For these households, which will be the "poorest" in our model, the time-allocation choice would not change, so will not their income. Yet, in the case the environmental quality E will improve (see discussion below) they will receive an additional benefit.
  - $l_z^* < \bar{z}$: uncertain effects with richer households receiving the worst welfare effects. Indeed, on the one side, the time allocation choices of these households will be distorted increasingly in their wage. This will certainly decrease welfare. On the other side, the uncertain environmental outcome can mitigate or worsen their utility outcome

  Changes in welfare for both types of households can be summarized in reduced form as follows:

$$\Delta U_i = \epsilon_{u_i,l_{iz}} \min(l_{iz}^* - \bar{l_z}, 0) + \epsilon_{u_i,e} \Delta E$$

- The key variable to understand the effect on the environment will be the change in the consumption of leisure c_{iz} as a consequence of working time regulation. There will be different forces at play:

  - *Change in income*: as a result of lower working hours, households will receive a lower income and given that leisure is a normal good, I expect the amount of leisure z to go down. The only way this can be achieved given a higher, by policy choice, l_{iz}, is by reducing leisure consumption c_{iz}

  - *Change in relative price of leisure*: as a result of higher leisure time l_{iz}, the marginal product of leisure consumption will be higher. As a result, households will enjoy a lower cost of producing leisure. In other words for one unit more of leisure I will now need to spend less money in leisure consumption. This, all else equal, would increase the leisure z enjoyed by households.

  Which of the effects will prevail will depend on the relative elasticities and on the strength of income and substitution effects for the two concurring changes.

- Given that, the effect on the environment will depend on two margins:
  - **Extensive margin**: as labor supplied decreases overall, the income available will be lower with a reduction in consumption of market goods and leisure and, therefore, a lower environmental footprint. This is a scale effect. This can be quantified as follows:

$$\Delta E = \int_0^1 \epsilon_{e,e_i}(\epsilon_{e_i,c_{im}}\epsilon_{c_{im},I}\Delta I + \epsilon_{e,e_i}(\epsilon_{e_i,c_{iz}}\epsilon_{c_{iz},I}\Delta I)di$$

    where here I assume that the change in c_i do not take into account the change in relative prices due to changes in the marginal product for c_{iz}. In the equation above, $I = l_m w_i$ (i.e. the work income of individuals after the policy change).

  - **Intensive margin**: this margin instead, consider in isolation the effect of the change in the relative price of leisure. From eq. 7 we have:

$$\frac{z_{i,l_z}}{z_{i,c_z}} = w_i$$

As w_i is still the same, but the numerator is now lower (more leisure time), households would like to increase c_z in order to keep the ratio above constant. The intuition is that with more leisure time available, leisure consumption is more productive. The environmental effect of this would be:

$$\Delta E = \int_0^1 \epsilon_{e,e_i}(\epsilon_{e_i,l_{iz}}\Delta l_{iz} + \epsilon_{e_i,c_{iz}}\Delta c_{iz})di$$

This effect will definitely depend on the sign of $\epsilon_{e_i,l_{iz}}$. Yet, maintaining a conservative assumption (i.e. $\epsilon_{e_i,l_{iz}} = 0$) we expect, overall, to observe a negative effect on the environment through the *intensive margin.* Moreover, agents that will increase their leisure consumption will be the higher income ones, which may have more environmentally harmful leisure consumption (i.e. flights, travels etc.).

Which of the two effects (i.e. extensive or intensive margin) will prevail will at the end depend on whether leisure consumption c_{iz} will decrease (as a result of the income change) or increase (as a result of a change in relative price). This is an open empirical question which can be explored in future works. Lastly, in the case c_{iz} decreases, working time reduction has also the potential to reduce carbon inequality as richer households will work less and emit less, while poorer households will not change their behavior.

$$\frac{\int_{l_z^* < \bar{l_z}} e_i di}{\int_{l_z^* > \bar{l_z}} e_j dj} \downarrow$$

The *main message* of this exercise is that by reducing working hours alone, policymakers might not be able to reduce emissions as agents will find now cheaper to produce the leisure commodity through leisure consumption. The only way to avoid this effect is to, contemporarily, increase the price of leisure consumption through a tax. Given that, the *complementarity* of different policy tools is key to achieving the desired environmental outcomes.

Conclusion

This study has presented a theoretical framework to analyze the environmental implications of consumption and time allocation among heterogeneous agents. The model predicts that wealthier households tend to engage in more consumption-intensive leisure activities, while lower-income households opt for more time-intensive leisure. Considering the relatively lower environmental impact associated with time-intensive leisure, a socially conscious planner would favor leisure bundles that prioritize time over consumption.

Various policy options have been examined, including a tax on leisure consumption and a reduction in working hours, both of which have the potential to reduce carbon emissions. However, the overall effectiveness of these policies will depend on the implementation of complementary measures. Therefore, it is crucial to consider a comprehensive policy package to maximize environmental benefits.

Future research in this field should focus on estimating the carbon footprint of leisure consumption and time allocation. Such estimates would enable the calibration of the proposed model and facilitate the exploration of different policy experiments. By further refining our understanding of the carbon impact of leisure activities and time allocation, policymakers can make more informed decisions to address environmental challenges effectively.

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