INTERNATIONAL WORKSHOP - MACROECONOMIC GREEN DYNAMICS

BOOK OF ABSTRACT

OPTIMAL TIMING AND CONTROL TO ERADICATE FIRMS' POLLUTING ACTIVITIES

THE ROLES OF FISCAL & MONETARY POLICIES

June 3-4, 2024. University of Urbino, IT.

International Workshop

Macroeconomic Green Dynamics

"Optimal Timing and Control to Eradicate Firms' Polluting Activities: The Roles of Fiscal and Monetary Policies"

[THE BOOK OF ABSTRACT]

University of Urbino

Department of Economics, Society, Politics

Urbino, Italy

June 3-4, 2024

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FOREWORD

This specialized workshop on non-linear macroeconomic dynamics applied to environmental issues follows previous conferences and workshops organized in Urbino on non-linear economic dynamics and policies. The workshop aims to bring interaction among economists and social scientists who carry out research at the knowledge frontier under the premise that monetary and fiscal policies analyzed through non-linear macroeconomics are essential to confront climate change. As a global issue, fiscal and monetary policies to mitigate climate change require cooperative and coordinated actions at the international level, including addressing the fair distribution of economic and social costs between countries/economies and supporting the firms' green productive transition. While governments' fiscal policy introducing a global carbon tax remains an open topic, a growing number of academics and policymakers are exploring the potential contribution that central banks and financial regulators can make to reducing carbon emissions, i.e., the role of monetary policies in addressing climate change. Therefore, fiscal and monetary policies play critical roles in the sustainability of firms' productive activities.

PROGRAM

University of Urbino Carlo Bo, Department of Economics, Society, and Politics, via Saffi 42, URBINO

Monday, June 3	Tuesday, June 4
8:50 Registration of participants	9:00 Session 4
9:00 Welcome address	10:30 Coffee break
9:30 Session 1	10:50 **Keynote lecture**
11:30 Coffee break	11:30 Session 5
11:50 **Keynote lecture**	13:00 Concluding remarks
12:30 Light lunch	13:05 Light lunch
14:00 Session 2	
15:30 **Keynote lecture**	
16:10 Coffee break	
16:30 Session 3	
18:00 **Keynote lecture**	
18:40 Closing	
20:00 Dinner	

MONDAY, JUNE 3

AULA BLU

8:50 **Registration of participants**

9:00 **Welcome Address**:
Giorgio Calcagnini: Rector of the University of Urbino Carlo Bo
Giuseppe Travaglini: Head of DESP - Department of Economics, Society, Politics
Gian Italo Bischi, Germana Giombini, Edgar J. Sanchez Carrera: Guest Editors of the journal Macroeconomic Dynamics for the special issue *Macroeconomic Green Dynamics*

9:30 **Session 1**
Chair: Francesca Grassetti

Dynamic effects of temporary and permanent environmental policies on abatement investment, waste stock and social welfare
Alessandro Bellocchi (Department of Economics, Society, and Politics, University of Urbino Carlo Bo), Enrico Saltari (Facoltà di Economia, Dipartimento di Economia e Diritto, Università di Roma La Sapienza), Giuseppe Travaglini (Department of Economics, Society, and Politics, University of Urbino Carlo Bo)

Financing constraints, climate policies and carbon emissions
Mattia Guerini (Università degli Studi di Brescia, and Fondazione ENI Enrico Mattei), Giovanni Marin (Università degli Studi di Urbino, and Fondazione ENI Enrico Mattei), Francesco Vona (Università degli Studi di Milano, and Fondazione ENI Enrico Mattei)

Heterogeneous expectations in two-sector DSGE model: Does the green transition trigger waves of greenflation?
Nicolás Blampied (Department of Economics, Masaryk University), Alessia Cafferata (Department of Management, University of Turin), Davide Radi (DiMSEFA, Catholic University of Milan)

Environmental Policy and the Dynamics of Industrial Location and Residential Choice
Giovanni Bernardo (Department of Law, University of Naples Federico II), Pasquale Commendatore (Department of Law, University of Naples Federico II, and Ismed-CNR), Ingrid Kubin (Vienna University of Economics and BA), Mauro Sodini (Department of Law, University of Naples Federico II)

A unified theory of human development
Luca Gori (Department of Law, University of Pisa), Simone Marsiglio (Department of Economics and Management, University of Pisa), Mauro Sodini (Department of Law, University of Naples Federico II, and Department of Finance, Faculty of Economics, Technical University of Ostrava, Czech Republic)

11:30 **coffee break**

11:50 **Keynote lecture – Francesco Drudi "Central Banking and Climate Change"**

12:30 **Light Lunch**

14:00 **Session 2**
Chair: Germana Giombini

Shock Therapy for Greener Growth: The Dynamics of Firms' R&D Investments
Esther Ann Bøler (Imperial College Business School, CEP & CEPR), Katinka Holtsmark (University of Oslo), Karen Helene Ulltveit-Moe (University of Oslo & CEPR).

Should I offset or should I plow? Voluntary Carbon Offsets and ETS in an Evolutionary Model
Matteo Mazzarano (Department of Political and International Sciences, University of Siena, and Florence School of Regulation, European University Institute), Massimiliano Rizzati (Department of Economics and Management, University of Brescia, and Fondazione Eni Enrico Mattei), Sergio Vergalli (Department of Economics and Management, University of Brescia, and Fondazione Eni Enrico Mattei), Simone Borghesi (Department of Political and International Sciences, University of Siena, and Florence School of Regulation, European University Institute)

On the dynamics of green, dirty and relocating firms under the Emissions Trading System
Angelo Antoci (DiSea, Department of Economics and Business, University of Sassari, Italy), Simone Borghesi (European University Institute - Florence School of Regulation Climate, and Department of Political and International Sciences, University of Siena, Italy), Paolo Russu (DiSea, Department of Economics and Business, University of Sassari, Italy), Mauro Sodini (Department of Law and

Economics, University of Naples "Federico II", Italy, and Department of Finance, Faculty of Economics, Technical University of Ostrava, Czech Republic)

Greenflation, Climateflation and Monetary Policy: The Dynamics of Sustainable Transition

Andrea Bacchiocchi, Federico Favaretto, Germana Giombini, Fabio Tramontana (Department of Economics, Society, and Politics, University of Urbino Carlo Bo)

15:30 **Keynote lecture – William A. Barnett "Economic Bifurcation and Chaos"**
https://uniurb-it.zoom.us/j/87836783980
Related book: https://www.worldscientific.com/worldscibooks/10.1142/13852#t=aboutBook

16:10 **Coffee Break**

16:30 **Session 3**
Chair: Giovanni Marin

The Impact of Environmental Regulation on Sustainable Development within the European Union: An Empirical Analysis

Xiang Weiyi (Institute of Economics and Finance, University of Szczecin, Poland)

Climate Actions, Public Investment and Inflationary Effects in a Small Open Economy

Guido Traficante (European University of Rome)

Assessing Social Life Cycle Assessment (S-LCA) in Global Healthcare Waste Management: Insights from Complementary Methodologies and Regional Disparities

Chiara Notarangelo (PhD student in "Future Earth, Climate Change and societal challenges" at University of Bologna and Research fellow at Sant'Anna University)

Pollution, public debt, and growth: the question of sustainability

Marion Davin (CEE-M, Univ Montpellier, CNRS, INRAE, SupAgro, Montpellier, France), Mouez Fodha (University Paris 1 Panthéon-Sorbonne and Paris School of Economics), Thomas Seegmuller (Aix Marseille Univ, CNRS, AMSE, Marseille, France)

18:00 **Keynote lecture – Bard Harstad "Greening Oil: Optimal Extraction During the Transition from Coal to Renewables"**
https://uniurb-it.zoom.us/j/87836783980

18:40 **Closing of the first day's presentations**

20:00 **Conference dinner**

TUESDAY, JUNE 4

AULA BLU

9:00 Session 4
Chair: Gian Italo Bischi

Unsustainability traps: ubiquitous appearance of prisoner's dilemma at different scales and structural policy approaches against climate change
Alessio Carrozzo-Magli (Dipartimento di Economia, Università di Bologna), Piero Manfredi (Dipartimento di Economia & Management, Università di Pisa)

The Green and the Brown: Environmental regulation and economic stability
Ingrid Kubin (Vienna University of Economics and Business), Thomas O. Zörner (Vienna University of Economics and Business, and Oesterreichische Nationalbank (OeNB))

An environmental growth model with technology choice
Luca Gori (Department of Law, University of Pisa), Francesco Purificato (Department of Law, University of Naples Federico II), Mauro Sodini (Department of Law, University of Naples Federico II, and Department of Finance, Faculty of Economics, Technical University of Ostrava, Czech Republic)

Green Transformation of an Overlapping-Generations Economy with Production Externalities
Paul Ritschel (Faculty of Business Studies and Economics, University of Kaiserslautern-Landau, Germany), Jan Wenzelburger (Faculty of Business Studies and Economics, University of Kaiserslautern-Landau, Germany)

10:30 **Coffee Break**

10:50 **Keynote Lecture – Irene Monasterolo "Climate risk from the lenses of complexity economics and finance"**

11:30 **Session 5**

Chair: Edgar J. Sanchez Carrera

An Agent-Based Model of Deception: Does Greenwashing Pay Off

Sebastian Ille (Northeastern University London), Edgar J. Sanchez Carrera (Department of Economics, Society, and Politics, University of Urbino Carlo Bo)

Climateflation and monetary policy in an environmental OLG growth model

Marwil J. Dávila-Fernández (Department of Economics and Statistics, University of Siena), Germana Giombini (Department of Economics, Society, and Politics, University of Urbino Carlo Bo), Edgar J. Sánchez-Carrera (Department of Economics, Society, and Politics, University of Urbino Carlo Bo)

The impact of FX Central Bank interventions in a model with heterogeneous agents

Daniela Federici (Dipartimento di Economia e Giurisprudenza, Università di Cassino e del Lazio Meridionale), Enrico Saltari (Facoltà di Economia, Dipartimento di Economia e Diritto, Università di Roma La Sapienza)

Designing a Green Memorandum: Central Bankers, Politicians, Monetary Policy and Macroprudential Regulation

Georgios E. Chortareas (Economics Group, King's Business School, King's College London), Donato Masciandaro (Department of Economics and Baffi Centre, Bocconi University), Riccardo Russo (Economics Group, King's Business School, King's College London)

13.00 **Concluding remarks**

13:05 **Light Lunch**

LIST OF PARTICIPANTS

KEYNOTE SPEAKERS

William A. Barnett. Oswald Distinguished Professor of Macroeconomics at the University of Kansas and Director, Center for Financial Stability, in New York City

Francesco Drudi. Principal Adviser in the Directorate General Monetary Policy of the European Central Bank

Bard Harstad. The David S. Lobel Professor in Business and Sustainability and Professor of Political Economy, Standford University

Irene Monasterolo. Professor of Climate Finance, Utrecht University

SPEAKERS

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Alessandro Bellocchi, Department of Economics, Society and Politics, University of Urbino Carlo Bo

Giovanni Bernardo, Department of Law, University of Naples Federico II

Simone Borghesi, European University Institute - Florence School of Regulation Climate, and Department of Political and International Sciences, University of Siena

