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Climate justice in an intergenerational sustainability framework: A Stochastic OLG model*

Cisco Gianluigi† Gatto Andrea‡

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Abstract

Climate justice as a commons is conceived as the intertemporal climate equity and equality exchange amongst generations. Sustainability, intended as the interplay amongst the economy, the society, the environment, and the governance, is essential to forge the climate justice theoretical framework. On this base, the study attempts to model intertemporal choice amongst generations in these four domains, making use of an overlapping generations (OLG) model. The proxies detected are GDP growth (economy), environmental quality (environment), and labor growth, and environmental investment (society) as assumptions. The governance dimension is captured by the difference in wealth between young and old generations. The work aims at replying to the following research question: *Which are the conditions for sustainable development such that climate justice holds?* The intra-intergenerational exchange is defined in two periods, while the individual provides their preferred economic and environmental choice mix as consumption-saving. This study shows that sustainable growth is achievable only with increased young effort and less leisure and consumption.

JEL Classification System: *E24, Q54, D63*

Keywords: *Overlapping generation, Climate justice, Endogenous labor, OLG model, Intergenerational Sustainability*

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†University of Naples Parthenope, Department of Economic and Legal Studies (DISEG), Via Generale Parisi 13, Palazzo Pacanowski (Napoli, Italy), Email: gianluigi.cisco@uniparthenope.it

‡Corresponding author. Natural Resources Institute, Greenwich University, Central Avenue, Chatham Maritime ME4 4TB. New College of the Humanities at Northeastern University, 19 Bedford Square, Fitzrovia, London - WC1B 3HH 360 Huntington Ave, Boston, MA 02115, USA. Centre for Studies on Europe, Azerbaijan State University of Economics (UNEC), Azerbaijan. Email: a.gatto@greenwich.ac.uk.

1 Introduction

Climate justice is nowadays an ecological and societal conundrum (Introcaso, 2018), calling for urgent governance actions targeting climate change adaptation (Sovacool, 2013). The issue became paramount in the international forums with the COP21 and major climate change and environmental protection summits (Gatto, 2020; IPCC, 2018; Rhodes, 2016), and got popularity after the recent climate strikes, climate activism, and civil society unrest. Climate justice is closely connected with energy and resource justice, sustainable development, and the common pools resources theory (Jenkins, 2018; Bickerstaff et al., 2013). Climate justice calls for vulnerability protection (Shue, 2014), where resilience actions to tackle resources sustainability are detected as priorities (Agovino et al., 2018).

In this sense, climate justice calls primarily energy resilience strategies and policies to face vulnerability and empower the vulnerable (Gatto & Busato, 2020; Gatto & Drago, 2020). Climate justice is an interdisciplinary issue, to be tackled with a multidimensional approach (Roser et al., 2015). In this work, climate is considered a commons. Thus, it presents the characteristic of displaying being highly rival in use, whereas its enjoyment is hardly excludable (Ostrom, 2015). For this reason, climate needs tailored governance and policy actions to achieve its most effective use and benefit.

Climate vulnerability and resilience are hot button topics in the international development agenda. This is particularly relevant for issues related to natural resources management, the energy-food-water nexus and overall climate change (Campbell et al., 2018). In 2015, the Sustainable Development Goals (SDGs) have settled 17 goals and 169 targets to tackle poverty and achieve sustainable development in OECD and least developed countries (UN, 2015). In this framework, the need for promoting climate resilience policies to face climate change vulnerability issues plays a crucial role (Brenkert and Malone, 2005). The world has become more vulnerable to a series of shocks and adverse events, especially regarding natural hazards. These stylized facts concerning climate change vulnerability affect often the most vulnerable categories, countries and minorities – e.g. people with disabilities, refugees and migrants, poor, women, youth, and rural people (Agovino et al., 2018; Gatto et al., 2016; Picot and Moss, 2014).

To the best knowledge of this research's authors, no scholarship modeling climate justice has been published so far – yielding a clear potential for research novelty. Nevertheless, the literature on climate change modeling is broad. Weitzman (2009) analyzed the economic implications of climate change calamities. Sen (2008) stressed the importance of renewable energy and the atmosphere for climate change. The concept of climate as a commons was modeled by Nordhaus (1994). Brenkert & Malone (2005) emphasized the role of vulnerability and resilience to climate change. Martens (2013) connected climate change with health studies, examining the effects of ozone depletion and global warming. Xu (2000) studied the effects of climate change on water governance. Koca et al. (2006), examined natural ecosystems impact, focusing on Sweden.