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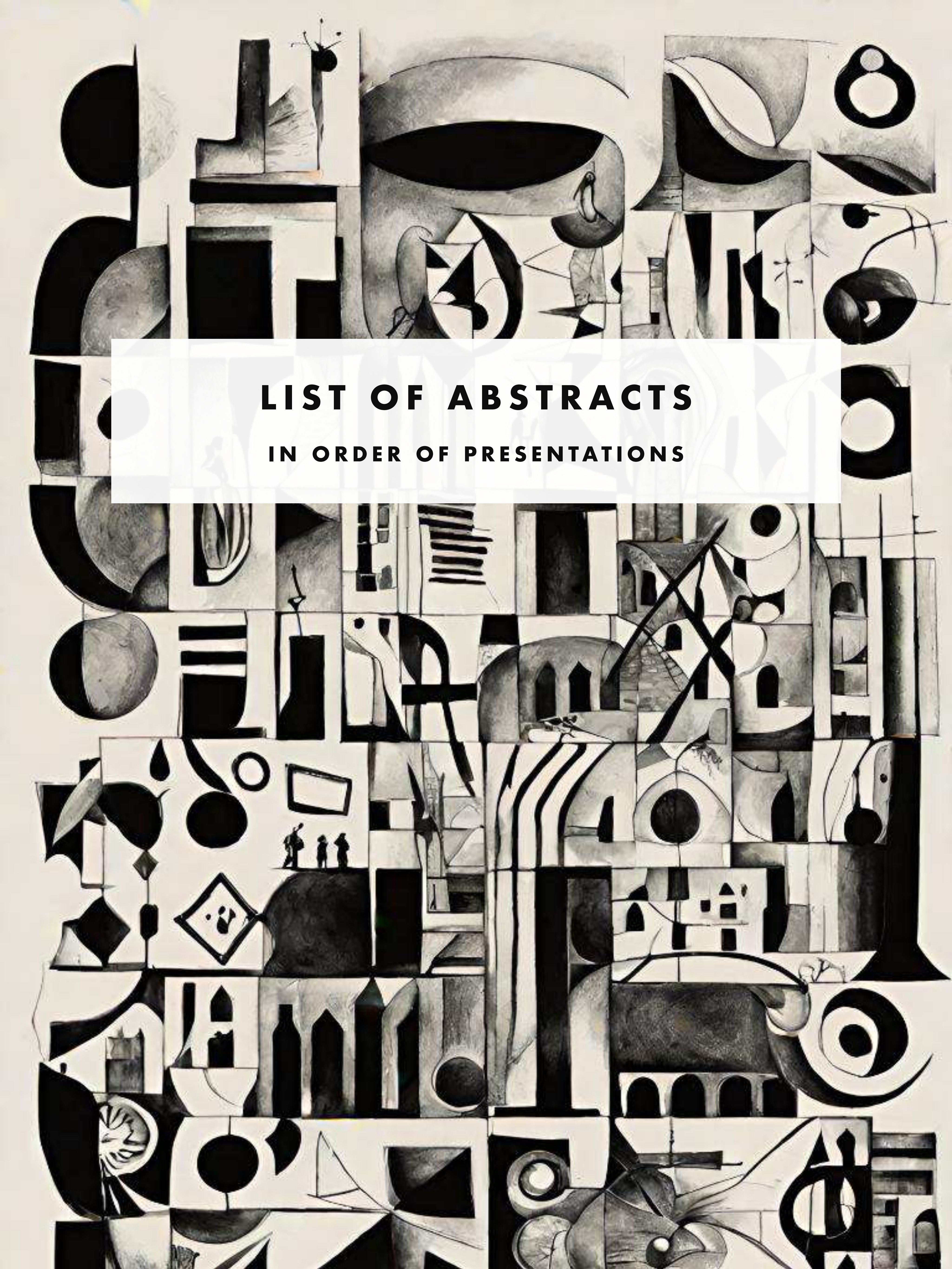

LIST OF ABSTRACTS

IN ORDER OF PRESENTATIONS

Dynamic effects of temporary and permanent environmental policies on abatement investment, waste stock and social welfare

Alessandro Bellocchi[1] Enrico Saltari[2] Giuseppe Travaglini[3]

Abstract

An intertemporal model of welfare with waste stock and abatement capital is presented. We show that since waste control is a dynamic welfare problem, the expectations of either *transitory* or *permanent* environmental policies determine the intertemporal allocation of (scarce) resources and their effects on welfare. We focus on three issues: the identification of a *dynamic criterion* to determine changes in welfare, abatement investment, consumption and waste over time; the *role of the government* in affecting the level of investment, should it be deemed not sufficient to control waste emissions; the impact of *temporary* and *permanent* subsidies and tax credits on abatement capital and waste stock. We provide new insights into the implementation of environmental policies, as their duration and timing determine the response of investments and waste emissions to policy changes and their effectiveness in terms of welfare.

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Financing constraints, climate policies and carbon emissions

Mattia Guerini[4] Giovanni Marin[5] Francesco Vona[6]

Abstract

The long-term effects of climate policies crucially depend on firms' capacity to successfully adapt by changing the input mix and investing in carbon-saving technologies. However, financially constrained firms will find it more difficult to change, invest and ultimately to reduce the carbon content of production. Little research has been conducted on the interaction of climate policy and financial constraint at the firm-level. This paper fills this gap by exploiting a unique database on French manufacturing companies containing detailed information on carbon emission, exposure to policies, and financial variables allowing one to build reliable indicators of financial constraints. Preliminary results suggest that after an expansionary monetary policy shock, more financially constrained tend to do more carbon-saving. Furthermore, our preliminary results also suggest that this effect is even stronger among the financially constrained firms that are regulated by the EU-ETS.

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Heterogeneous expectations in two-sector DSGE model: Does the green transition trigger waves of greenflation?

Nicolás Blampied[7] Alessia Cafferata[8] Davide Radi[9]

Abstract

In recent years, many attempts have been made trying to incorporate the environment into Dynamic Stochastic General Equilibrium (DSGE) models. This prolific strand of literature includes Heutel (2012), Annicchiarico and Di Dio (2015), and Hassel and Krusell (2018), among other relevant works. Extending the DSGE model framework has proven to hold potential to evaluate the role of monetary policy in the presence of climate change and the transition risks it brings along.

However, one of the main limitations DSGE models face, is the assumption of rational expectations. Both empirical - see, e.g., Ito (1990) and Shiller (2000) - and experimental studies - see, e.g., Hommes (2011) - highlight that agents are usually affected by bounded rationality, and cognitive biases are more present when strong uncertainty prevails, as found in Sordi and Vercelli (2012). More recently, a vast literature has incorporated heterogeneous expectations into NK models. Among others, this literature includes papers like Branch and McGough (2010), Massaro (2013), Di Bartolomeo et al. (2016), where agents have to choose between two different expectations rule.

The limitations of DSGE models would certainly be relevant when incorporating climate related risks, which are highly non-linear. The risks carried along by climate change are still unclear, with physical impacts possibly affecting inflation rates and structural variables such as the long-run trend equilibrium real interest rate, and transition risks that could highly depend on the productivity of green investments, which is still uncertain as well - see, e.g., Angeli et al (2022).

In this paper, given the high levels of uncertainty surrounding transition risks, we aim to analyze whether shocks faced by brown and green sectors may trigger waves of inflation (greenflation) depending on the anchoring of inflation expectations derived from the different degrees of risks faced by each sector. We extend the analysis of Hommes and Lustenhouver (2019) to a two-sector framework, and following the two sector setup of

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Singh and Beetsma (2018), we introduce heterogeneous expectations into this latter and model the anchoring of inflation and output expectations as the variance of expectations around central bank targets. In addition, we push the analysis further and allow the anchoring of expectations to differ across sectors.

Singh and Beetsma (2018), provide a microfounded two-sector model, given by the following structural equations:

$$\begin{aligned}
\tilde{y}_t &= E_t\tilde{y}_{t+1} - \Xi\left[r_t - E_t\left(\eta\pi_{s,t+1} + (1-\eta)\,\pi_{f,t+1}\right) - r_t^{n*}\right] \\
\pi_{s,t} &= \kappa_s\left[\Theta\tilde{y}_t - (1-\eta)\,\tilde{T}_t\right] + \beta E_t\pi_{s,t+1} \\
\pi_{f,t} &= \kappa_f\left[\Theta\tilde{y}_t + \eta\tilde{T}_t\right] + \beta E_t\pi_{f,t+1} \\
\Delta\tilde{T}_t &= \pi_{s,t} - \pi_{f,t} - \Delta T_t^*
\end{aligned} \qquad (1)$$

where $\bar{y}$ is the log-linearized value of output and π_s, π_f are the inflation rates of the sticky sector and of the flexible sector, respectively; η captures the weight of sector s in the final product and β is the discount factor.
Moreover $\kappa_s = (\frac{(1-\theta_s\beta)(1-\theta_s)}{\theta_s}$ and $\kappa_f = \frac{(1-\theta_f\beta)(1-\theta_f)}{\theta_f}$, Δ is the first-difference operator, $\Theta = \frac{(1-\chi)(\phi+\sigma)}{(1+\chi)(\phi+\sigma)}$, $\Xi = \sigma^{-1}(1+\chi(\phi+\sigma))$ with 0 < x < 1 indicating the share of final output as input in the production and r_t^{n*} is the equilibrium interest t rate, and $\Delta T_t^* = \Delta z_{f,t} - \Delta z_{s,t}$. In this setup, we relax the assumption of the representative agent and the rational expectations hypothesis by assuming the existence of some degree of heterogeneity. Hommes and Lustenhouwer (2019) introduce in a log-linearized NK model a continuum of heterogeneous expectations where agents form their expectations about the future inflation rate and the output gap level on the base of past forecasting performance. They follow the same rule but they calibrate expectation values out of a distribution around the targets of the central bank. The degree of the “anchoring” of expectations is captured by the variance of the distribution of possible expectation values.

In addition, expectation formation follows a heuristic switching model à la Brock and Hommes (1997), according to which they learn from better performing agents and update their own expectations following:

$$n_t^{z,h} = \frac{e^{\omega U_{t-1}^{z,h}}}{\sum_{h=1}^{H} e^{\omega U_{t-1}^{z,h}}},\ z = \pi, x \qquad (2)$$

where H is the total number of prediction values, $U_t^{z,h}$ is the fitness measure of heuristic h for variable z in period t, and ω is the intensity of choice. In the case of inflation, Eq.(2) turns into:

$$E_t\pi_{t+1} = \pi^T + \frac{\frac{1}{H}\sum_{h=1}^{H} b_h e^{-\omega(\pi_{t-1}-b-\pi^T)^2}}{\frac{1}{H}\sum_{h=1}^{H} e^{-\omega(\pi_{t-1}-b-\pi^T)^2}} \tag{3}$$

which can be re-expressed as:

$$E_t\pi_{t+1} = \pi^T + \frac{\frac{1}{H}\sum_{h=1}^{H} b_h e^{-\omega(\pi_{t-1}-b-\pi^T)^2}}{\frac{1}{H}\sum_{h=1}^{H} e^{-\omega(\pi_{t-1}-b-\pi^T)^2}} \tag{4}$$

To this aim, Brock et al. (2005) show that if the total number of prediction values go to infinity the dynamics approximate the dynamics of Eq.(4) with the so called large type limit (LTL), as a continuum of prediction biases. Then the expectations become:

$$E_t\pi_{t+1} = \pi^T + \frac{\displaystyle\int_{-\infty}^{\infty} b e^{-\omega(\pi_{t-1}-b-\pi^T)^2} e^{-\frac{b^2}{2s^2}} db}{\displaystyle\int_{-\infty}^{\infty} e^{-\omega(\pi_{t-1}-b-\pi^T)^2} e^{-\frac{b^2}{2s^2}} db} \tag{5}$$

The large type limit is a bayesian updating. Agents try to learn in each period about the correct values of the target, with a their prior of N ~ $(0, s^2)$, with the variance s^2 inversely related to the intensity of choice ω. Moreover, s^2 also reflects the anchoring of expectations to the targets of the central bank. In particular, when agents are more anchored to the target, i.e. s^2 is low, aggregate expectations will always stay closer to the targets, while agents are less anchored to the target and just follow the economic situation in the opposite case.

In our paper, we assume that the level of anchoring differs between sectors, depending on the risks they face with respect to the green transition. A priori, given the high level of uncertainty that surrounds climate relate risks, the aim is to test the dynamics of the DSGE model under heterogeneous expectations. Working with expectations as in Eq.(5) allows us to explicitly work with a two-sector model with heterogeneous expectations, and test whether sectoral shocks trigger waves of greenflation depending on the level of anchoring of inflation expectations in each sector.

Our main findings show that shocks hitting the relatively less anchored sector trigger waves of aggregate inflation, while shocks on the relatively more anchored model produce milder effects. These results seem to indicate that holding a relatively stable transition risk may reduce the chances to suffers waves of greenflation. In terms of policy implications, this may suggest the need to target transition risks as a way to keep relatively homogeneous levels of anchoring of expectations in both sectors.

Environmental Policy and the Dynamics of Industrial Location and Residential Choice.

Giovanni Bernardo[10] Pasquale Commendatore[11] Ingrid Kubin[12] Mauro Sodini[13]

Extended Abstract

Research question

Ecological challenges have a truly international dimension. In many instances, the causes of environmental issues are internationally interlinked and the consequences are not regionally confined. However, even when the causes and effects of environmental problems seem locally bounded, the flow of goods across borders and international factor migration could transmit effects of these environmental problems and of the policies, which are implemented to deal with them, throughout the international economic network.

A popular hypothesis is that individuals, especially those with higher human capital, migrate from polluted areas (Chen et al., 2022), whereas firms relocate from areas with strict environmental regulations because of higher operating costs. The latter hypothesis, known as the pollution haven hypothesis, suggests that firms tend to concentrate in areas with less stringent environmental regulations (Levinson and Taylor, 2008). This leads to the phenomenon of exporting pollution and creates a markedly uneven distribution of polluting emissions (Martin et al., 2014; Schenker et al., 2018). On closer inspection, however, the incentives for mobility are ambiguous: firms are attracted not only to low factor cost regions but also to regions with a larger local market; people are attracted not only to regions with less pollution but also to regions with better availability of goods.

The aim of this paper is to show how environmental regulation may affect the long-run distribution of people and firms (and pollution), taking explicitly into account that their location decisions have different motivations. We find that only highly uneven environmental regulations lead to results corresponding to the pollution haven hypothesis: people concentrate in the region with high environmental standards and thus good

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environmental quality, whereas firms agglomerate in the region with low environmental standards and thus low environmental quality. In contrast, moderate environmental regulations in one region contributes to a better environmental quality in both regions.

Model framework

We study this question in a New Economic Geography framework (Krugman, 1991) as it allows to study simultaneously the interaction of mobile firms, mobile households, and commodity trade. We extend the analysis put forward by Commendatore et al. (2023) by incorporating a Command and Control (CAC) policy that requires firms to comply with a prescribed green technology standard. Our study focuses on an economy consisting of two regions, denoted region 1 and region 2, both belonging to the same Union. This economy comprises two main sectors, agriculture and manufacturing. In agriculture, perfect competition prevails; while in manufacturing monopolistic competition prevails. Two types of households live in the economy: (unskilled) workers endowed with labour (their total number is L) and skilled workers/entrepreneurs (their total number is E) endowed with human capital (H). Workers do not work at distance. Entrepreneurs may work at distance allocating their endowment of H between the regions. In our model, individuals exhibit globally uniform characteristics, experiencing the negative effects of local pollution while benefiting from improved access to commodities within their location.

Within this framework, firms are homogeneous emitting pollutants with only local effects. Environmental dynamics are introduced in a very modest form, with pollution treated as a continuous flow rather than accumulating over time. Commodities are traded internationally, and cross-border trade involves iceberg trade costs denoted by τ. This implies that moving away from the original market increases the cost of trading.

In terms of environmental governance, we assume that the two regions do not behave symmetrically concerning the adoption of a green technology standard within the manufacturing sector, as only one region implements the environmental policy. Under this policy, in the region where the policy is adopted companies are required to implement abatement measures to reduce local emissions, albeit at the cost of higher production costs. In addition, a tax is imposed to local households and its revenues are used to subsidise companies' abatement activities.

Model dynamics

The dynamic model is two-dimensional. The state variables are the shares of entrenpreneurial households living in region 1 (λ) and the share of human capital allocated in region 1 (η). The dynamic processes involved are: the entrepreneurs residence choices that are driven by the (indirect) utility differential between the two regions; and human capital allocation that depends on the remuneration differential between the two regions.

Human capital regional remunerations.

The remuneration rates of one unit of human capital w_1 and w_2 are

$$\begin{aligned} w_1 &= \frac{\alpha}{\sigma F[1+(1-x)\theta]}\left[\frac{L}{2}+\lambda E+\phi\left(\frac{L}{2}+(1-\lambda)E\right)\right] \\ w_2 &= \frac{\alpha}{\sigma F}\left[\phi\left(\frac{L}{2}+\lambda E\right)+\frac{L}{2}+(1-\lambda)E\right], \end{aligned}$$

where α and σ are parameters of the demand functions; and where we used the standard definition of trade freeness: $\phi = \tau^{1-\sigma}$ with $0 \leq \phi < 1$. Environmental policy is captured by two parameters. First, θ denotes the increase in the fixed input F required by the green technology standard, the greater θ the more stringent is the required standard in terms of polluting emissions imposed to firms. Second, x denotes the reduction of these costs by a local subsidy. Notice that w_1 and w_2 depend on the market size (determined by λ) and production costs (affected by θ) and they do not depend on local competition (determined by η that affects the share of local firms).

Indirect utility of entrepreneurs

The entrepreneurs regional indirect utilities u_1 and u_2 are

$$\begin{aligned} u_1 &= \frac{H}{E}\overline{w} - tax + \overline{c_A} + \frac{\alpha}{\sigma-1}\frac{H}{F}\left(\frac{\eta}{1+\theta}+\phi\,(1-\eta)\right) - \frac{\delta}{2}\varepsilon_1^2 \\ u_2 &= \frac{H}{E}\overline{w} + \overline{c_A} + \frac{\alpha}{\sigma-1}\frac{H}{F}\left(\phi\frac{\eta}{1+\theta}+1-\eta\right) - \frac{\delta}{2}\varepsilon_2^2 \end{aligned}$$

where $\overline{c_A}$ is the (given) households' endowment of the agricutural good; $tax = \frac{s\frac{\eta H}{(1+\theta)F}}{\frac{L}{2}+\lambda E}$; represents local taxation; $\overline{w} = \eta w_1 + (1-\eta) w_2$ represents the average remuneration of a unit of human capital; δ represents the intensity of the pollution effect on utility.

The regional pollution emissions are proportional to the local output and are accounted by ε_i $(i=1,\ 2)$:

$$\begin{aligned}\varepsilon_1 &= N_1 w_1 \frac{[1+(1-x)\theta]}{1+\theta}\sigma F \\ \varepsilon_2 &= N_2 w_2 \sigma F\end{aligned}$$

where N_i is the number of firms residing in region i. Note that u_1 and u_2 depend on available local varieties (depending on η), local emissions (affected by θ) and local taxation (affected by x).

The dynamic map

We assume that the mobility choices of households and firms (the latter following human capital allocation decisions) are determined by an adaptive mechanism resembling the replicator dynamics. In particular, residential choices are driven by the utility differential $\Omega(\lambda,\eta) = \frac{u_1-\overline{u}}{\overline{u}}$ as follows

$$f(\lambda,\eta) = \lambda\left(1+\gamma_\lambda \Omega(\lambda,\eta)\right),$$

where $\overline{u} = \lambda u_1 + (1-\lambda)u_2$ and γ_λ is the adjustment speed; and human capital allocation depends on the remuneration differential $\Psi(\lambda,\eta) = \frac{w_1-\overline{w}}{\overline{w}}$ as follows:

$$g(\lambda,\eta) = \eta\left(1+\gamma_\eta \Psi(\lambda,\eta)\right),$$

where γ_η is the adjustment speed. After introducing the usual constraints on shares, the 2-D map corresponds to

$$T : (\lambda,\eta) \rightarrow (F(\lambda,\eta), G(\lambda,\eta))$$

where

$$\begin{aligned}F(\lambda,\eta) &= \begin{cases} 0 & if \quad f(\lambda,\eta)\le 0 \\ f(\lambda,\eta) & if \quad 0 < f(\lambda,\eta) < 1 \\ 1 & if \quad f(\lambda,\eta) \ge 1 \end{cases} \\ G(\lambda,\eta) &= \begin{cases} 0 & if \quad g(\lambda,\eta)\le 0 \\ g(\lambda,\eta) & if \quad 0 < g(\lambda,\eta) < 1 \\ 1 & if \quad g(\lambda,\eta) \ge 1 \end{cases}\end{aligned}$$

The 2-D map T has a piecewise smooth definition with flat branches. Its domain corresponds to the unit square u = [0, 1] × [0, 1].

Long-run stationary equilibria (map T fixed points)

The long-run stationary equilibria of the dynamic model corresponds to the fixed points of map T. The fixed points of T are located: i) in the interior of u (interior equilibria); ii) on one side of u (border equilibria); iii) on one of the corners of u (core-periphery equilibria).

We briefly discuss here some of the properties of the interior equilibria. The interior equilibria are obtained by solving:

$$\begin{aligned} w_1(\lambda) &= w_2(\lambda) \\ u_1(\lambda,\eta) &= u_2(\lambda,\eta) \end{aligned}$$

There is a maximim of two interior equilibria that we denote $I_1 = (\eta_1, \lambda)$ and $I_2 = (\eta_2, \lambda)$, where λ solves directly the first of the above expressions. We do not provide here the expressions for λ, η_1 and η_2 for reasons of space. However it is possible show conditions under which I_1 and I_2 exist for a large set of parameter values. Additionally, there are parameter values for which one of the equilibrium states, denoted as I_1, exhibits stability. In particular, Figure 1, which is plotted for economically meaningful parameter values (namely, $\sigma = 3$, $E = 1$, $H = 1$, $L = 2$, $F = 0.05$, $\alpha = 0.1$, $\gamma_\lambda = 2$, $\gamma_\eta = 2$; $\delta = 0.1$, $\bar{c_A} = 1$, $\phi = 0.35$, $x = 0.2$ and $0 \leq \theta \leq 0.5$), shows that I_1 has very interesting economic properties, which we will briefly discuss in the following final section.