At the same time, the authors are not aware of further applications of OLG models to climate justice. OLG models have been utilized for disentangling climate-economy interactions by Howarth (1998). Stephan et al. (1997) modeled infinitely-lived agents as for the economics of global warming. Sachs (2014) oriented a climate change OLS model on global warming and inter-generational wellbeing. Schneider et al. (2012) focused on the trade-offs amongst generations in a continuous-time. John & Pecchenino (1994) were most concerned about the existing connections between growth and the environment. Bayer & Cansier (1996) scrutinized the issue through the lens of systematic intergenerational discounting.

This work assumes climate justice coming from the intergenerational climate equity and equality, being deliverable solely throughout an ethical, sustainable approach (Stern and Taylor, 2017; McKinnon, 2015; UNESCO, 2014). In this regard, sustainability requires the simultaneous combination of a balanced economic, social, environmental, and governance mix. Holding these conceptual premises, the study attempts to contribute to the existing theoretical literature on climate justice, offering a model to theorize the intertemporal choice amongst generations in these four domains. For such scope, it is exploited an overlapping generations (OLG) model. Thus, it is proposed as a research question: *Which are the conditions for sustainable development such that climate justice holds?*

The study has previously explored the phenomenon of climate justice and interconnected vulnerability and resilience issues, drafting a review on climate change modeling. The paper's remainder is as follows: section 2 presents the OLG model developed in this study, focusing on the welfare measure and competitive equilibrium. Thus, section 3 provides the calibration and steady-state conditions, whereas section 4, investigates the impulse response analysis. Therefore, section 5 drafts the work's conclusions and policy implications, sketching the paper's limitations and future research

2 The Model

This section shows the main features of the model. As in the standard Diamond's OLG model (1965), this study considers an overlapping generations model in which each consumer lives two periods: young and old. In each period $t > 0$, a new generation of identical consumers is born. The size of generation t is given by $N_t = (1+n)^t$, with $n > 0$. All consumers have one unit of time endowment, which can be allocated between work and leisure. Retirement is obligatory in the second period of life, so the labor supply of old consumers is zero. Consumers - both young and old -, benefit from environmental quality. The latter is not considered a control variable - it is indirectly improved through investments that produce beneficial effects only after a period of time. Consider a consumer who is born at time $t \geqslant 0$. Let $c_{y,t}$ and $c_{o,t+1}$ denote his consumption when young and old, respectively, l_t denote his labor supply when young and Q_t is the environmental quality index. The consumer's preferences are represented by:

$$U_t\left(c_{y,t}, l_t, Q_t, c_{o,t+1}, Q_{t+1}\right) = \frac{c_{y,t}^{1-\sigma_c}}{1-\sigma_c} + A\frac{Q_t^{1-\sigma_e}}{1-\sigma_e} - B\frac{l_t^{1+\psi}}{1+\psi} + \beta\left(\frac{c_{o,t+1}^{1-\sigma_c}}{1-\sigma_c} + A\frac{Q_{t+1}^{1-\sigma_e}}{1-\sigma_e}\right)\ if\ \sigma \neq 1 \tag{1}$$

$$U_t\left(c_{y,t}, l_t, Q_t, c_{o,t+1}, Q_{t+1}\right) = \ln(c_{y,t}) + A\ln(Q_t) - B\frac{l_t^{1+\psi}}{1+\psi} + \beta\left[\ln(c_{o,t+1}) + A\ln(Q_{t+1})\right] \; if\ \sigma = 1 \tag{2}$$