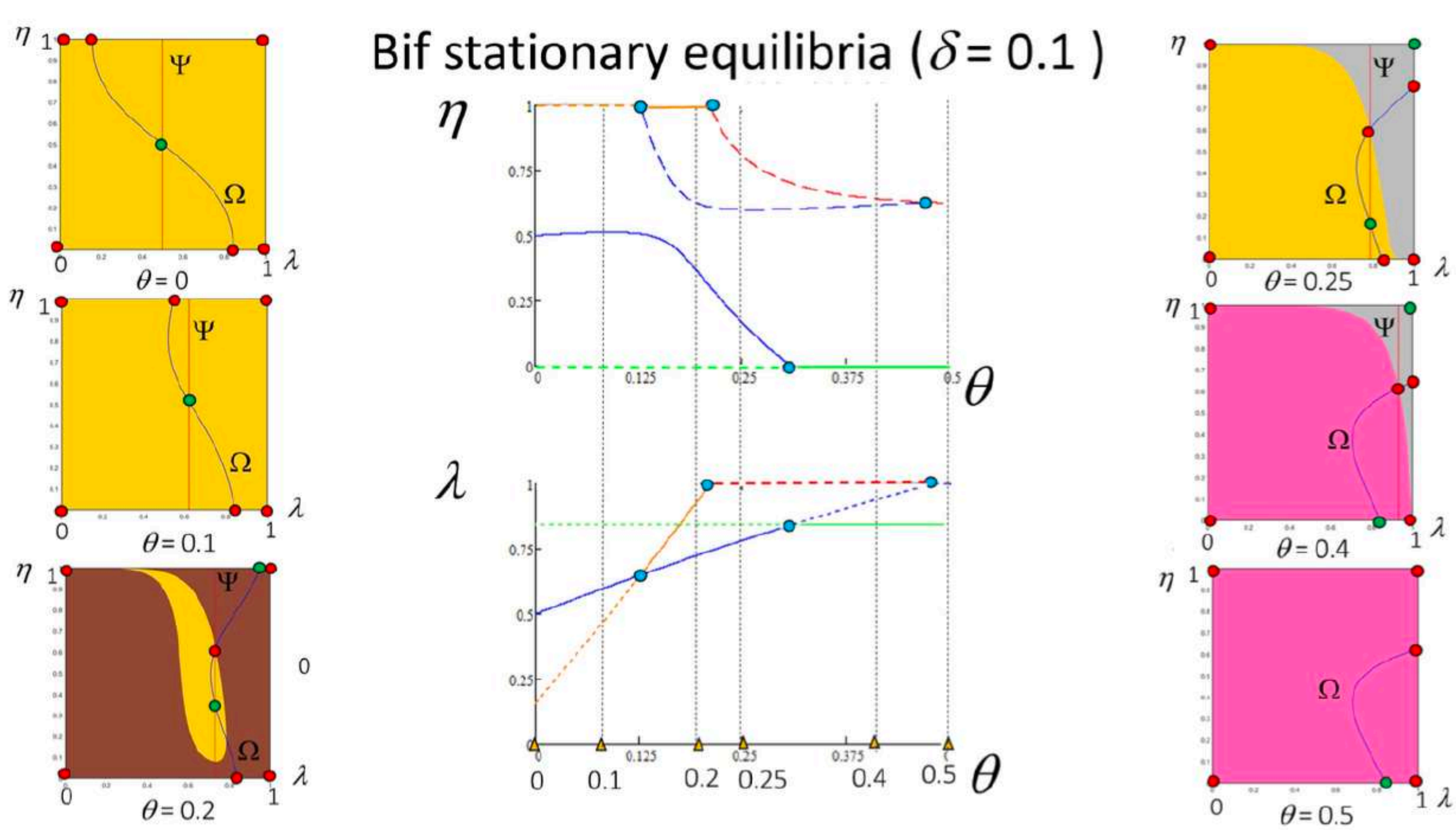

Figure 1: Long-run stationaty equilibria

Finally, note that Figure 1 gives further information concerning the behaviour with respect to θ of other fixed points of map T (the middle panels) and the basins of attraction of the locally stable fixed points for different values of θ (the six diagrams on the left and on the right in Figure 1).

Economic Interpretation of the main result

Exploring the behaviour of the stable interior equilibrium I_1 with respect to θ (corresponding to the blue solid lines in the two middle panels of Figure 1, we find some interesting results. In particular, two plausible scenarios emerge depending on the value of θ. When θ is large, the pollution haven hypothesis prevails. By further raising the green technology standard, firms will migrate from the region where the technology is adopted (region 1) to another location characterised by higher pollution (region 2). Fixed costs become so high that the incentive to reallocate human capital units becomes too strong (η in the upper middle panel of Figure 1 decreases). The number of firms therefore increases. Conversely, in the scenario where θ assumes small values, a contrasting result emerges. An increase in θ acts as a magnet for human capital towards the region that adopts green technology standards (η in the upper middle panel of Figure 1 increases), driven by the expanding market size. Nevertheless, the share of firms located in region 1 also declines, due to the increasing requirement of human capital as a fixed input relative to region 2. Regarding the number of households (λ) residing in region 1, it shows a steady upward trend with respect to θ (see the lower middle panel in Figure 1), due to the pronounced impact of the escalation of θ on the utility function. This effect is due both directly to the reduction in polluting emissions and indirectly to the reduction in the number of polluting firms. Finally, we find that an increase in θ can lead to an overall reduction in polluting emissions within the two-region economy by reducing the total number of firms.

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A unified theory of human development

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Abstract

We develop a simple framework to characterize the economic, demographic and ecological transitions that have been experienced in developed countries since the industrial revolution. The economic transition from persistent stagnation to sustained growth has been favored by the demographic transition associated with the switch from a high to a low fertility regime. Such transitions have also been accompanied by an ecological transition (also referred to as the environmental Kuznets curve) in which environmental quality has First deteriorated due to the increased pollutant emissions and then improved due to growing investments in environmental preservation activities. In order to analyze the joint economic, demographic and ecological dynamics we extend a simple unified growth setup to account for the environmental Kuznets curve. Our model is capable to describe endogenously the switches between the three main phases observed in the long term development experience of modern economies: a Malthusian era (low prosperity, high fertility, high environmental quality), a modern growth era (high prosperity, low fertility, low environmental quality), and a sustainable development or climate change era (mid prosperity, low fertility, high environmental quality). Such switches between regimes occur as a natural consequence of economic growth which, by relaxing resource constraints, allows to increase investments in education first and those in environmental protection then.

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Shock Therapy for Greener Growth:

The Dynamics of Firms' R&D Investments

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Abstract

The transition from fossil fuels to clean energy requires a large-scale shift in technological development from fossil to clean technologies. We analyze how a strong negative shock to the expected returns of oil producers may contribute to a green shift in R&D among the suppliers to the oil industry. First, we develop a theoretical framework of directed technical change, where we show that a negative shock to profitability in oil production may induce exposed firms to shift their R&D activity towards green innovation. Second, we exploit a major oil price shock in 2014 and propose a novel method of identifying firms' exposure to variations in the oil price. We find that firms that were relatively more exposed to the oil price shock increased their clean R&D investments more than firms that were less exposed to the shock. Our findings have important implications for how to design effective policies that promote environmentally sustainable economic growth.

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Should I offset or should I plow?

Voluntary Carbon Offsets and ETS in an Evolutionary Model

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Abstract

Polluting firms offset their climate-forcing emissions by proposing land managers, often farmers, to participate in Voluntary Carbon Markets (VCM). The offsetters allocate part of their land for carbon absorption under compensation. This polluter-absorber interaction has unclear environmental and economic implications, especially when evolving along a Compliance Carbon Market (CCM) of allowances such as the Emission Trading Systems. This study presents an evolutionary model explaining how carbon leakage (CL), the preference to relocate industrial activities in jurisdictions devoid of mandatory permit requirements, can influence VCM. Furthermore, this work compares the environmental performance and market competitiveness of offsetting practices. In particular, it analyzes two different forms, one requiring land-use substitution and the other being additional to agricultural practices. The results indicate that while firms might be willing to enter in VCM, CL reduces the demand for offsets, driving farmers to exit them. However, the environmental performance and competitive outcome of both sides of the VCM improves when offsetting practices are additional to agricultural activities.

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On the dynamics of green, dirty and relocating firms under the Emissions Trading System

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Abstract

The debate on the carbon leakage risk of unilateral climate policies is gaining momentum since the increase in carbon prices and in the ambition of emissions reduction targets might induce more firms to delocalize their activity in the future. To investigate this issue, we propose a simple theoretical model which analyses the choices of a population of firms subject to an Emissions Trading System (ETS). Each firm has three alternative strategies at disposal: (i) "green": stop polluting by investing in a clean technology, (ii) "dirty": keep polluting by purchasing the correspondent emission allowances under the ETS, (iii) "relocating": keep polluting by relocating its activities to an ETS-free jurisdiction.

We examine the dynamics emerging from the interaction of green, dirty and relocating firms and perform comparative dynamics at different values of some key ETS design features, such as the number of allowances granted for free to ETS firms, the quantity of allowances being auctioned, and the allowances minimum price level. Numerical simulations show the possible coexistence of the three types of firms at the equilibrium or the extinction of some of them under different parameter values. Finally, we discuss the policy implications deriving from the results of the model stressing the impact of the ETS design on firms' decarbonization and delocalization.

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Greenflation, Climateflation and Monetary Policy: The Dynamics of Sustainable Transition

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Extended Abstract

Introduction

The green transition will fundamentally transform our economies. The road to environmentally sustainable activities requires unprecedented large-scale investments in technical innovations and renewable energies to reduce greenhouse gas emissions on a path toward net zero.

The relatively large upfront costs incurred in these capital-intensive expenditures are particularly susceptible to changes in the cost of credit (Schnabel, 2023). Interest rate variations contribute to the changes in the "levelised cost of electricity" (LCOE) of renewable energies[32].

A change in the monetary policy stance can influence both the financing cost of renewable investment and the discount rate employed to estimate the present costs of building and operating a generating plant throughout its lifespan. In periods characterized by relatively low and declining interest rates, the cost of electricity from renewable sources could be considered comparable to that of conventional power plants (Fraunhofer Inst. for Solar Energy Systems, 2021).

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[32] LCOE measures the average net present cost of electricity generation for a generator over its lifetime. It is widely used for investment planning and consistently comparing different electricity generation methods.

However, the recent marked rise in global interest rates poses risks to the profitability of renewable energy investment compared to fossil fuel-based systems with fears of slowing down the pace of decarbonisation. For example, Monnin (2015) finds that at interest rate levels above 2%, the average cost of producing electricity is higher for green energy technologies. Since fossil fuel-based power plants have comparably low upfront costs, a persistent rise in the cost of capital may discourage efforts to decarbonise our economies rapidly.

Several empirical works confirm that renewable energies become relatively more competitive when interest rates are low (Schmidt, et al., 2019; Egli, F., et al., 2018). Simulations suggest that the LCOE of a gas-fired power plant would change only marginally if discount rates were to double, in comparison that of offshore wind and solar energy could rise by nearly 45% (International Energy Agency, 2020).

The recent geopolitical tensions and conflicts, such as the one between Ukraine and Russia, impacted global markets with increased volatility in energy markets, particularly the prices of commodities such as oil and natural gas. Any disruptions in the energy supply chain could lead to higher energy prices, potentially contributing to inflationary pressures. If this on the one side, could represent a push to accelerate the transition towards less fossil-fuel-dependent technologies, on the other, it requires an appropriate monetary policy response. This involves raising interest rates to dampen inflationary pressures that can increase the cost of credit for renewable technologies characterized by high capital-intensive expenditures.

Furthermore, central banks should also address different types of financial risk related to climate change (Schnabel, 2022). The first is ”climateflation” and occurs whenever extreme weather events such as wildfires or floods hit companies’ or their customers’ premises and destroy their warehouses, manufacturing plants, data centers, and supply chains. This implies a ”physical risk” from climate change that can reduce the manufacturing capacity of an economy and bring disruptions and interruptions of supply chains, leading to increased production costs, reduced productivity, and inflationary pressures. (Alogoskoufis et al. 2021). The firm level of carbon emission and pollution contributes to the rise in the frequency of such adverse climatic events and natural disasters that bring direct and indirect physical assets damages and increase inflation.

In addition, ”greenflation” involves the so-called transition risks that include all the costs related to the societal and economic shifts toward a low-carbon and more climate-friendly production model. These costs include, among others, a growing legal and regulatory environmental-friendly framework that increases compliance risk, litigation, and liability costs associated with climate-sensitive investments and the widespread diffusion of economic policies aimed at reducing the use of fossil fuels and carbon emissions (e.g. a carbon tax) (ECB/ESRB 2021).

These concerns expose central banks to a potential dilemma. On the one hand, it could strongly address inflation and its ”climateflation” and ”greenflation” components with the concrete risk of slowing down sustainable investment and the pace of decarbonisation; on the other, it can be softer in the monetary tightening at the cost of resulting partially inconsistent with the objective of price stability, but not undermining the green transition.

This work tries to answer such a dilemma by highlighting how environmental factors and climate-related challenges can influence economic dynamics, allocation of resources between renewable and conventional power plants, and inflationary trends within an economy. Addressing climateflation is a complex task. It requires a holistic approach integrating climate policy, economic policy, and sustainable development strategies to mitigate climate risks while managing inflationary pressures.

In the next section, we briefly present the dynamic model that integrates monetary policy, the evolution of sustainable investment in an industry, and the inflation dynamics that include climateflation and greenflation effects.

Model

First, we introduce the indicator LCOE to measure the competitiveness or efficiency of a technology in our model. LCOE represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. It is calculated, in eq. (1), as the ratio between all the discounted costs over the lifetime of an electricity-generating plant divided by the discounted sum of the expected energy amounts delivered (Lai & McCulloch, 2017).

$$LCOE = \frac{I_t + \sum_{t=1}^{n} \frac{M_t}{(1+i_t)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+i_t)^t}} \qquad (1)$$

In particular, I_t is the initial investment expenditure for the energy plant in the present year t, also defined as Capital Expenditures (CAPEX), M_t represents the operations, maintenance, and fuel expenditures in each year t over the technology lifetime, also defined as Operating Expenditures (OPEX), E_t is the electrical energy generated in each year t over the technology lifetime. Lastly, i_t is the interest rate prevailing in the economy each year t (i.e., discount rate) and n represents the expected lifetime in years of the power station.

For the sake of simplicity, we focus on an industry where two different technologies are available. The distinction is between a green/renewable energy generator (G) and a non-green/fossil-fuel-based energy generator(N).

To reduce the complexity of the LCOE formula, we assume only two periods: present and future, meaning that the firm bears the initial investment expenditure I at present time t, whereas the operations, maintenance, and fuel expected expenditures will be sustained in the future (i.e., over the expected life- time of the power plant). Consequently, it is possible to aggregate in a unique parameter M all expected OPEX and discount this value with a compound rate regime. The same applies to the expected sum of electricity generated over the system's operational life E.

Since LCOE is a "cost" indicator, the lower its value the better the average cost per energy unit of the generator. However, we are interested in an indicator of the efficiency of the technology or, similarly, of the profitability of the energy plant investment. For this reason, we employ the reverse of LCOE and define it as$R = LCOE^{-1}$. Thus, R measures the yield of the technology in terms of electricity produced over both capital and maintenance expenditures for its entire lifetime. This profitability indicator for the green technology R_G is:

$$R_G = \frac{\frac{E_G}{1+i_t}}{I_G + \frac{M_G}{1+i_t}} \tag{2}$$

This profitability indicator for the competing non-green technology R_N is:

$$R_N = \frac{\frac{E_N}{1+i_t}}{I_N + \frac{M_N}{1+i_t}} \tag{3}$$

Transitioning to renewable energy sources by implementing energy-efficient processes may require significant upfront investments. Consequently, we expect the green technology to have a higher I cost (or CAPEX) than a conventional one, i.e. $I_G > I_N$. However, once implemented, renewable plants could have an advantage over fossil-based generators due to the lower cost of maintenance and no fuel expenditure required (e.g. photovoltaic, solar, and wind energy). Thus, OP EX are relatively lower for sustainable energy generators: $M_G < M_N$.

For the monetary policy framework, a simple Taylor rule that links the nominal interest rate controlled by the central bank (CB) at time t with the actual inflation rate π_t is employed:

$$i_t = \bar{i} - \bar{\pi} + \beta(\pi_t - \bar{\pi}) \quad (4)$$

where $\bar{\pi}$ is the inflation target of the CB, $\bar{i}$ is the nominal interest rate target of the CB, and $\beta > 0$ is the parameter that regulates the sensitivity of the interest rate changes to the actual inflation gap[33].

We assume an industry of fixed dimension D and analyse the evolution of firms' green and non-green investments in energy generators over time. In particular, the dynamic variable $0 \leq x(t) = \dfrac{G}{D} \leq 1$ represents the share of green investment (i.e., green or renewable electric generator) employed in the industry at time t. The complementary dynamic variable $0 \leq 1 - x(t) = \dfrac{N}{D} \leq 1$ represents the share of non-green investment (i.e., conventional or fossil-based electric generator) employed in the industry at time t.

The decision of the firms of the industry to invest in green technology $x(t) \in [0,1]$ is assumed to evolve in discrete time, according to an exponential Replicator Dynamics (RD) as in Cabrales and Sobel (1992):

$$x_{t+1} = (1-\alpha)\, x_t + \alpha \frac{x_t}{x_t + (1-x_t)\, e^{\,(R_G - R_N)}} \quad (5)$$

with $0 \leq \alpha \leq 1$ a parameter of inertia that regulates the speed of adjustment in time of the share $x(t)$. In particular, the lower α, the higher the switching cost from one technology to the other.

The RD in eq. (5) provides an evolutionary mechanism such that the share of green investment/renewable generators (i.e., x) in each period t increases (decreases) when its expected profitability R_G is higher (lower) than the expected profitability of the non-green investment/fossil fuel-based generators R_N.

The level of carbon emission or, more in general, pollution P at time t is a positive function of the share of non-green technology employed in the industry (for now we employ a generic function f):

$$P_t = f(1 - x_t) \quad (6)$$

[33] For typical Western central banks, $\beta > 1$ as deviations from the inflation target are addressed with more than proportional increase in nominal interest rate. However, it is also possible to assume $\beta \leq 1$.

because the higher the share of non-green or fossil-fuel-based electricity generators in the industry at time t, the higher the emission or pollution generated in the economy.

Lastly, the inflation dynamics is represented by the following difference equation:

$$\pi_{t+1} = \gamma\, \pi_t + E(\pi_{t+1}) \tag{7}$$

with $0 \leq \gamma \leq 1$ as the anchoring parameter of the current inflation value. Inflation in the next period depends partly on actual inflation $\bar{\pi}$ (i.e. based on the well-known literature on the viscosity of price changes) and partly on the inflation expectation $E(\pi_{t+1})$.
The inflation expectation in eq. (8) includes two effects related to climate change:

$$E(\pi_{t+1}) = \kappa\, P_t + \rho\, (x_t - \bar{x}) \tag{8}$$

The first effect kP_t is denominated Climateflation.
Climate change can have significant economic consequences, including damage to infrastructure, disruptions and interruptions of product supply, increased healthcare costs due to climate-related illnesses, and higher insurance premiums for properties exposed to climate risks. These impacts can lead to increased production costs, reduced productivity, and supply chain disruptions, all of which can contribute to inflationary pressures. This effect is positively associated with the number of polluting companies in the economy contributing to worsening climate-related disasters. In our framework, the pollution is positively dependent on the share of firms adopting fossil-fuel-based generators as highlighted in eq. (6). The resulting emissions of these non-green technologies accelerate the pace and the frequency of natural disasters, generating supply shocks and bottlenecks that, mediated by the parameter $\kappa > 0$, ultimately lead to Climateflation.

The second effect is called Greenflation, which refers to rising prices for goods and services due to the costs associated with transitioning to a more environmentally sustainable economy. This is because, in the short and medium term, the offer of intermediate goods (i.e. resource scarcity) and technology is given, making it complicated to update it to increasing demand for green technologies. In addition to the expenses related to the implementation and transition to green technologies, complying with environmental regulations to meet environmental standards and requirements, or adapting to the impacts of climate change can be expensive. These forces generate upward pressure on prices captured by the term $\rho(x - \bar{x})$. When the share of green investment in the economy x (i.e. the demand) exceeds the supply $\bar{x}$, given by the actual level of technology and the amount of raw materials and commodities employed in the transition (e.g. rare materials), inflationary pressure mounts mediated by the parameter $\rho > 0$. Changing the parameter $\bar{x}$ allows us to consider technological advancements that reduce the shortages or different supply constraints depending on the specific industrial sector or economy considered.

The result is that Climateflation and Greenflation have two opposite effects on inflation. The first positively depends on $1-x$ through the emission generated by this typology of investment, while the second positively depends on x due to the cost associated with the sustainable transition. Generally, the literature distinguishes based on the time horizon of these two effects, identifying the first as a long-run effect on inflation and the second as a short-medium consequence as the economy adjusts to new production and consumption patterns.

In this framework, the CB internalizes the inflation expectation in its monetary policy rule in eq. (4), so that the change of the interest rate instrument could also address the inflation components related to climate change (i.e. dealing with a typical externality) and green transition.

In turn, interest rate changes affect the decisions of the firms in the industry because they act as a discount rate in eqs. (2) and (3), changing the relative convenience (i.e. profitability) of one technology over the other.

All in all, it is possible to close the system by inserting the Taylor rule in eq. (4) into the eqs. (2) and (3) and plugging the pollution function (6) in eq.(8).

The resulting two-dimensional non-linear system in discrete time can be concisely represented as:

$$\begin{cases} x_{t+1} = f(x_t, \pi_t) \\ \pi_{t+1} = g(\pi_t, x_t) \end{cases} \tag{9}$$

where *f* and *g* are functions.
Since the dynamic adjustment process reported by (9) is expressed in terms of differential equations, the usual methods for analyzing stability, bifurcations and different types of attractors can be applied. This will be the subject of the next section.

In order to shed light on the dynamic behavior of the system, we will first study its equilibrium points, i.e., their position on the phase plane and their local stability. Besides analytical results, we will also show simulations to analyze the properties and global stability of the system. The model will be calibrated by relying on a plausible set of parameters retrieved from the empirical literature. Then, we let individual parameters vary to perform a comparative analysis of the possible equilibria, changing the values of the costs (CAPEX and OPEX), efficiency, and emissions of the two technologies, in the monetary policy inflation target and response, and in the effects of climateflation and greenflation.

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The Impact of Environmental Regulation on Sustainable Development within the European Union: An Empirical Analysis

Xiang Weiy[34]

Abstract

The interplay between environmental regulation and Sustainable Development Goals (SDGs) has gained increasing relevance amid global environmental challenges. This research investigates the impact of environmental regulation on SDGs within the European Union (EU), particularly focusing on economic growth, environmental quality, labour, and environmental investment. The investigation highlights the critical roles of technology and human capital in economic growth and examines how these factors are influenced by environmental policies. Based on the Overlapping Generation (OLG) theory, this paper utilises panel data from 27 EU economies from 2013 to 2022. Also, it employs fixed effect models, mediation effect models, and OLS regression experiments to assess the impact of environmental regulation on economic output, considering the interplay between technology and human health in human capital. This empirical analysis uncovers a complex relationship between environmental regulations and the achievement of SDG goals, underscoring the need for refined, sector-specific environmental policies that leverage technological innovation and the development of human capital to foster sustainable, resilient, and inclusive economic growth across the EU. The findings advocate for the strategic calibration of environmental policies to better align with sustainable development objectives, highlighting the varied impacts of these regulations on labour-intensive and capital-intensive industries. The study calls for further research into the long-term effects of environmental policies on economic resilience and environmental integrity, aiming to support the EU's sustainable development agenda.

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Climate Actions, Public Investment and Inflationary Effects in a Small Open Economy

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Abstract

This paper studies the role of public investment and international spillovers in response to climate actions. Using a small-open economy model of a country belonging to a monetary union, I show that the inflationary and recessionary effects of a green policy (reduction in emissions or a higher price of fossil energy) can be dampened when the government follows a productive public spending which spurs private sector's productivity and induces a real depreciation. Moreover, the paper documents that when the climate action is followed just by the domestic economy, it is significantly more costly and the foreign counterpart enjoys the benefits of this kind of policy.