Where $\sigma > 0$ is the risk aversion and the inverse of the IES in consumption, $\psi > 0$ is the inverse of the Frisch elasticity of labour supply, $\beta \in (0,1)$ is the subjective discount factor, A and B are a positive constant. The environmental quality at time $t+1$ (measured by the environmental index Q) is degraded by consumption of the old at time t and improved by environmental investments, m_t. Following John and Pecchenino (1994) and Angelopoulos (2010,2013):

$$Q_{t+1} = (1-\delta)\bar{Q} + \delta Q_t - P_t + \phi m_t \tag{3}$$

where $\bar{Q}$ represents environmental quality without pollution, P_t is the current pollution flow, m_t is private spending on abatement activities, and $0 \leq \delta \leq 1$ is parameters measuring the degree of environmental persistence and ϕ define how private investments convert into improvement of the environmental quality index. In detail, pollution is proportional to output:

$$P_t = \gamma Y_t \tag{4}$$

where $\gamma > 0$ denote the emissions intensity. Therefore, consumer can save in two types of assets: physical capital and an environmental worthless asset. Taking $\{w_t, R_{t+1}\}$ as given, the consumer's problem is to choose an allocation $\{c_{y,t}, l_t, c_{o,t+1}, s_t, m_t\}$ so as to maximize his lifetime utility in (1) or (2), subject to the budget constraints:

$$c_{y,t} + m_t + s_t = w_t l_t \tag{5}$$

$$c_{o,t+1} = s_t R_{t+1} \tag{6}$$

The first-order conditions for this problem are given by:

$$c_{y,t}^{-\sigma} = \frac{c_{0,t}^{-\sigma}}{(\beta R_{t+1})} \tag{7}$$

$$w_t c_{y,t}^{-\sigma} = A l_t^{\psi} \tag{8}$$

$$c_{y,t} = (A\beta\phi)^{-\frac{1}{\sigma_c}} Q_{t+1}^{\frac{\sigma_e}{\sigma_c}} \tag{9}$$

Using these equations, we can obtain

$$c_{y,t} = \frac{c_{o,t}}{(\beta R_{t+1})^{-\frac{1}{\sigma}}} = \frac{w_t l_t}{1 + \beta^{\frac{1}{\sigma}} R_{t+1}^{\frac{1}{\sigma}-1}} \tag{10}$$

$$s_t + m_t = \Gamma\left(R_{t+1}\right) w_t l_t, \quad \Gamma\left(R_{t+1}\right) = \frac{\beta^{\frac{1}{\sigma}} R_{t+1}^{\frac{1}{\sigma}-1}}{1 + \beta^{\frac{1}{\sigma}} R_{t+1}^{\frac{1}{\sigma}-1}} \tag{11}$$

An increase in R_{t+1} has two opposing effects on saving which are captured by the function $\Gamma(R_{t+1})$. First, consumer will receive more interest income when he is old - this determining

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an income effect which encourages consumption when young and discouraging saving. Second, an increase in interest rate also lowers the relative price of future consumption. This creates an inter-temporal substitution effect which discourages consumption when young and promotes saving. The strength of the two effects depends on the value of σ_c In particular, the inter-temporal substitution effect dominates when $\sigma_c < 1$, and $\sigma_c > 1$, the income effect dominates. The two effects exactly cancel out when $\sigma_c = 1$.

On the supply side of the economy, there is a large number of identical firms. In each period, each firm hires labour and physical capital from the competitive factor markets, and produces output according to:

$$Y_t(K_t, L_t) = AK_t^{\alpha} L_t^{1-\alpha} \tag{12}$$

Moreover, the first-order conditions are:

$$R_t = \alpha K_t^{\alpha-1} L_t^{1-\alpha} \tag{13}$$

$$w_t = (1-\alpha) K_t^{\alpha} L_t^{-\alpha} \tag{14}$$

To assess the implications on welfare, as in Mendicino and Pescatori (2007), we evaluate the welfare of the young and old agents separately:

$$W_{y,t} = E_t \sum_{t=0}^{\infty} \beta^t U_{y,t} \tag{15}$$

$$W_{o,t} = E_t \sum_{t=0}^{\infty} \beta^t U_{o,t} \tag{16}$$

The current welfare is measured by the discounted utility function.