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Assessing Social Life Cycle Assessment (S-LCA) in Global Healthcare Waste Management: Insights from Complementary Methodologies and Regional Disparities

Chiara Notarangelo[36]

Extended Abstract

Introduction

Healthcare Waste Management (HCWM) is a critical domain that intersects environmental, economic, and social concerns, with ramifications extending beyond healthcare facilities.
Mismanagement of healthcare waste not only contributes to global environmental issues, such as global warming and the release of toxic substances into the environment (WHO, 2018), but also leads to economic inefficiencies due to the misallocation of hazardous and non-hazardous waste, ultimately raising disposal costs (W.H. Shrank et al. 2019, SHOPP 2020). Moreover, poor waste management can have profound social impacts, affecting local communities through contaminated air, water, and disease transmission (S.M. Exposto et al 2022, I. Kondratenko et al. 2023).
In the realm of product and service evaluation, sustainability principles are often evaluated through various methodologies, each addressing different aspects of sustainability. Specifically, Life Cycle Assessment (LCA) assesses environmental footprint, Life Cycle Cost Analysis (LCCA) the economic one, while Social Life Cycle Assessment (S-LCA) analyses the social impact. In the field of HCWM, recent studies have applied LCA and LCCA to study various aspects of the topic. For instance, Campion et al. (2015) analyzed the environmental footprint of disposal custom packs used in hospitals, aiming to design a less impactful custom pack. Alshqaqee et al. (2020) conducted a systematic review highlighting the current state of the art of hospital services' carbon footprint, while Djati et al. (2018) tested the suitability of LCA in the health service industry. Additionally, Ali et al. (2016) examined the application of LCA to solid healthcare waste. Similarly, LCCA has been employed in HCWM research, albeit less extensively. Imron and Husin (2021) combined engineering techniques with LCCA to evaluate the eco-efficiency of hospital devices, while Harris and Fitzgerald (2015) studied the life-cycle cost of flooring products for healthcare buildings. Furthermore, some studies have integrated both LCA and LCCA to provide a comprehensive evaluation of healthcare waste management practices. For instance, Soares et

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al. (2021) analyzed the eco-efficiency of treatment technologies, and Unger et al. (2012) compared the environmental and economic impacts of reusable and disposal medical products using both methodologies. Unger and Landis (2016) modeled the environmental and economic impacts of medical device supply chains under varying levels of reprocessed devices. Despite the progress in applying LCA and LCCA to HCWM, the utilization of Social-Life Cycle Assessment (S-LCA) remains relatively limited. While S-LCA has been generally employed in waste management studies, its focus has primarily been on urban waste, with limited attention given to healthcare waste, which comprises a significant portion of hazardous waste requiring specialized treatment. In light of these gaps in the literature, this research aims to answers the following research questions:

- How do complementary methodologies enhance the application of S-LCA in the healthcare waste sector?
- What disparities exist between methodologies similar to S-LCA in the context of HCW research, and what is their significance?

Methodology

The methodology employed in this study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-ScR) elaborated by Tricco et al. (2018). To ensure a comprehensive review, papers published from 2006 onwards were considered, following the notable increase in peer-reviewed studies in the Healthcare Waste Management (HCWM) sector during this period (Ranjbari et al., 2022). Inclusion criteria encompassed official reports, guidelines from reputable institutions, and English-language documents, both quantitative and qualitative. Moreover, the selection of the starting point in 2006 aligns with the ISO 14040 standard, which serves as the foundation for S-LCA. Keywords were carefully selected to develop an efficient search string, targeting relevant literature in HCWM. The principal databases utilized were Web of Science and Scopus. The search strategy was designed to yield studies focusing on the assessment of social and health impacts of healthcare waste, employing terms such as "assessment," "impact," "evaluation," "outcome," "effect," “consequence," and "footprint," along with keywords related to social and health aspects, and healthcare waste management. Following the initial screening, which yielded over 509 results, papers underwent a rigorous selection process. Each paper needed to positively answer two key questions: whether it directly or indirectly addressed HCWM and whether it considered social impacts of healthcare waste. This process resulted in a refined selection of 141 papers. In the final selection phase, articles were carefully evaluated based on their methodologies and alignment with S-LCA categories relevant to HCWM. Papers that analysed at least one of the topic considered in at least one of the S-LCA categories were included in the final literature review. Ultimately, 88 papers were selected for comprehensive analysis. Throughout the selection process, stringent criteria were applied to ensure the relevance and quality.

Results and Conclusions

The results of the study reveal significant insights into the application of complementary methodologies in assessing Social Life Cycle Assessment (S-LCA) within the Healthcare Waste Management (HCWM) sector. Among the various complementary methodologies, two predominant groups emerged: Multi-Criteria Decision Analysis (MCDA) and surveys, with the latter being the more direct method. In the case of MCDA, topics closely aligned with S-LCA subcategories primarily pertained to treatment technologies. These subcategories exhibited heterogeneity, contrasting with the more homogeneous and recurrent themes observed in surveys. Notably, surveys often focused on aspects such as workers' health and security, social benefits, community engagement, and access to material resources. Furthermore, the distribution of case studies across continents highlighted Asia as a significant region where HCWM challenges are prevalent. This trend is particularly evident in countries like India, where HCWM issues are pronounced and inadequately managed. Challenges in HCWM in such regions stem from factors such as outdated treatment technologies and insufficient staff training, leading to public health risks and the proliferation of illegal activities such as scavenging. In regions facing humanitarian crises, such as Palestine and Bangladesh, HCWM challenges exacerbate existing socio-economic issues. While frontline hospital staff are involved in waste management, critical decision-making lies with external stakeholders, including government officials. However, it's essential to recognize that HCWM challenges in these contexts are symptomatic of broader socio-political instabilities, requiring a multifaceted approach to address underlying issues. Overall, the study underscores the urgent need for comprehensive strategies to address HCWM challenges globally. By shedding light on the complexities and disparities across regions, this research aims to inform policy and practice, ultimately contributing to more effective and sustainable healthcare waste management systems.

Pollution, public debt, and growth: the question of sustainability

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Abstract

This paper examines an endogenous growth model that allows us to consider the dynamic evolution of debt, pollution and growth. Debt evolves according to financing adaptation and mitigation efforts, and to the decrease in fiscal revenue resulting from the damages caused by global pollution. Three types of features are important for our analysis: The technological one through the negative effect of pollution on TFP; The fiscal policy; The initial level of pollution and debt with respect to capital. Indeed, if the initial level of pollution is too high, the economy is relegated to an endogenous tipping zone where pollution perpetually increases relatively to capital. If the effect of pollution on TFP is too strong, the economy cannot converge to a stable and sustainable long run balanced growth path. If the income tax rates are high enough, we can converge to a stable balanced growth path with low pollution and high debt relatively to capital. This sustainable equilibrium can even be characterized by higher growth and welfare.

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Unsustainability traps: ubiquitous appearance of prisoner's dilemma at different scales and structural policy approaches against climate change

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Abstract

The threat of global climate change calls for major cooperative actions at many different scales to ensure a rapid transition over a global sustainable pathway. We investigated the threats to cooperation by a suite of multi-agent, multi-countries, game-theoretic models encompassing a great deal of interactions relevant for sustainability choices. We show that unsustainability of the current development paradigm emerges as a ubiquitous phenomenon due to the ultimate nature of prisoner dilemma of economic interactions at all scales. Even if unsustainability can be removed at lower scales, it re-appears when reconsidering the problem at the higher level. At the top of the hierarchy, that of between-countries interactions, no structural intervention deters defection. Things dramatically worsen in the presence of socio-economic inequalities because poor agents cannot but be unsustainable. Moreover, "bulimic" countries force globalization to persistently trigger unsustainability. This work offers a general background for political actions going beyond current palliative interventions.

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The Green and the Brown: Environmental regulation and economic stability

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Extended Abstract

There is a growing interest in the role of fiscal and monetary policy and their interaction during the green transition. However, many papers either offer a static view with only one type of regulation, or abstract from potential nonlinear (interaction) effects of regulation, or neglect the role of credit markets. In this paper, we aim to combine these aspects and present a nonlinear model in which agents choose between green and brown investments, which ultimately differ in their intergenerational and environmental impacts as well as in their need for credit financing. Thus, we analyze the linkages between macroeconomic dynamics and the environment while assessing the (interaction) effects of fiscal and financial policies on the income distribution between young and old agents as well as between different groups of old agents.

A growing body of literature approaches the issue from different angles. Tackling climate change has entered almost all government agendas with several instruments as remedies. For example, taxation through Pigouvian taxes (Baiardi and Menegatti, 2011) or the importance of abatement technologies and their financing have received attention in the literature (Porter and van der Linde, 1995; Brock, 2010). But also in the context of central banking, the implications of climate change and the potential scope for regulation are more widely discussed. Recently, some studies even argue for "green" quantitative easing (QE), i.e. central bank purchases of bonds issued by non-polluting firms (Ferrari and Landi, 2021; Abiry et al., 2022). Similarly, financial regulators may adjust collateral policies either to relax eligibility requirements or to reduce haircuts on eligible green assets for obtaining short-term funding (Giovanardi et al., 2021). In addition, the European Central Bank (ECB) has started to accept sustainability bonds as collateral (EU Regulation, 2020). From an institutional perspective, for example, Pichler and Sorger (2018) assesses the implications of delegating climate policy to a supranational authority in order to avoid commonly encountered coordination and inconsistency problems. In another model, proposed by Raberto et al. (2019), appropriate banking and regulatory policies are derived to promote the shift from speculative to more environmentally friendly and sustainable investments.

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To assess the linkages between financial market dynamics and the environment, we extend a nonlinear model introduced by Matsuyama et al. (2016). In an overlapping generations setting, agents choose a utility maximizing allocation of their net worth to Green or Brown projects, which ultimately differ in their general equilibrium effects and their impact on the environment. Green projects use capital, labor, and the environment as resource inputs and generate monetary spillovers to the next generation by employing young agents. They generate a certain rate of return equal to the marginal product of capital without requiring external financing. Brown projects fail to do so because they require no labor input, are independently profitable, and are assumed to generate higher returns but must be financed by borrowing. In addition, they are assumed to emit pollution and thus have a negative impact on environmental quality. Agents who want to start Brown projects have to borrow from the competitive capital market and have to pledge their expected net returns as collateral. However, because of their negative external environmental effects, brown projects are subject to environmental regulation along two dimensions. The contribution of the Browns and their exposure to environmental risks may reduce the value of the projects' returns, so that the collateral is subject to an additional environmental haircut. In addition to this financial regulation, they are also subject to a fiscal regulation in the form of an environmental tax.

We follow Caravaggio and Sodini (2018) to model the environment, which is assumed to deteriorate with increasing activity of brown projects emitting pollution. In terms of regulation, we have two ways to mitigate environmental damage. On the one hand, a higher environmental haircut reduces the feasibility of starting a Brown project and thus improves the environment. Reduced Brown activity will also reduce emissions. However, the reduction of Brown projects will reduce the income of the economy, driving a wedge into the income of old agents. Thus, fiscal regulation has a significant impact on the distribution of income in the economy, potentially creating a trade-off between the environment and income. Fiscal regulation by taxing Brown projects channels some profits away from Brown projects. This reduces the number of active brown projects, resulting in reduced emissions that directly improve the environment. In addition, the environmental tax collected can either be used to finance abatement technologies or invested directly in improving the environment.

The resulting dynamic equation (derivations omitted in this extended abstract) is two-dimensional in capital per worker, k and the environment E, and piecewise smooth with twelve parameters. The production function for Green output is Cobb-Douglas with environment, capital, and labor as inputs (the corresponding parameters are γ,α and $(1-\alpha)$). Each Brown project requires an investment of m and yields a profit B. The emission produced by one Brown project is equal to Ω and the natural stock of the environment is given by $\bar{E}$. Finally, there are three policy parameters: μ represents the financial regulation and it is the percentage of the expected returns of Brown projects that can be pledged as collateral in order to get the credit needed to start the project. Fiscal regulation involves a tax rate θ applied to the Brown project's profits and a share φ that controls how much of the accrued taxes (θBXt) goes to direct environmental improvement ($(1 - \theta)$ goes to abatement activities). The parameters ε_I and ε_A govern the productivity of these improvement and abatement activities. Given a profitability and regulatory constraint that agents face, the dynamic map consists of three regimes, denoted by Ψ_i, $i \in (L, M, R)$, which are separated by the thresholds k_c and k_μ and reads as follows.

$$k_{t+1} = \begin{cases} \Psi_L = k_t^\alpha E_t^\gamma & \text{if } k_t \leq k_c \\ \Psi_M = \left[\frac{\alpha}{1-\alpha}\frac{1}{\mu B(1-\theta)}\left(1 - \frac{k_t^\alpha E_t^\gamma}{m}\right)\right]^{\frac{1}{1-\alpha}} E_t^{\frac{\gamma}{1-\alpha}} & \text{if } k_c \leq k_t \leq k_\mu \\ \Psi_R = \left[\frac{\alpha}{1-\alpha}\frac{1}{B(1-\theta)}\right]^{\frac{1}{1-\alpha}} E_t^{\frac{\gamma}{1-\alpha}} & \text{if } k_t \geq k_\mu \end{cases} \tag{1}$$

$$E_{t+1} = \frac{\bar{E} + [\varphi\theta B X_t]^{\varepsilon_I}}{1 + [(1-\varphi)\theta B X_t]^{\varepsilon_A}\Omega X_t} \qquad \forall k_t$$

Note that the first equation is taken directly from Matsuyama et al. (2016), but extended to account for the additional environmental production input. The law of motion for the physical capital includes three regimes. The first and second regime are separated by k_c, implicitly defined as $k_c = \left[\frac{\alpha}{1-\alpha}\frac{1}{\mu B(1-\theta)}\left(1 - \frac{k_c^\alpha E_t^\gamma}{m}\right) E_t^{\alpha\gamma}\right]^{\frac{1}{\alpha(1-\alpha)}}$. The threshold between the second and third regime is $k_\mu = [m(1-\mu)E_t^{-\gamma}]^{1/\alpha}$. X_t denotes the number of Brown projects and is equal to $\frac{k_t^\alpha E_t^\gamma - k_{t+1}}{m}$. The second equation describes the environmental dynamics and is modeled in the spirit of Caravaggio and Sodini (2018). We denote $\bar{E}$ as the natural level of the environmental resource, which is reduced by pollution proportional to the number of Brown projects, $\Omega \cdot X_t$. In the nominator, the invested taxes contribute to the direct improvement of the environment, while the abatement technology in the denominator reduces the negative effects of emissions. Both technologies have diminishing marginal productivity. The following constraints were applied to the twelve parameters as follows: $0 < \alpha, \gamma, \mu, \varphi, \theta, \varepsilon_I < 1$; $m > 1$, $\varepsilon_A < 0$, and $B, \Omega, \bar{E} > 0$.

The model has complex dynamics. We focus our analysis on the role of three environmental policy parameters, μ,θ, and φ. We provide some analytical results for the three possible fixed points of the model (in each regime there is the possibility of one fixed point), namely explicit expressions for various border collisions. We are thus able to describe the parameter space for each of the three fixed points as it depends on environmental policy. To gain further insights, we use simulation studies that highlight the possibility of cyclical and complex dynamics. A reduction of μ (stricter environmental haircut) improves environmental quality, but may trigger cycles and thus risk economic instability. Higher environmental taxes also appear to be potentially destabilizing to the economy, leading to a complex pattern of interactions between financial and fiscal regulation. In our analysis, we pay particular attention to environmental quality. Finally, we analyze the distributional consequences of environmental policies: They are to be expected, since the income distribution depends on the relative number of Green and Brown investments: Green investments favor the income of the young generation, while old agents benefit more from brown projects. We also look at the distribution among different groups in the old generation, between investors in Green projects, investors in Brown projects, and lenders. Our preliminary results confirm that both types of regulation have a positive effect on environmental quality. If we consider only the financial regulation through the environmental haircut, setting it too high makes it impossible to start Brown projects. While emissions are reduced to zero, no taxes are generated to improve environmental quality. On the other hand, in such a situation, the income of the economy is lower than in a state where Brown projects are active. Moreover, the lower income comes mainly from the low returns of the old generation. The same effect has a prohibitively high tax on Brown projects. However, if they are high enough, but not too high to discourage Brown activity, they generate positive environmental externalities through abatement and improvement. The interaction of the two regulations leads to some instabilities, generating cyclical fluctuations in the economy's output and agents' income, as well as in the environment. In particular, in terms of average income and environmental quality over the respective cycles, there are several optimal combinations of financial and fiscal regulation.

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An environmental growth model with technology choice

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Extended Abstract

Introduction

The overlapping generations (OLG) paradigm has become over the years one of the most powerful approaches, in the theoretical and applied literature, to investigate economic dynamic issues. The OLG model has been used to study several questions regarding economic growth, development, population economics, the economics of infectious diseases and environmental economics. Regarding environmental problems, since the seminal work of John and Pecchenino (1994), many papers have focused on the study of the interconnection that exists between economic activity and environmental quality. The success of modelling environmental problems through the OLG framework is due, among other things, to the fact that the role played by agents' decisions emerges naturally in that finite-time framework. In this sense, generations do not coordinate themselves and the presence of a public good (environmental quality) generates problems of individual under-investment dedicated to the maintenance and/or improvement of the environment. In other words, each generation does not consider the effects of its decisions on the environment that will be inherited by future generations. Particularly fruitful has been the line of research focusing on environmental quality modelled as a public good that produces a flow of welfare directly to consumers. Typical examples of the benefits of a high level of environmental quality are clean water and clean air. When these resources are degraded due to human activity, they must be replaced by private goods. To clarify this issue, we recall some textbook instances include air filters and water treatment facilities, bottled water, soundproofing such as double-glazed windows to mitigate noise pollution from urban traffic, and medications for pollution-related ailments (e.g., asthma and skin conditions). In these instances, individuals are now compelled to purchase goods that were once freely accessible (such as clean air, clean water, quiet surroundings, etc.); through consuming these goods, they endeavour to regain the satisfaction they previously derived from a

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pristine environment in its original state (i.e., before environmental degradation occurred). This phenomenon of substitution - originally outlined in a seminal work by Hirsch (1976) who introduced the notion of "defensive consumption" - extends beyond these textbook examples and has become so prevalent in modern societies that it may contribute to a significant portion of the GDP.

A further feature that has been observed from the study of these phenomena is that they are characterised by the presence of strongly nonlinear relationships, which can give rise to oscillatory dynamics, not converging to steady states. In particular, Zhang (1999) shows that a simple Cobb-Douglas specification of both the production function and the utility function and an environmental dynamic driven by a linear process, with environmental expenditures and with perfect foresight agents, can generate equilibrium dynamics described by a logistic map, with the relevant dynamic spectrum of phenomena it implies. Similar results have also been obtained in OLG models with a different modelling setting in which agents do not directly invest in environment maintenance but only incur defensive expenditures (Seegmuller and Verchère, 2007; Antoci and Sodini, 2009; Raffin and Seegmuller, 2014; Antoci et al., 2016). In recent years, several authors have focused on the study of different types of economic models in the presence of some forms of non-derivability or discontinuity in the maps describing their dynamics. In this respect, we recall the models used to describe (1) the development of financial markets (Tramontana and Westerhoff, 2016; Gardini et al., 2022; Sushko and Tramontana, 2024), (2) the evolutionary dynamics in oligopolistic models with bounded rationality (Buccella et al., 2023), (3) growth cycles in OLG models with perfect foresight (Matsuyama, 2007; Asano et al., 2012; Asano and Yokoo, 2019; Umezuki and Yokoo, 2019).

The present paper investigates the role of technological choices on environmental dynamics in an OLG model à la John and Pecchenino (1994). The work specifically considers technological choices made in every period the generation of the owners of the firms, i.e. the generation of the currently- living old aged. This implies that technological choices spilling over onto the environmental quality of subsequent generations produce another channel of non-coordination between agents, in addition to the classical non-coordination phenomenon related to consumption choices and environmental expenditure. From a dynamic point of view, this is a further source for the emergence of endogenous cycles. In this context, the article also investigates how possible public interventions, through taxation and incentives, can foster a transition towards technologies with a lower impact on environmental quality compared to standard technologies.

The model

The basic model is outlined as follows. The work considers a modified version of the OLG model proposed by John and Pecchenino (1994), whose analysis has been subsequently deepened by Zhang (1999). The representative individual born at time t has preferences defined over consumption and environmental quality at $t + 1$ (old age), respectively denoted by C_{t+1} and E_{t+1}. Preferences are captured by the utility function

$$U(C_{t+1}, E_{t+1}) = \ln C_{t+1} + \eta \ln E_{t+1} \tag{1}$$

where η measures the relative weight the individual gives to environmental quality against consumption. During the youth, the agent supplies inelastically his time endowment (which is normalized to 1) to the productive sector receiving a wage w_t that he will divide between saving, s_t, for consumption when old, and investment in environmental maintenance,m_t, for improving the environmental quality at $t + 1$.

Environmental quality is assumed to evolve according to

$$E_{t+1} = (1-b)E_t - \beta C_t + \gamma m_t; \tag{2}$$

where $b \in (0,1)$ measures the speed of reversion of the environmental quality to 0. As in John and Pecchenino (1994), the term βC_t describes the consumption degradation of the environment by the old of the previous generation (those both at time t-1), and γm_t measures the environmental improvement chosen by the young of the current generation (those born at time t).

Agents are the owners of the firms and then supply their saving s_t to firms earning the gross return $R^e_{t+1} - \delta$ where $R^e_{t+1} = 1 + r^e_{t+1}$ is the real interest factor and $\delta \in (0,1)$ is the depreciation rate of capital. Then, the representative individual has the following budget constraints over periods t and $t+1$:

$$C_{t+1} = (R^e_{t+1} - \delta)s_t, \tag{3}$$

$$w_t = s_t + m_t, \tag{4}$$

$$C_{t+1}, m_t, s_t \geq 0. \tag{5}$$

and the expression in (2).

On the production side, unlike the common OLG models, we assume that there are two different technologies (Cobb-Douglas with constant returns to scale). We also assume that, at the beginning of every period, the firm considers a discrete-choice problem about technology selection. The production function in per worker terms is given by

$$y_t = A_i k_t^{\alpha_i}, \quad i = 1, 2,$$

where $A_i > 0$ is the total factor productivity and $\alpha_i \in (0,1)$ is the capital share of the production of technology i, $y_t = Y_t/L_t$ (output per worker) and $k_t = K_t/L_t$ (capital per worker), and $L_t = L = 1$is the number of workers at time t. We follow Umezuki and Yokoo (2019) and assume that the owner of each firm, who belongs to the old generation, selects the technology leading to the highest return at time t, which is given by $R_t = \alpha_i A_u k_t^{\alpha_i - 1}$.

The dynamics can then be represented by a piecewise one-dimensional map. The aim of the work is to characterise its major properties.

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Green Transformation of an Overlapping-Generations Economy with Production Externalities

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Extended Abstract

Motivation.

The decarbonisation of large economies is an urgent topic on the international policy agenda in Europe and elsewhere. A key problem is find effective policy measures that promote the reduction of greenhouse-gas emissions for the production of goods and services. In recent years, government authorities worldwide have implemented policies aimed at reducing the polluting activities of firms to combat anthropogenic climate change. Despite these efforts, global emissions from fossil fuels are at an all-time high, e.g., see Friedlingstein et al. (2022). Therefore, the question of which policy interventions are most effective is of central importance for the success of any decarbonisation strategy.

The Stern (2007) report on the economics of climate change has inspired a host of research on the economic effects of climate change. The theoretical foundation of the climate debate is typically a Ramsey-type model with an infinitely-lived representative agent (ILA). However, a number of contributions, e.g. see Stephan, Müller-Fürstenberger, and Previdoli (1997); Howarth (2000); Schneider, Traeger, and Winkler (2012) and others have emphasized that overlapping-generations models (OLG) provide a more convenient framework to address intra- and intergenerational aspects of climate change. It is well-known that under certain assumptions on altruism, OLG models and ILA models are equivalent, cf. Barro (1974). The extent to which this equivalence holds in the presence of externalities is yet unclear. The current discussion on how to deal with climate change suggests that individual savings and consumption decisions are dominated by individual motives rather than an altruistic motive to transfer wealth to future generations.

The starting point of our article is the observation that modern climate economics requires a framework with overlapping generations. OLG models capture the important real-world feature that the life span of each generation is finite, and it is for this reason that each generation maximises utility with a planning horizon that is finite and not infinite. As a

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consequence, private discounting of future wealth differs from the discounting of an infinitely-lived social planner, because it is natural to assume that the perspective of heterogeneous individuals does not account for the needs of generations in the distant future. Moreover, an advantage of OLG models over ILA models is that intra- and intergenerational distributions of benefits and obligations, including positive and negative externalities, can be made explicit. The transfer mechanisms, such as taxation, pensions, and social security, are well-understood. Public debt and asset prices link the wealth positions of current to future generations. OLG models are thus well-suited to address the fact that optimal climate policies will require intergenerational transfers, e.g., see Howarth (2000).