2.1 Competitive Equilibrium

The decentralize competitive equilibrium for a given process followed by technology the initial value for the capital stock, the environmental quality and pollution is a list of sequences $\{c_{y,t}, c_{o,t}, l_t, Q_t, m_t\}_{t=o}^{\infty}$, and prices $\{R_t, w_t\}_{t=o}^{\infty}$ such that the markets is clear, consumers maximize their utility function subject to to their budget constraints, firms maximize the profit and the environmental quality follow their law of motion. From the competitive equilibrium, it is obtained the following law of motion

$$(1+n)k_{t+1} = s_{t+1} = (1-\alpha)\left[\frac{\beta^{\frac{1}{\sigma}} R_{t+1}^{\frac{1}{\sigma}-1}}{1+\beta^{\frac{1}{\sigma}} R_{t+1}^{\frac{1}{\sigma}-1}}\right]\left(\frac{k_t}{l_t}\right)^{-\alpha} l_t - m_t \tag{17}$$

If the investment in pollution reduction is positive, all other things being equal, the capital (savings) decrease. Adjusting the hours worked can enable sustainable growth.

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3 Calibration and Steady State Conditions

This section presents model calibration between parameters drawn for typical macroeconomic literature and environmental parameters extracted from selected studies on emission and global temperature dynamics. The model is calibrated for the US economy. Table 1 lists the parameter values for the basic model. Parameters characterizing the dirty economy and household preferences are reasonably standard. The values are chosen for the household subjective discount factor β, capital depreciation rate δ are calibrated as in most overlapping generation models studies (e.g., Diamond, 1965).The parameters characterizing the environmental sector are in line with John and Pecchenino (1994), Angelopoulos (2010) and Annicchiarico & Di Dio (2015).Table1 lists the parameters used in the model.

Parameter	**Description**	**Value**
β	Discount Factor	0.99
δ	Depreciation Rate Capital	0.025
σ	Risk aversion parameter	1
ψ	Inverse of Frish Elasticity	1
α	Share of capital	0.30
γ	Pollution intensity	0.38
δ	degree of environmental persistence	0.10
ϕ	environmental investment converters	1
ρ	Persistence of the technology shock	0.90
σ	Standard deviation of the technology shock	0.01

Table 1- Model Calibration

We now provide a specific numerical example in order to determine the steady-state values . We used the software Dynare to obtain a solution for the equilibrium using a nonlinear Newton-type solver. Table 2 reports the deterministic steady-state for the key variables in accord with the discussed calibration and considering different value for the risk aversion parameter (σ).

Variables	**OLG**	**OLG-Q**	**OLG-Q**	**OLG-Q**
	$\sigma = 1$	$\sigma = 1$	$\sigma = 0.7$	$\sigma = 2$
R	1.492	1.915	2.352	1.661
y	0.166	0.191	0.170	0.192
k	0.034	0.030	0.022	0.034
l	0.331	0.424	0.422	0.401
m	0.000	0.029	0.027	0.023
Q	0.000	0.033	0.033	0.027
P	0.017	0.019	0.017	0.019
W_y	-4.63	-7.63	-64.52	1.16
W_o	-2.52	-4.74	-21.61	2.08

Table 2- Numerical Example-Steady State

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The table shows the steady-state values of the variables chosen for the definition of climatic justice. The first column shows the value in the standard Diamond OLG model. In this case, $m^* = 0$, and the environmental quality index is equal to zero. In the model described in this work, a sustainable-development hypothesis holds if $R^*$and l^* are higher than the case without environmental investment. When σ_c is equal to one, both the environmental quality index and pollution increase, but this is obtained through increased labor. Improving the quality of the environment has a greater impact on young people. The impact becomes even more important if $\sigma_c = 2$. There is a reduction in intra-generational justice. In lower risk aversion, an environmental and socially sustainable growth profile can be achieved. A high level of output can be achieved by improving environmental quality and reducing generation inequalities.

4 Impulse Response Analysis

In this section, we provide the results of a technology shock. In detail, in order to verify the impact of the shock on the climate justice variables, we provide a comparison of our model with the classical Diamond model. Figure 1 shows the Impulse response functions after a positive productivity shock of the 1%. This latter follow an $AR(1)$ process with an *IID-Normal* error term. The simulations have been obtained using numerical analysis and perturbation methods to simulate the economy and compute the equilibrium conditions outside the steady-state. We solve the model using a second-order Taylor approximation around its steady state.[1]

All results are reported as percentage deviations from the steady-state. As shown in Fig 1, productivity shock determines the growth of the output in both cases. The model with environmental investments allows reaching a greater output peak, triggered by a rise in labor from the young generation. Instead, the hours worked do not undergo a significant change in the classical model, and the environmental investments are equal to zero. Both young and old consumption increase after a technology shock. The young generations achieve less increase in the Diamond model augment with environmental investment since they use a part of their income to improve the environmental quality. By contrast, the old generation can consume a greater quantity if the younger generations invest in improving environmental quality. The standard OLG model does not allow sustainable development. However, the OLG model with environmental investments allows for sustainable growth and improvement of environmental quality. The commitment of young people to reduce pollution allows the growth of the well-being of both generations.

5 Conclusion and Policy Implication

The stylized facts synthesized draw a world where economic growth needs and prosperity for all have to be coupled with sustainability for the main international community goals. The limits to growth were signaled already in 1972 from the Club of Rome (Meadows et al., 1972), where it was expressed the necessity to foster a long-term, inter-generational, and

[1] See Judd (1998) and Schmitt-Grohé and Uribe (2004).

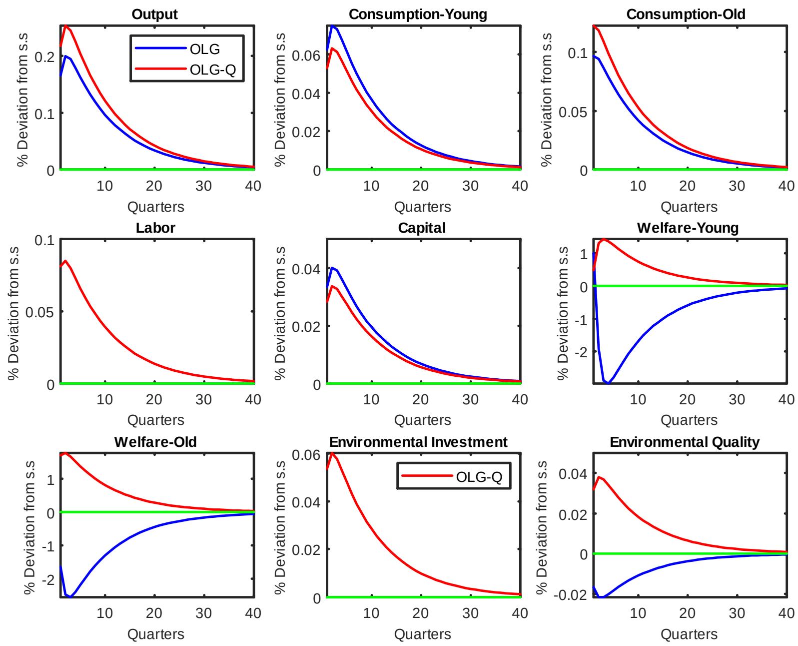

Figure 1: Impulse response to a technology shock (1%) .

inclusive development. In this regard, the complex phenomena tackled by the sustainable development started requiring a multidimensional approach, that was faced through a number of methodologies, solvable thanks to diverse composite indicators techniques (Nardo et al., 2005; Drago & Gatto, 2018).

Climate justice relies on practical actions fostering the vulnerable empowerment. A major help can come from microfinance. Through a set of instruments, as microloans to jumpstart or consolidate micro-entrepreneurship, remittances from workers abroad, microinsurance against shocks, and saving schemes, these programs aim to work for women, youth, rural people, and vulnerable categories empowerment, ensuring climate resilience policies – above all connecting them with energy, food and water security, resilience, and justice (Gatto and Busato, 2020). These features are recently becoming of great effectiveness whether connected with energy, agriculture, water and resources, passing by entrepreneurship boosting (Gatto & Drago, 2019). An example is the implementation of microfinancial programs for energy entrepreneurship in sub-Saharan Africa.

In this paper, it has been shown that when $R^*(m^*) > R^*$, labor supply is elastic and consumers are less risk-averse, it possible reaches a stationary state in which climate justice holds. Besides, this study shows that sustainable growth is achievable only with an increase in young effort and with a reduction in their leisure and consumption. Achieving this balance is linked to consumer culture: they want a smoothed consumption profile over time, reducing its variability. The households' risk aversion makes it harder to achieve the desirable stationary equilibrium. The model displays potential for further implementations. One direction for future research is to extend these results to a Ramsey Model in order to analyze the optimal taxation. Another possibility is to extend the model to allow an inter-generational analysis.

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