Contribution of the article.

In this article, we develop a two-period lived OLG model with three sectors and a negative production externality. Two goods are produced from capital and labour input. A polluting brown and a non-polluting green sector produce an intermediate good, interpreted as energy, that is needed as input for the production of a final good for consumption and investment. All production factors are paid their marginal products as is standard in multi-sector growth models with perfect competition and frictionless factor mobility. Since the green and the brown output are perfect substitutes, they have the same price. By incorporating three sectors, two energy sectors and a final-goods sector, we provide a framework in which the transition of an economy that uses brown energy, that is, an energy with a strong negative externality such as greenhouse-gas emissions, to an economy that primarily uses green energy with no such externality, can be studied.

The purpose of the article is to address the effectiveness of fiscal policies in reducing the polluting activities of firms in a competitive environment. The idea is that pricing the damage of emissions on assets, i.e., the degree of air pollution, will promote the profitability of the green firm and thus increase the production of green energy. This kind of intervention will have an effect on economic growth, on the distribution of incomes, as well as on the welfare of agents.

In the spirit of Calvo and Obstfeld (1988), Burton (1993), and Marini and Scaramozzino (1995), we also consider a benevolent social planner who maximises discounted lifetime utilities of all generations, taking into account the emission externality. We analyse the trade-off between production efficiency, capital accumulation, and the internalisation of the externality. Indeed, the trade-off between economic growth and abatement of emissions is at the heart of the current political debate on combating climate change. Similar to Bovenberg and Heijdra (1998, 2002), we will show how fiscal policies can be used to re- distribute the benefits from consumption and the damages from the externalities. Finally, we address the question to which extend a social planner who is limited to tax income and emissions and subsidize green energy is able to implement the social optimum.

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An Agent-Based Model of Deception: Does Greenwashing Pay Off

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Extended Abstract

The rise of corporate social responsibility (CSR) in recent years is part of a growing trend by firms to reaffirm their responsibility towards the communities they serve. At the same time, the rising threat of climate change, has shifted the public focus to the contributing role of firms to climate change, excess waste and other environmental impacts of provision. Consequently, ESG (environmental, social and governance) investing has now become a major principle for global investment strategies and investors are seeking environmentally responsible firms that pledge to reduce harmful practices, regulate their energy consumption, and neutralise the negative environmental externalities of their business.

While CSR increases the profit opportunities of firms, it dictates a balanced approach to the provision of socio-economic and environmental benefits, sustainability, and profit. Firms discovered CSR as an opportunity to boost their reputation and brand image as well as encourage investment and customer retention. Some firms, however, have abandoned a balanced approach and use it as a vehicle to maximise profits by making false claims about the social responsibility of their practices. Within the context of environmental responsibility, such actions have been termed greenwashing (or green sheen). Going back to the mid 1980s, this term has become synonymous with various strategies, ranging from deliberate vagueness and confusing information in their product description, false labels, opaque and shifting targets (green rinsing) as well as deceptive imagery to shifting the blame to consumers (green shifting) and deliberately underreporting, as well as hiding (green crowding) and falsifying information. In turn, policymakers are implementing policies that aim to protect consumers and investors and offer guidelines to differentiate green products from those that have been greenwashed. Examples are the U.S. Federal Trade Commission (FTC) as well as IFRS S1 and S2 issued by the International Sustainability Standards Board's (ISSB) in the United Kingdom. However, it remains unclear how affective these regulations are.

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In this paper, we study the strategic behaviour of firms to better understand their incentives to greenwash as well as the effectiveness of policies to prevent such actions. Greenwashing has several interesting strategic characteristics. As a deceptive strategy, it critically depends on the risk of discovery and the costs attributed to such a case in relation to the benefits of successful greenwashing. While policymakers attempt to address both the risk and the ensuing potential costs, it is important to realise that greenwashing is subject to peer dynamics and externalities. On the one hand, the reputational costs to firms are smaller in industries where milder forms of greenwashing are common. At the same time, a frequent exposure to greenwashing practices erodes trust of the public in these industries. Green policies are then perceived as being highly likely greenwashing and honest firms are inclined to hide their sustainability goals to avoid being erroneously labelled as greenwashers (a strategy known as green hushing). On the other hand, highly competitive markets in which greenwashing is uncommon, transparency is high, and regulation is strict, it is not only the high likelihood of discovery but also the strong reputational impact on a firm in relation to its competitors that discourages greenwashing. This creates a strategic complementarity between firms which is reinforced by a technological path dependency that can make it difficult to switch between a real green and a greenwashing strategy.

In addition, to minimise discovery, firms green scam consumers and in doing so, engage in a form of aggressive mimicry. The latter describes an evolutionary strategy in which predators convince their prey of their harmlessness by superficially resembling an innocuous third party. Similarly, green washing firms attempt to pose as sustainable firms to attract customers and investors. Our model makes use of the strategic complementarity as well as the well-studied dynamics of aggressive mimicry to explain greenwashing.

We investigate the ways in which different learning algorithms in combination with spatial patterns of interaction influence a firm's susceptibility to greenwashing as well as the impact of countering policies.

Climateflation and monetary policy in an environmental OLG growth model

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Abstract

Recent empirical evidence is challenging the conventional paradigm in macroeconomics, which assumes money is neutral in the long run. Moreover, central banks are gradually acknowledging that climate change can potentially impact price stability, and the term *climateflation* has entered the vocabulary of policymakers. This paper contributes to current developments between these two major themes. We present an Overlapping Generations (OLG) model to study the interplay between conventional monetary pol- icy and the environment in a context where the so-called "independence hypothesis" does not hold. Individuals are assumed to derive utility from consumption and environmental quality. Firms operate in a competitive market, but output is weighted by a damage function reflecting a negative externality from ecological degradation. We innovate by linking the environment to inflation through inflationary expectations in a modified Phillips curve. Central banks set the nominal interest rate using a generalised Taylor rule. They affect wealth composition via the individual's intertemporal optimisation problem. Numerical experiments allow us to assess the robustness of the trade-off between environmental quality and economic activity when (i) expectations are more responsive to *climateflation,* (ii) the monetary authority is more inflation- averse, (iii) the central bank increases the inflation target, and (iv) fiscal policy is less stringent.

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The impact of FX Central Bank interventions in a model with heterogeneous agents

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Extended Abstract

This paper aims at revisiting the issue of effectiveness of central bank interventions in the FX market in order to stabilize the exchange rate towards its equilibrum value. We investigate the impact of FX Central Bank (CB) interventions on the dynamics of the Euro/ Dollar exchange rate in the presence of agents with heterogeneous beliefs. It has become evident that it is not possible to understand exchange rate behaviour by relying on models with representative agents.

There is now abundant evidence that market participants have quite heterogeneous beliefs on future exchange rates. These different expectations introduce non-linear features in the dynamics of the exchange rate. The starting point of our paper is that the exchange rate is determined in the foreign exchange market through the demand for and supply. This is a truism, but it should be complemented by the observation that, when all the sources of demand and supply - including the monetary authorities through their reaction function - are accounted for, that is, once one has specified behavioural equations for all the items included in the balance of payments, the exchange rate comes out of the solution of an implicit dynamic equation. Differently from most of the literature on this subject, the novelty of our framework is the inclusion of commercial traders. Their behaviour is more characterized by a non-linearity due to the fact that, as widely documented, the Marshall-Lerner condition is not satisfied.

The formulation of the excess demands (demand minus supply) of the various agents is as follows. Our classification is functional. It follows that a commercial trader who wants to profit from the leads and lags of trade (namely, is anticipating payments for imports and/or delaying the collection of receipts from exports in the expectation of a depreciation of the domestic currency) is behaving like a speculator.

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In a nutshell:

1. In the foreign exchange market non-speculators (commercial traders, etc.) are permanently present, whose excess demand only depends on the current exchange rate. A non-linearity in the excess demand of non-speculators is considered.

2. Next, there are the speculators, who demand and supply foreign exchange in the expectation of a change in the exchange rate. According to a standard distinction, we consider two categories of speculators, fundamentalists and chartists:

   (a) Fundamentalists hold regressive expectations, namely they think that the current exchange rate will move toward its "equilibrium" value, There are several ways to define such a value; we believe that the most appropriate one is the equilibrium exchange rate, NATREX (acronym of NATural Real EXchange rate).

   (b) Chartists hold extrapolative expectations.

3. Finally, suppose that the monetary authorities are also operating in the foreign exchange market with the aim of influencing the exchange rate, taking into account NATREX.

The excess demands of the agents are as follows:

The excess demands of the private agents (non speculators, fundamentalists, chartists) determine the market exchange rate r_μ:

$$E_n(t) + E_{sc}(t) + E_{sf}(t) = 0 \qquad \Longrightarrow r_\mu \tag{1}$$

The monetary authorities intervene with their excess demand E_G, which is to be considered as a control variable, $E_G = u$, so as to determine the "corrected" exchange rate r_ω

$$E_n(t) + E_{sf}(t) + E_{sc}(t) + u = 0 \qquad \Longrightarrow r_\omega \tag{2}$$

Let us now specify the determinants of the various excess demands.

- In the foreign exchange market non-speculators (commercial traders, etc.) are permanently present, whose excess demand,$E_n(t)$; only depends on the current exchange rate.

- The chartists excess demand, $E_{sc}(t)$, depends on the first and possibly the second derivative of the exchange rate

- The fundamentalists excess demand, $E_{sf}(t)$; depends positively on the difference between the equilibrium exchange rate and the current exchange rate.

Despite the wide use of direct interventions by the central banks, researchers have questioned the effectiveness CB interventions. Within the literature devoted to the conduct of foreign exchange rate policies, the issue of effectiveness is the one which has received the greatest attention. In this paper the objective of the CB policy is to drive the current exchange rate towards the NATREX. More precisely, the CB target exchange rate is that which minimizes the deviations of the actual exchange rate from the NATREX. This problem is solved using the following optimal control tecnique:

$$\min_{(u)} \int_0^t [N_n(t) - r_\omega(t)]^2 dt \tag{3}$$

s.t.

$$\dot{r_\omega} = \varphi(r_\omega, t, u) \tag{4}$$

where Eq. (4) is obtained substituting the various excess demands in the equilibrium equation (2).

Using daily observations of the nominal Euro/Dollar exchange rate over the period January 2, 1975 to December 29, 2003 (weekends and holidays are neglected), we show that for most of the sample period CB interventions have been effective in driving the actual exchange rate towards the NATREX, thus exerting a stabilizing influence on the exchange rate.

Designing a Green Memorandum:Central Bankers, Politicians, Monetary Policy and Macroprudential Regulation

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Abstract

Major central banks like the Federal Reserve (FED) and the European Central Bank (ECB) have been investigating for almost a decade how monetary and macroprudential policies can incorporate climate risks and favour the "green" transition. Still, these aspects pose a series of questions, not only in terms of policy effectiveness, but also regarding central banks' independence, neutrality and legitimacy. This may be one of the reasons why the FED has recently started a "retreat" from the environmental domain. An analysis of these issues based on a purely economic approach would risk underestimating the trade–offs they may entail, and thus be biased in favour of central banks' interventions. We develop a political economy setting based on a Walsh contract, which can be interpreted as a memorandum that government and central bank can implement, and represents a way for the former to legitimise (or push for) the intervention of the latter under the legitimacy of elected authority. This setting eliminates the bias, unveiling the trade–offs that could result from the principal–agent relation between government and central bank: accounting for and tackling climate risks could lead central banks to miss their extant policy targets, not necessarily making "brown" firms greener, and potentially resulting in welfare distortions. On the other hand, it is thanks to this memorandum that the possibility of a green transition favoured by the central bank is made possible. We conclude that central banks should keep a cautious stance when deciding to enter the climate arena.

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